

## INVESTIGATION OF THE INFLUENCE OF FINELY DISPERSED SOLID SUBSTANCES OF THE ATMOSPHERIC AIR ON HUMANS

Ivan Kozii 

Sumy State University,  
2, Rymyskogo-Korsakova Str., Sumy, 40007, Ukraine  
*i.kozii@ecolog.sumdu.edu.ua*

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**Abstract.** An analytical study of the impact of solids contained in the air of urban areas on human health was conducted. Based on the analysis of the database of the Organization for Economic Cooperation and Development and the State Statistics Service of Ukraine on the emissions of substances into the atmosphere, it was established that the effects of solids on humans depend on particle diameter, morphological and physicochemical characteristics. The analytical research has shown that suspended airborne substances primarily damage the respiratory system and cause harm to the human cardiovascular system. The forecast model of emissions of finely dispersed suspended solids (PM<sub>2.5</sub> and less) in Ukraine until 2030 was obtained. The critical analysis of indicators of admissible levels of pollution, considering the comparative characteristic of foreign and domestic standards of admissible concentration of suspended solids in the atmospheric air of settlements, was carried out.

**Keywords:** fine particles, emissions, atmosphere, pollution, diseases.

### 1. Introduction

Atmospheric air pollution is one of the most important environmental and hygienic problems for most cities around the world. The level of air pollution within the settlement is determined by changes in emissions from industrial enterprises, transport infrastructure, as well as individual meteorological conditions unique to each city. The content of suspended solids in the air is one of the essential indicators of air quality in the urban environment. Particle size, as an important factor, determines the degree and intensity of their impact on health, along with the chemical composition and shape

(C et al., 2019; W, X, 2019). Solid particles are mainly formed during fuel combustion in various industries (Particulate Matters, 2020; Hurets et al., 2017), including transport, energy, household, industry and agriculture, which requires rational organizational and technological decisions to reduce the negative impact on the environment and the humans.

In September 2021 (WHO global air quality guidelines, 2021), the world community agreed that the determining factor influencing the level of safe human activity is solid particles equal to or smaller than 2.5 microns (μm) in diameter (PM<sub>2.5</sub>). They are able to penetrate deep into the lungs. PM<sub>2.5</sub> can even enter the bloodstream and cause cardiovascular and respiratory disorders, as well as affect other organs. In 2013, the International Agency for Research on Cancer (IARC) classified air pollution and particulate matter as carcinogenic.

### 2. Materials and Methods

Mineral suspended solids, volcanic dust, etc., that have been present in the natural atmospheric background since the birth of mankind on the planet, can cause specific respiratory diseases, such as pneumoconiosis (Jang, 2012). This group of diseases is associated with the accumulation of dust in the lungs and the reaction of lung tissue to its presence (Veremchuk et al., 2018; Kim, 2020). Nowadays, such diseases are mainly related to the influence of mineral suspensions, which are of great industrial importance – asbestos, coal and silica. Pneumoconiosis caused by quartz dust (SiO<sub>2</sub>), is called silicosis, those caused by silicates (silicic acid) –

silicosis, by coal dust – siderosis, by asbestos – asbestosis, by aluminum – aluminosis, etc. (Raffetti et al., 2019; Go, Cohen, 2020).

There is a statistically established relationship between air pollution and overall morbidity (Kozii et al., 2021). According to publications (Moreno et al., 2019; Ishtiaq et al., 2018), the contribution of air pollution to the frequency and severity of the most common diseases of the respiratory system, digestion, skin, allergic reactions, etc. is up to 30 % of the total number of factors affecting health. Diseases associated with air pollution also include cardiovascular disease, birth defects, neuropsychiatric disorders in children, malignant neoplasms (lung, breast, thyroid) and many other health changes. related to genetic, immunological, infectious and other factors (Xu, Shu, 2014; Taiwo et al., 2019; Trojanowska, Świetlik, 2019). The peculiarity of the impact of air pollution on humans is that some pollutants immediately affect the human body and others – only after a particular time.

