https://www.sworldjournal.com/index.php/swj/article/view/swj06-02-026
DOI: 10.30888/2663-5712.2020-06-02-026

УДК 551.510.42

ANALYSIS OF AIR CONTENT AND EFFECTS OF SUSPENDED PARTICLES $PM_{2,5}$ ON THE HUMAN ORGANISM

АНАЛІЗ ВМІСТУ У ПОВІТРІ ТА ВПЛИВУ ЗВАЖЕНИХ ЧАСТОК PM2,5 НА ОРГАНІЗМ ЛЮДИНИ

Samborskyi A.V. / Самборський А.В.
student / студент
ORCID: 0000-0002-7150-8800
Fedotov O.V. / Федотов О.В.
d.b.s., prof. / д.б.н., проф.
ORCID: 0000-0002-1423-3361
Hoshko K.O. / Гошко К.О.
student / студент
ORCID: 0000-0002-9601-0435
Donetsk National Medical University, Mariupol, Shevchenko 80, 87500
Донецький національний медичний університет, м. Маріуполь, Т. Шевченка 80, 87500

Abstract. *Particulate matter (PM) is a widespread air pollutant, including a mixture of solid and liquid particles suspended in air. Unlike larger particles, $PM_{2.5}$ easily penetrate biological barriers and therefore pose the greatest threat to the body. They make up 40-70% of all suspended air particles and are the most dangerous for human health. These particles are able to penetrate deep into the lungs and settle there. For particles $PM_{2.5}$ subsidence rate is 15 times lower than for PM_{10}, and is approximately 0,2 mm/s. This value is compensated by even a slight upward air flow. Of course, part of $PM_{2.5}$ settles, including with rains, but there are so many sources of these particles in the city, they are constantly accumulating in the atmosphere. The negative effect is not immediate, but delayed. But this is no less serious. The main danger of $PM_{2.5}$ lies not in sharp jumps in concentration, but in the chronic effects of these particles on the body.*

Keywords: *particulate matter, content in the environment, effects on human health*

Introduction.

Man is a biological being, therefore all natural factors and conditions in which he lives affect health.

The airspace of our planet always contains dust. However, along with the dust that we can detect, there is also dust, so small that the naked human eye is unable to recognize it. This substance in the air is called fine dust, which includes solid particles, as well as microscopic droplets of liquids. With the development of the accuracy of measuring instruments, it was possible to calculate the size range of fine particles, which is from 10 μm to 2.5 μm (micrometer). It is on the basis of their size that these particles received their alternative designations – particulate matter (PM). The share from PM_{10} to $PM_{2.5}$ is constantly in a suspended state of the airspace. The composition of this finely dispersed substance includes: pieces of soot, particles of mineral salts, compounds of heavy metals, various allergens, plant pollen, bacteria, microorganisms and the remains of their vital activity, tobacco and exhaust smoke. Particles from PM_{10} to $PM_{2.5}$ are contained in absolutely any airspace, regardless of geographic location: in the mountains, steppes, on the sea coast, in the forest. However, the air of megalopolises itself contains the highest concentration, as well as a chemically more aggressive "bouquet" of these particles. [2-5]

The main difference between PM_{10} and $PM_{2.5}$ particles comes from their classification. PM_{10} particles are larger and heavier. According to their properties, volatility is less pronounced than that of particles of the $PM_{2.5}$ discharge. A very good example of PM_{10} sedimentation in winter is contaminated snow flanking highways with heavy traffic. In addition, our body has a mucous membrane, as well as protective hairs on the respiratory organs, which trap PM_{10} particles. Smaller and lighter particles of $PM_{2.5}$ are suspended for a long time and practically do not settle. It is they who pose the greatest risk to human health, as they penetrate the lungs and have a negative effect on the vital internal organs of a person.

