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Analysis of atmospheric air in the city of Kryvyi Rih and the contribution of motor vehicles to the pollution of the city

Halaktionov Mykola [1]*, Hanoshenko Olena [2]

[1] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0009-0006-7949-5713
[2] National University «Yuri Kondratyuk Poltava Polytechnic» https://orcid.org/0000-0002-9818-4084
*Corresponding author E-mail: nikolay@galaktionov.com

Atmospheric air pollution is a significant problem of large cities, which leads to deterioration of the quality of life of the population. The city of Kryvyi Rih is characterized by a significant concentration of industrial facilities of the mining and metallurgical complex and motor vehicles, the combined effect of which causes technogenic stress on the environment. As a result of the study, it was established that the impact of motor vehicles on the atmospheric air of the city of Kryvyi Rih is increasing. An analysis of the impact of the city's industrial facilities on the state of atmospheric air was carried out, and the contribution of motor vehicles to air pollution was determined. Areas with the most intense traffic were identified, where emissions from mobile sources were analyzed and recommendations were made to reduce the impact of these emissions

Keywords: atmospheric air, emissions of pollutants, vehicles

Аналіз стану атмосферного повітря у місті Кривий Ріг та вклад автотранспорту у забруднення міста

Галактіонов М.С.[1]*, Ганошенко О.М.[2]

[1] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
[2] Національний університет «Полтавська політехніка імені Юрія Кондратюка»
*Адреса для листування E-mail: nikolay@galaktionov.com

Забруднення атмосферного повітря є суттєвою проблемою великих міст, що призводить до погіршення якості життя населення. Велика концентрація промислових об'єктів та автотранспорту являється головною причиною забруднення атмосферного повітря. Місто Кривий Ріг характеризується значною концентрацією промислових об'єктів гірничо-металургійного комплексу, сукупний вплив яких спричиняє техногенне навантаження на довкілля, а викиди автотранспорту погіршують ситуацію із забрудненням повітряного середовища. Проблема викидів від автотранспорту стає все більш актуальною на фоні постійного зростання кількості транспортних засобів та збільшення середнього віку автомобілів, які експлуатуються на території нашої країни. Постійне збільшення автомобілів призводить до утворення заторів на найбільш жвавих ділянках доріг та на перехрестях, що призводить до локальних джерел забруднень вздовж цих шляхів. Основною особливістю автомобільного забруднення є той факт, що шкідливі викиди у складі відпрацьованих газів відбувається в самих нижніх, приземних шарах атмосфери, саме там, де протікає основна життєдіяльність людини. У результаті дослідження встановлено, що вплив автотранспорту на атмосферне повітря м. Кривого Рогу збільшується та здійснюється техногенне навантаження на екологічний стан міста. Збільшення кількості автомобілів сприяє зростанню кількості викидів від пересувних джерел у загальний фон забруднення атмосферного повітря міста. Проведено аналіз впливу промислових об'єктів міста на стан атмосферного повітря та визначено вклад автотранспорту в забруднення повітря. Визначено ділянки з найбільш інтенсивним рухом автомобільного транспорту, де проведено аналіз викидів від пересувних джерел та запропоновано рекомендації щодо скорочення впливу цих викидів.

Ключові слова: автотранспорт, атмосферне повітря, викиди забруднюючих речовин

Introduction

Atmospheric air is the main environment for people's existence, the deterioration of atmospheric air quality caused by anthropogenic influence leads to a decrease in the quality of life and deterioration of the health of the population. The air quality of industrial cities, such as Kryvyi Rih, does not meet the established standards of maximum permissible concentrations (MPC), which is caused by emissions from enterprises and vehicles.

Against the background of a constant increase in the number of cars in cities, emissions from motor vehicles make up a large part of the total level of air pollution. The increase in the number of motor vehicles causes more stress on the urban infrastructure and leads to traffic congestion at junctions and intersections, which leads to the accumulation of cars at these nodes and increased emissions. The problem is very relevant and needs a more detailed consideration for its solution.

Review of the research sources and publications

The impact of motor vehicles is a painful problem for society, therefore it is considered in many scientific works.