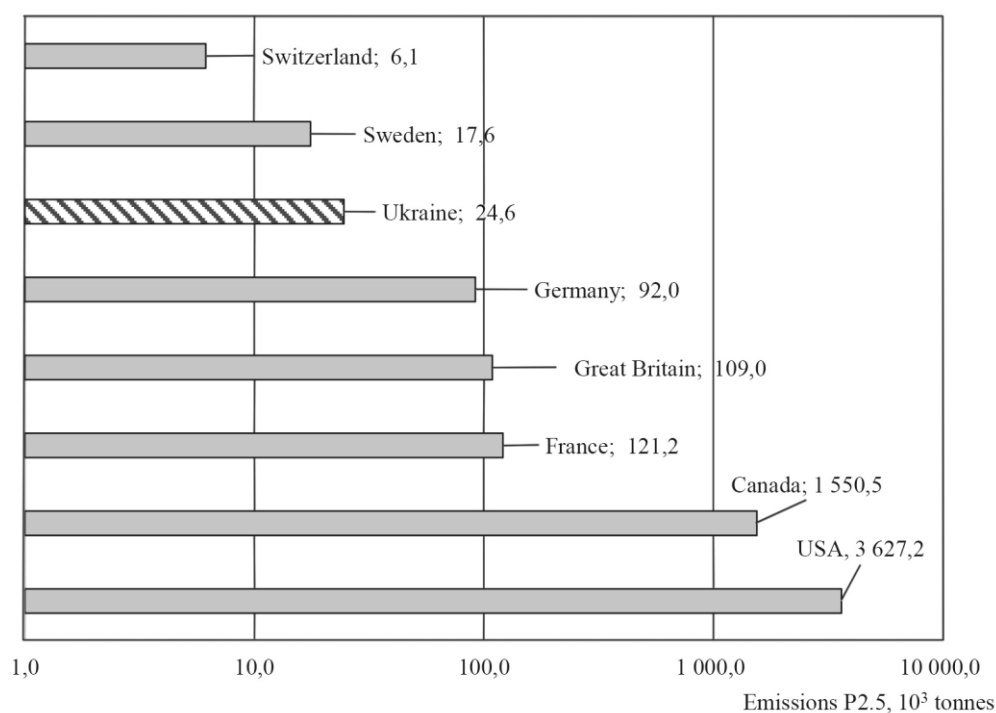
Long-term living near highways is associated with the development of chronic respiratory diseases, heart disease and reduced life expectancy. Especially harmful are exhausts of diesel engines (Patel, Jain, 2021; Chernyshev et al., 2019). It should be noted that the condition of roads in Ukraine is such that a significant number of them do not have quality coverage, which hinders the processes of air dust (Abulude, 2016).

Thus, the aim of the work is an analytical study of dust emissions which contain fine dust on human life. The following tasks were defined for this purpose:

- to conduct an analytical study of databases of pollutant emissions from the Organization for Economic Cooperation and Development and the State Statistics Service of Ukraine;
- to analyze the environmental risks to human life from air pollution by fine dust;
- to analyze the main sources of formation of fine substances in Ukraine;
- to build a forecast model of emissions of solids in Ukraine by 2030;
- to analyze the indicators of permissible levels of pollution, taking into account the comparative characteristics of foreign and domestic standards of permissible concentration of suspended solids in the air of settlements.

### 3. Results and Discussion

To assess the volume of emissions of fine substances into the atmosphere, a comparative analysis of the database on pollutant emissions of the Organization for Economic Cooperation and Development (OECD, 2021) and the database of the State Statistics Service of Ukraine (Derzhavna sluzhba statystyky Ukrainy, 2020) was conducted. The comparison is shown in Fig. 1.