The mass concentration of $PM_{2.5}$ particles is a key parameter for assessing air quality and its threat to human health. According to the standards of the World Health Organization (WHO), the average annual level of $PM_{2.5}$ should be no more than 10 μg/m³, and the average daily level is no more than 25 μg/m³. Exceeding the latter is permissible no more than 3 days a year. [1-3]

The actual concentration of airborne particles is assessed by various environmental monitoring services around the world. The largest online air monitoring is The World Air Quality Index. It shows the air quality index in cities around the world. This index is calculated for all indicators of air pollutants. And the main one is $PM_{2.5}$. This is due to an elementary fact: $PM_{2.5}$ shares are dangerous. And this danger is becoming more and more evident. In May 2019, an international research group commissioned by the World Health Organization conducted a large-scale study, according to which 8,800,000. Early deaths occur when exposed to dust.

Hence the relevance of the research topic: according to the latest WHO data, the mortality rate from air pollution in Ukraine is one of the highest in the world and is 120 deaths per 100,000 population. In the list of toxic substances in the air, the World Health Organization put $PM_{2.5}$ fine particles in the first place. The mass concentration of $PM_{2.5}$ is a key parameter for assessing air quality and its threat to human health. [1, 5-8]

The aim of the work is to analyze the data of monitoring the state of dustiness in the atmospheric air in Mariupol with fine fractions of $PM_{2.5}$, studying the effect of $PM_{2.5}$ on the human body and the environment.

Materials and methods: analysis of scientific literature and periodicals; observation; comparison, analysis and generalization of the results of monitoring the state of dustiness of the atmospheric air in Mariupol with dust of fine fractions – 2,5 micrometers.

Results and discussion.

Suspended particulate matter (PM) is a widespread air pollutant, including a mixture of solid and liquid particles suspended in air.

The most common chemical components of PM include sulfates, nitrates, ammonia, other inorganic ions such as sodium, potassium, calcium, magnesium ions, chloride ions, organic and elemental carbon, crustal minerals, metals (including vanadium, cadmium, copper, nickel and zinc) and polycyclic aromatic hydrocarbons (PAH). Biological components, such as allergens and microorganisms, are also found in PM.

By origin, $PM_{2.5}$ is divided into primary and secondary.

Primary ones are emitted into the air ready-made when emissions of pollutants occur as a result of human activity (industrial waste, exhaust from cars, diesel generators, pesticides in agriculture, etc.) or nature (for example, forest fires, volcanic eruptions). These are small pieces of soot, asphalt and car tires, particles of mineral salts (sulfates, nitrates), heavy metal compounds (mainly oxides). Biological pollutants (some allergens and microorganisms) also belong to $PM_{2.5}$.

Secondary ones are formed directly in the atmosphere as a result of the interaction of sulfur dioxide, formed as a result of combustion of sulfur-containing fuels, and nitrogen oxidation products emitted by vehicles and some industrial enterprises.

According to the type of source, $PM_{2.5}$ particles are divided into: artificial (anthropogenic) and natural (non-anthropogenic). The main artificial (anthropogenic) supplier of particles is transport. Internal combustion engines and industrial processes for the combustion of solid fuels (coal, brown coal, oil), construction, mining, many types of production (especially the production of cement, ceramics, bricks, ceramics production), in cities, the source can be road erosion and erasing brake pads and tires. Even agriculture is a source of ammonia from which secondary $PM_{2.5}$ can be formed.

The main supplier of natural (non-anthropogenic) particles is soil erosion in arid regions and organic evaporation.

All particles and droplets less than 2.5 microns in size are suspended in the air. Unlike larger particles, they easily penetrate biological barriers and therefore pose the greatest threat to the human body.

The main danger of $PM_{2.5}$ lies not in sharp jumps in concentration, but in the chronic effects of these particles on the body.

The main ways of penetration of small dispersed particles into the human body: into the lungs – during breathing, the stomach – during eating and drinking, into other tissues – through the pores of the skin and mucous membranes. Our respiratory system is designed to cleanse the body of coarse dust, but not small particulate matter. First, $PM_{2.5}$ is deposited in the lungs, then it spreads through the blood to the internal organs. Scientists from many countries of the world have established a connection between an increase in the level of pollution with a reduction in life expectancy, an increase in the percentage of patients with respiratory and cardiovascular diseases, and pulmonological oncology. First of all, part of the population is at risk, susceptible to heart and lung diseases, children and the elderly, pregnant women, workers in the open air.