**Fig. 1.** Emissions of P2.5 in Ukraine and some countries (2019)

As you can see in Fig.1, Ukraine is not the first in terms of PM2.5 emissions, ahead of Sweden, which is

quite progressive in environmental activities. Unfortunately, the network of observations of the SES

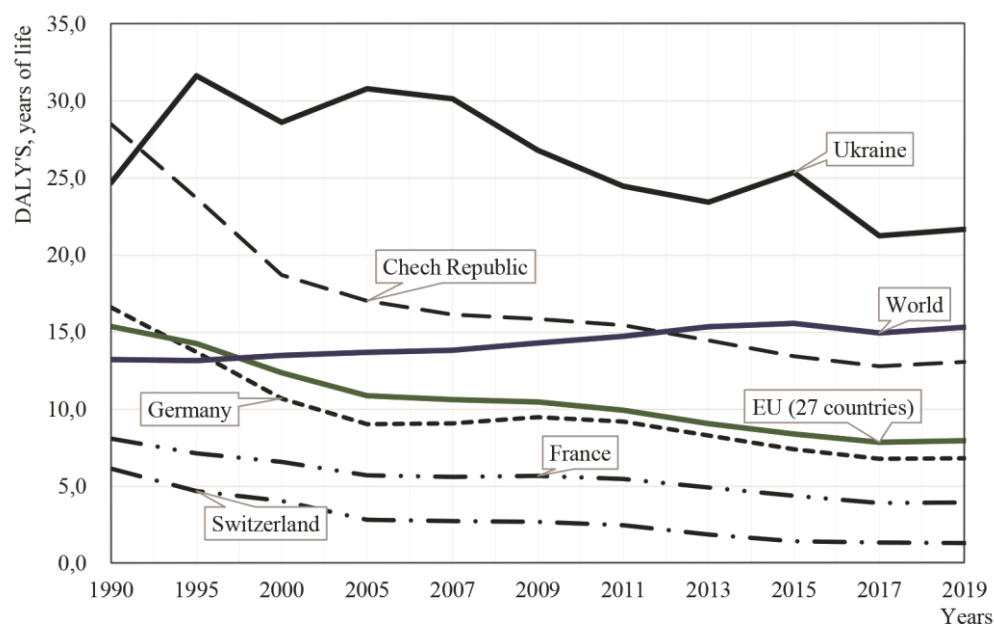
of Ukraine does not record solid particles smaller than PM<sub>2.5</sub> due to the lack of modern measuring equipment. Therefore, dust is measured in total mass, and then correction factors are used to estimate the approximate value of fine dust.

We will analyze the environmental risks of air pollution by fine dust, which correlate with certain indicators of public health in Ukraine and other countries. One such indicator is the loss of life expectancy per 1,000 population in the country due to illness, disability and premature death (DALY), which

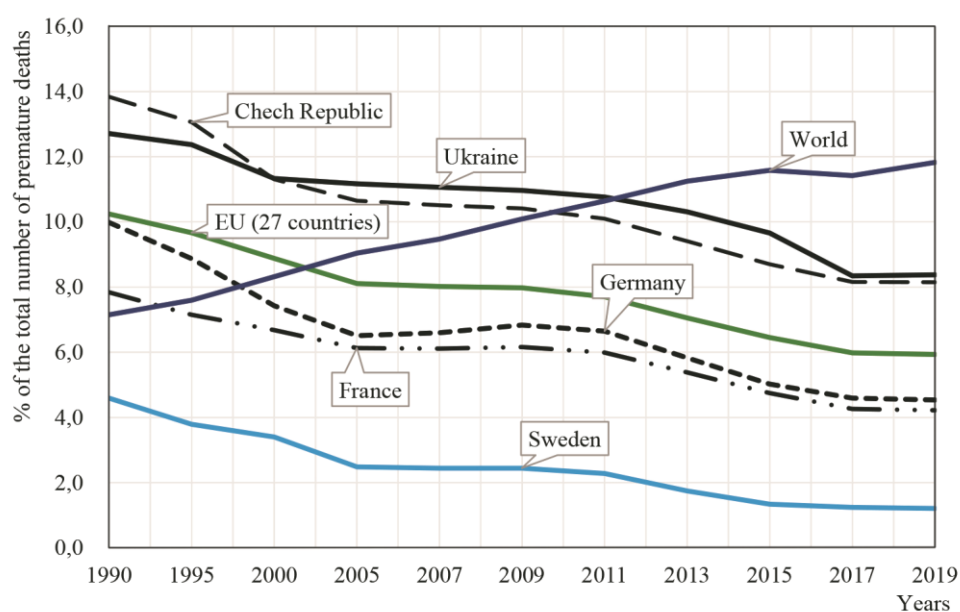
are associated with emissions of suspended solids into the atmosphere (Fig. 2).

The maximum value of DALY for Ukraine was in 1995 and accounted for 32 years per 1,000 people. A slight decrease in the indicator, unfortunately, does not allow Ukraine to reach the values of European countries.

Another indicator of air pollution by fine dust is represented by the percentage of premature deaths associated with emissions of suspended solids into the atmosphere from the total number of premature deaths (Fig. 3).



**Fig. 2.** Dynamics of life expectancy per 1,000 people (DALY) due to illness, disability and premature death associated with suspended emissions



**Fig. 3.** Premature mortality, which is associated with emissions of suspended solids into the atmosphere, % of the total number of premature deaths

As you can see in Fig. 3, Ukraine has a positive trend compared to the overall picture of premature mortality due to air pollution by fine particles in the world.

The analysis of the database of the State Statistics of Ukraine on emissions of fine substances PM<sub>2.5</sub> is given in Table 1.

According to OECD data, emissions of fine PM<sub>2.5</sub> particles in Ukraine by main sources of formation are shown in Fig. 4.

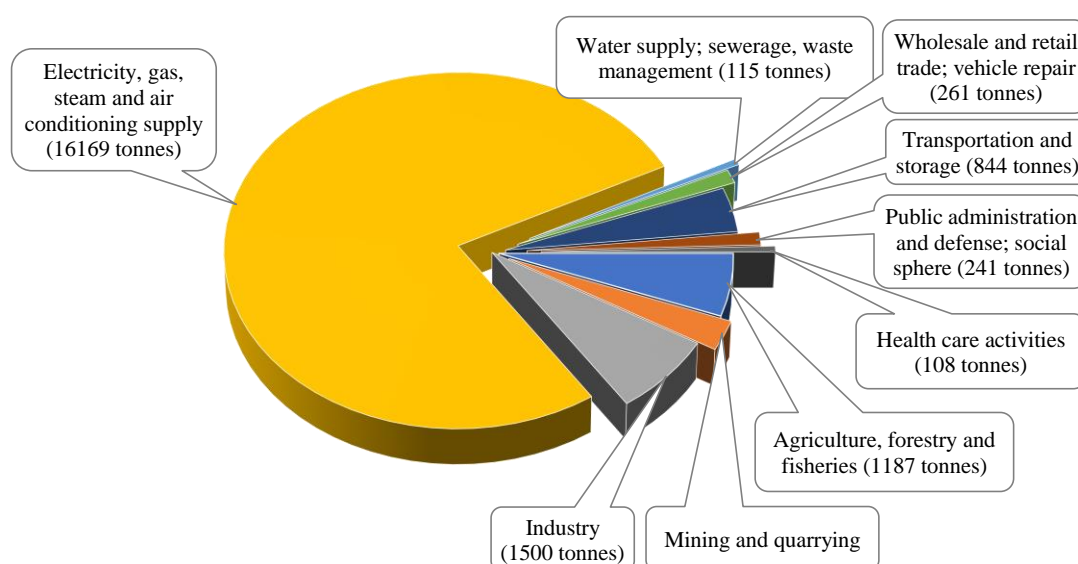
As you can see in Fig. 4, the main sources of air pollution with fine suspended solids are thermal power plants and the gas transmission system. The whole chain of thermal energy production – extraction, transportation, processing of raw materials, energy production – is a stable source of emissions of fine suspended solids into the atmosphere, affecting the population of both small villages and large cities. According to experts, the contribution of thermal energy to air pollution reaches 27–30 %, with solid suspended particles accounting for 31 % of total emissions.

Table 1

PM<sub>2.5</sub> emissions in Ukraine

Polluting substance	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Weighted particles (size 2.5 $\mu\text{m}$ and less), thousand tons	40.7	42.3	34.5	27.1	24	19.7	34.1	13.5	21.2	24.6	22.3

The maximum value of DALY for Ukraine was in 1995 and it was 32 years per 1.000 people.