Long-term studies of the behavior of fine dust in the body have revealed six main mechanisms of the harmful effects of $PM_{2.5}$. [1, 2]

1. Rapid breathing, cardiac arrhythmia due to the excitation of pulmonary receptors. This mechanism is based on the appropriate response to a stimulus that enters the body. Thus, the bronchi narrow and cough becomes more frequent, sore throat and irritation in the chest cavity appear. As for cardiac arrhythmias, a relationship was found between the increased content of fine particles and cases of such a disease in humans.

2. destruction of the pulmonary epithelium. Fine-grained dust entering the lungs destroys the surface of the alveoli, which are responsible for gas exchange, and this

causes hypoxia or hypercapnia.

3. Inflammation in response. When $PM_{2.5}$ particles enter the body, the brain instructs the bone marrow to get rid of foreign bodies. in response to signals from the brain, the bone marrow secretes immune bodies – macrophages. They envelop the particles, causing inflammation in the lungs.

4. Blood clotting increases. Fine-grained dust can also cause such an effect, because together with the bone marrow it secretes macrophages, the liver secretes the CRP protein, which increases blood clotting, which, in turn, can lead to thrombosis.

5. Destabilization of lipid deposits. Due to the fact that macrophages, in addition to fine particles, can destroy the walls of blood vessels, the fibrous "lining" becomes thinner, and an atherosclerotic plaque can escape into the lumen of the vessel, which will create an even greater risk of thrombosis.

6. Constriction of blood vessels. Scientists have proven the relationship between the content of fine dust in the body and the narrowing of arterial vessels, and this, in turn, leads to atherosclerosis.

With an increased concentration of $PM_{2.5}$, chronic cardiopulmonary diseases (asthma, ischemic heart disease, cerebrovascular diseases and others) are exacerbated, and allergens and microorganisms contained in dispersed particles also provoke allergic reactions. Children also become vulnerable. A constant increased concentration of fine dispersed particles of $PM_{2.5}$ can lead to pathologies such as a slowdown in the development of lung growth, impairment and insufficiency of lung function. One of the constituent particles of $PM_{2.5}$ are polycyclic aromatic hydrocarbons, which have a strong carcinogenic and toxic effect on the cells of the body, resulting in oncological diseases, for example, lung cancer. According to the WHO, in 2012, every eighth death in the world was due to air pollution. Of these, 70% are associated with cardiovascular disease, the rest with lung disease.

According to the latest WHO data, the death rate from air pollution in Ukraine is the highest in the world at 120 deaths per 100,000 population. Mortality from air pollution in Ukraine is 5 times higher than in 5 clean countries combined.

If in Europe the level of $PM_{2.5}$ has been monitored for a long time, in our country, relatively recently, they began to pay attention to the problem of air pollution with fine particles.

In almost all large cities of Ukraine, air pollution by suspended particles significantly exceeds the target levels recommended by the WHO. Even where there is no heavy industry and other large stationary sources of air pollution, it still contains toxic aerosols. This has a significant contribution from the transport sector. We everywhere have high emissions from vehicles due to high sulfur content in fuel, a large number of old cars and poor quality of road surfaces.

But industrial cities – Kryvyi Rih, Mariupol, Dnieper and Kamenskoe (formerly Dniprodzerzhinsk) – suffer the most from pollution by suspended particles. In these cities, the total concentration of suspended particles, not differentiated in composition, according to official data, is more than two times higher than the maximum permissible standards, so the levels of pollution in these cities are hazardous to health.

It is known that the city of Mariupol has serious environmental problems.

According to the air pollution index in 2019, Mariupol was in first place among 39 cities of Ukraine. Several basic chemical compounds are constantly present in the air of the city, but the highest content of fine dust $PM_{2.5}$.

They began to pay attention to dust particles of $PM_{2.5}$ fractions in Mariupol in 2017, when two stationary support posts were installed at the expense of the regional fund for environmental protection. These certified fixed reference posts analyze the environmental situation in real time and provide information on the state of the atmospheric air online. One such stationary post is OASP-02 located in the Kalmiusskiy region (112 Metallurgov Ave.), the second is OASP-03 in the Levoberezhny District (21 Pobedy Ave.) Mariupol metro station. The stations measure the amount of dust of the $PM_{2.5}$ fraction. The measurement results are available online on the website of the Department of Ecology and Natural Resources of the Donetsk Regional State Administration. We analyzed the data of the aforementioned stationary posts for 2018 and 2019.