**Fig. 4.** Emissions of suspended particles by main activities in Ukraine (PM<sub>2.5</sub> and less)

According to Table 1, and using the built-in functions of the software product MS Excel, a forecast model of emissions of fine suspended solids (PM<sub>2.5</sub> and less) in Ukraine until 2030 was obtained (Fig. 5).

According to the projected scenario, (taking into account 4 seasons of the year, interpolation of data for previous years and a confidence interval of 95 %) Ukraine can achieve its goal of reducing emissions of fine suspended solids by 22.5 % of emissions in 2015 (Rishennya KMU, 2019), but not everything depends on emissions.

At the end of 2020, the United Nations Development Program in Ukraine and the United

Nations Development Program in Moldova partnered with the European Space Agency and its EO Clinic program to test the use of satellite data to understand air pollution.

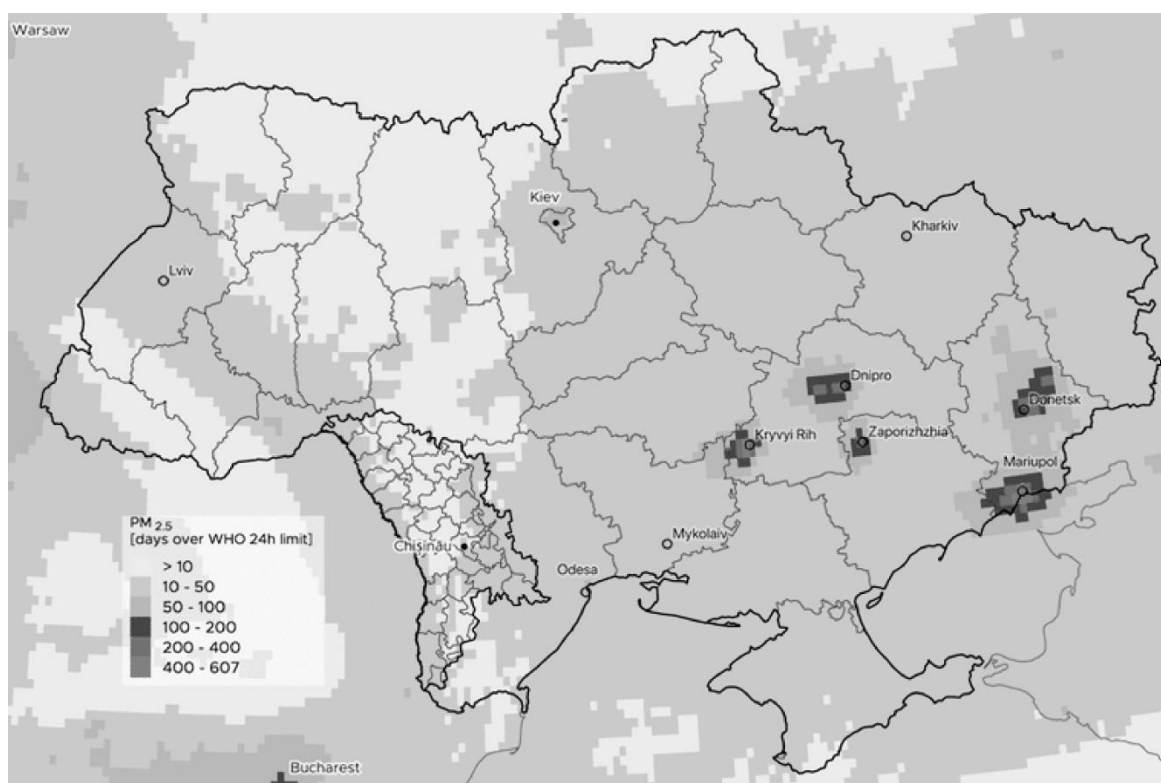
The levels of air pollution for six major pollutants, including PM<sub>2.5</sub>, were studied in the largest Ukrainian cities and the regions with developed industries throughout Ukraine. Analysts from Everis and World from Space used data from the Sentinel-5 satellite under the Copernicus Sentinel-5p program and the Copernicus Atmospheric Monitoring Service (CAMS) to visualize air pollution and the spread of polluting gases and to find patterns throughout the territory (Kylymnyk,

Replication-Receiver, 2021). The results of the monitoring which has been conducted for 16 months in

the period from May 2018 to July 2020 are shown in Fig. 6.