Since in Ukraine, unfortunately, there are no approved average daily (average annual) dust emission standards of the $PM_{2.5}$ fraction, they relied on the standards recommended by the WHO: the average annual $PM_{2.5}$ level should be no more than 10 μg/m³, and the average daily level should not be more than 25 μg/m³. Exceeding the latter is permissible no more than 3 days a year.

According to the monitoring results, it was found that $PM_{2,5}$ suspended particles is a constant component of the city's air environment. In total, in 2018, according to the data of the OASP-02 post (Kalmiussky district), the maximum permissible average daily dust level of $PM_{2,5}$ fractions was exceeded 36 days (Fig.), With a norm of no more than 3 days a year, for 2019 the maximum permissible the average daily dust level of the $PM_{2,5}$ fractions was exceeded for 42 days (Fig.). The average annual indicator for 2018, according to the data of the OASP-02 post, was 15.5 μg/m³, with the norm not exceeding 10 μg/m3. By 2019, this figure was already equal to 19.1 μg/m³.

In total, in 2018, according to the data of the OASP-03 post (Levoberezhny district), the maximum permissible average daily dust level of PM2.5 fractions was exceeded 62 days (Fig.), With a norm of no more than 3 days a year. By 2019, the maximum permissible average daily dust level of $PM_{2,5}$ fractions was exceeded up to 86 days (Fig.). The average annual indicator, according to the data of the OASP-03 station, was 18 μg/m³, with the norm not exceeding 10 μg/m³. By 2019, this figure was already equal to 21.8 μg /m³.

Calculations showed that in the city the level of concentration in the air of suspended particles $PM_{2,5}$ is much exceeded, and in 2019 the excess not only did not decrease, but even increased several times.

Unfortunately, there has never been a study in the city that has established an exact link between the rise in human deaths and environmental degradation. But world research exists, and they are disappointing. Globally, air pollution causes an additional 120 deaths per 100,000 people a year. First of all, these are deaths from pulmonary and cardiovascular diseases, which were caused mainly by microscopic particles of $PM_{2,5}$, which settle in the lungs and enter the bloodstream. One more

figure: $PM_{2,5}$ shares reduce life expectancy by an average of 8.6 months. In total, $PM_{2,5}$ is associated with 3% of deaths from diseases of the cardiovascular and respiratory system and 5% of deaths from lung cancer.