**Fig. 5.** Forecast of emissions of fine suspended solids (PM2.5 and less) in Ukraine



**Fig. 6.** Satellite ("Sentinel-5") visualization of air pollution PM2.5 in Ukraine for 16 months of monitoring

The cities with the highest concentration of PM2.5 are usually Kryvyi Rih, Dnipro and Zaporizhia, where this level was exceeded more than 200 times during the study period, and Mariupol and Donetsk, where the level was exceeded more than 400 times during the same period.

In world practice, standards for the content of fine particles in the air are established by official

documents of the World Health Organization and the European Union: 1. National ambient air quality standards for particular matter, 2006; 2. WHO air quality guidelines for particular matter, ozone, nitrogen dioxide and sulfur dioxide, 2006.

Air pollution is harmful to human health even in lower concentrations than previously thought. Over the last 15 years, there has been more evidence of the

negative impact of suspended solids of atmospheric air on various aspects of human health (causing 7 million premature deaths), so the WHO has updated the AQG to reduce the maximum permissible concentration of harmful substances in the air (WHO Global Air Quality Guidelines, 2021).

The concentration of suspended solids in the air is an important environmental characteristic that allows assessing the quality of atmospheric air. In Table 2, the PM<sub>2.5</sub> concentration standards in Ukraine, the United States, Europe, and some Asian countries, as well as WHO recommendations are compared.

Table 2

**Standards of concentrations of PM<sub>2.5</sub> in atmospheric air in Ukraine and some other countries**

Standard	Average annual, mg/year	Average daily maximum concentration limit, mg/year
Ukraine	0.01	0.025
USA	0.012	0.025
EU	0.025	not normalized
China	0.035	0.075
Japan	0.015	0.035
South Korea	0.025	0.05
WHO Recommendations (2021)	0.004	0.015

As can be seen from Table 2, standards for safe concentrations of fine particles in Ukraine are more stringent than in some countries. However, the norms of permissible concentrations are only a standard of a safe environment, which in real conditions often do not correspond to reality (Leonard, 2018).

The effect of PM<sub>2.5</sub> on human health is due to the content of respirable particles that are so small in diameter that they can penetrate the thoracic respiratory system. This effect of respirable PM<sub>2.5</sub> particles is due to both short-term (hours or days) and long-term (months or years) exposure and includes:

- respiratory and cardiovascular morbidity, exacerbation of asthma and an increase in the number of hospitalizations;
- mortality of cardiovascular and respiratory diseases, lung cancer.

The consequences of exposure to PM<sub>2.5</sub>, which is dangerous to human health during short-term exposure, include asthma, bronchitis, respiratory infections, coronary heart disease, etc.; with prolonged exposure – chronic bronchitis, allergies, vascular obstruction, decreased levels and life expectancy.

The paper (Erp et al., 2012) presents the results of the research that confirms that the reduction of surface air pollution as a result of long-term and continuous organizational and technological solutions at production facilities (improvement of technology, gas cleaning equipment) has a positive effect on public health. This, in turn, allows us to assess the effectiveness of organizational and technical solutions and develop recommendations for improving the air quality of populated areas.

#### 4. Conclusions

Thus, the analysis of data on the effects of fine suspended solids in the air on humans allows us to conclude that solid particles are a significant danger depending on their size, morphometric and physicochemical characteristics. The respiratory organs of people living near industrial enterprises, near highways and harmful industries are primarily affected. Based on the analytical study, it is necessary to assess the structure and composition of fine particles in the air, regardless of the size of the settlement and the number of inhabitants in it. One of the ways to reduce the impact of air pollution on the health of the population of any city, which are of particular importance, include

- regulatory – structural changes (reduction of energy consumption, especially energy produced by fuel combustion; optimization of major production processes of industrial facilities, utilities, land use planning; modernization of gas treatment equipment production facilities; change of modes of transport (greening of transport));
- legislative regulation (stricter air quality standards, limitation of maximum allowable emissions from various sources);
- changes in behavior at the individual level (use of environmentally friendly methods of movement, greening of household energy sources).

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