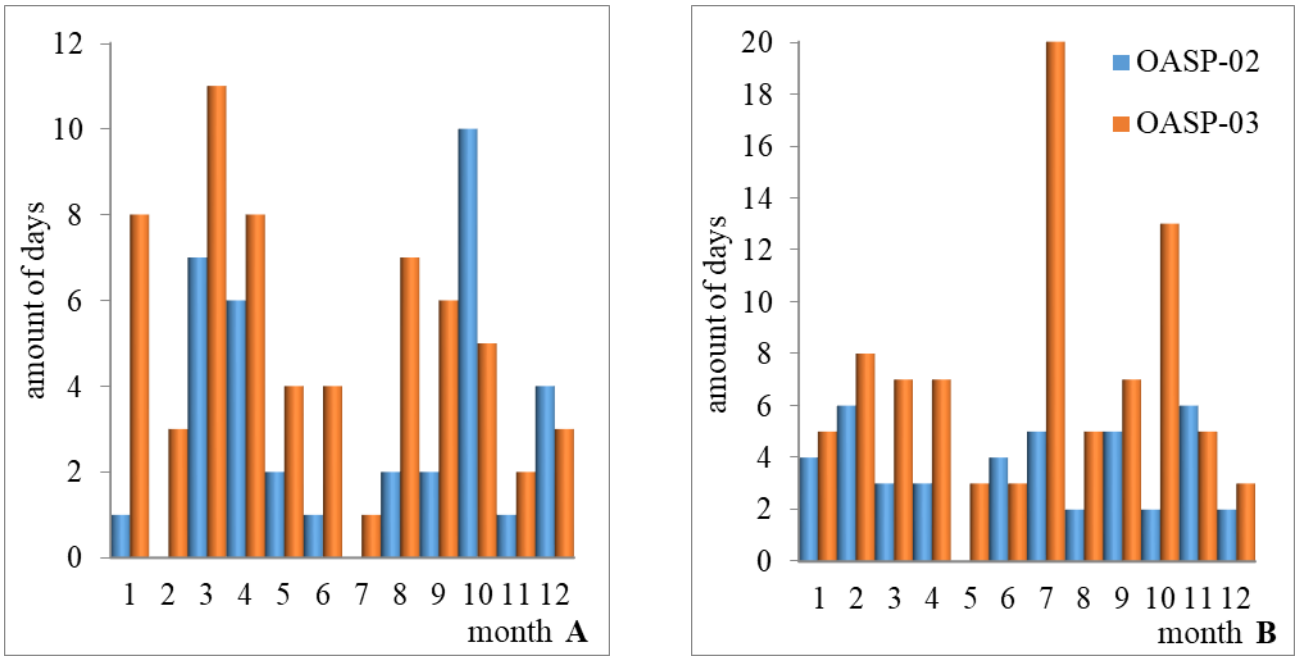

Figure. Comparison of indicators of exceeding the maximum permissible average daily dust level of fractions $PM_{2.5}$ in 2018 (A) and 2019 (B).

Conclusions.

Thus, $PM_{2,5}$ suspended particles are a widespread air pollutant that is present in industrial cities, where people live.

The influence of $PM_{2,5}$ on human health has been proven by many studies. Scientists from many countries of the world have established a connection between an increase in the level of pollution with a reduction in life expectancy, an increase in the percentage of patients with respiratory and cardiovascular diseases, and pulmonological oncology. First of all, population groups are at risk, susceptible to heart and lung diseases, as well as children, pregnant women and the elderly.

References:

1. Brauer M., Amann M., Burnett R.T., Cohen A., Dentener F., Ezzati M., Henderson S.B., Krzyzanowski M., Martin R.V., Van Dingenen R. et al. Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. Environ. Sci. Technol. 2012, 46. – P. 652-660. DOI: 10.1021/es2025752

2. Chan T.L., Lippmann M. Experimental measurements and empirical modelling of the regional deposition of inhaled particles in humans. Am. Ind. Hyg. Assoc. J. 1980, 41. – P. 399-409. DOI: 10.1080/15298668091424942

3. The criteria of assessment of ecological state of environment on thresholds of sensitivity of bioindicators / Bespalova S.V., Goretsky O.S., Glukhov A.Z., Zlotin A.Z., Maksimovich V.A., Govta N.V., Ljaljuk N.M., Markina T. Yu., Maslodudova E.N., Mashtaler A.V., Safonov A.I., Fedotov O.V., Shtirts A.D. // Problems of ecology and nature protection of the technogenic region. 2011, – P. 25-43. ISSN:

2077-3366

4. Dominici F., Peng R.D., Bell M.L., Pham L., Dermott A.M., Zeger S.L., Samet J.M. Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. J. Am. Med. Assoc. 2006, 295. – P. 1127-1134. DOI: 10.1001/jama.295.10.1127

5. Kumar P., Morawska L., Birmili W., Paasonen P., Hu M., Kulmala M., Harrison R.M., Norford L., Britter R. Ultrafine particles in cities. Environ. Int. 2014, 66. – P. 1-10. DOI: 10.1016/j.envint.2014.01.013

6. Lelieveld J., Barlas C., Giannadaki D., Pozzer A. Model calculated global, regional and megacity premature mortality due to air pollution. Atmos. Chem. Phys. 2013, 13. – P. 7023-7037. DOI: 10.5194/acp-13-7023-2013

7. Pope C.A., Burnett R.T., Thun M.J., Calle E.E., Krewski D., Ito K., Thurston G.D. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc. 2002, 287. – P. 1132-1141. DOI: 10.1001/jama.287.9.1132

8. Sayegh A., Tate J.E., Ropkin, K. Understanding how roadside concentrations of NOx are influenced by the background levels, traffic density, and meteorological conditions using Boosted Regression Trees. Atmos. Environ. 2016, 127. – P. 163-175. DOI: 10.1016/j.atmosenv.2015.12.024

Article sent: 27.12.2020