In a number of studies, the negative impact of motor vehicles on the state of the atmospheric air, risks for the health of the population are indicated. Some sources note that the rapid increase in the number of cars leads to negative processes that complicate the normal functioning of the road infrastructure of cities and the related problems of environmental pollution. Also, an outdated, imperfect system of road infrastructure is considered as a factor of influence, which is associated with numerous traffic jams on highways and streets. The problem of the aging of vehicles, ways and methods of handling this type of waste have been studied. The problem of noise pollution from motor vehicles is considered.

A number of sources indicate that motor vehicles are the biggest factor in atmospheric air pollution in megacities [1-9].

Definition of unsolved aspects of the problem

The constant development of industry in Kryvyi Rih is causing constant pressure on the state of the city's environment, and vehicle emissions worsen the situation with air pollution. The city of Kryvyi Rih is the longest city in Europe, its length from north to south is 126 km , every year there is an increase in the number of motor vehicles, which in turn requires the development of road infrastructure and the implementation of measures to reduce such an impact on the environment.

Thus, a more detailed study of the impact of motor vehicles on industrially loaded regions, the development of comprehensive environmental protection measures, the implementation of a monitoring system for emissions of pollutants from motor vehicles, and the regulation of legal aspects are necessary to reduce risks to public health.

Problem statement

The purpose of the study is to analyze the impact of motor vehicles on general atmospheric air pollution in the city of Kryvyi Rih and to develop recommendations for reducing this impact.

The main tasks of the research are: 1) to determine the impact of motor vehicles on the state of atmospheric air pollution in the city; 2) to determine the intensity of motor vehicle traffic on the busiest highways of the city; 3) determine the intensity of emissions from ICE vehicles; 4) propose recommendations for improving the state of atmospheric air in the city of Kryvyi Rih.

Basic material and results

The city of Kryvyi Rih is one of the centers of heavy industry in Ukraine. The state of the environment of such cities is formed under the influence of long-term intensive activity of mining, metallurgical, machine-building, chemical industry, heat energy and building materials enterprises. In general, despite the fact that in recent years there has been a tendency to decrease anthropogenic impact on the environment, the level of man-made load remains high, and the ecological situation is unsatisfactory.

The volume of emissions into the atmospheric air of the city of Kryvyi Rih, including the volume of emissions from mobile sources (vehicles) from 2008 to 2021 are shown in Table 1 [10-12].

As we can see from the table, the main contribution to the air pollution of the city is made by the emissions of industrial facilities. The implementation of environmental protection measures to reduce emissions by enterprises during the last decade led to a decrease in the volume of emissions by stationary sources, but in contrast to this, the city recorded an increase in the number of cars. In this way, the impact of motor vehicles becomes more significant.

According to the data of the Ministry of Internal Affairs of Ukraine, the Department of the State Traffic Inspection of the Ministry of Internal Affairs and Communications of Ukraine in the Dnipropetrovsk region, as of 2008, 105,901 vehicles belonging to legal entities and the population were registered in the city [13].

According to the Unified State Register of Vehicles, as of January 1, 2022, 174,596 vehicles were registered in the city of Kryvyi Rih [14].

Thus, the number of motor vehicles registered in the city of Kryvyi Rih increased by 65% from 2008 to 2022.

The ecological situation in the city is also formed under the influence of a number of factors related to the increase in the number of road vehicles.

The observation was carried out from 8:00 to 10:00 in the morning and reflects the peak loads on the transport infrastructure due to the movement of the population from home to the place of work, the intensity of traffic in other hours decreases.

Table 1 – Dynamics of emissions of pollutants into the atmospheric air of the city of Kryvyi Rih

Years	Total emission thousand tons	Emissions into atmospheric air of polluting substances by stationary sources		Emissions of pollutants into atmospheric air by mobile sources	
		thousand tons	%	thousand tons	%
1	2	3	4	5	6
2008	487,835	449,433	92,1	38,402	7,9
2009	321,649**	321,649	-	*	-
2010	395,032**	395,032	-	*	-
2011	411,555	358,56	87	52,995	13
2012	411,939	354,6	86	57,339	14
2013	404,506	351,778	87	52,728	13
2014	376,365	327,374	87	48,991	13
2015	369,149	327,031	89	42,118	11
2016	342,881**	342,881	-	*	-
2017	323,904**	323,904	-	*	-
2018	267,433**	267,433	-	*	-
2019	268,328**	268,328	-	*	-
2020	224,248**	224,248	-	*	-
2021	228,535**	228,535	-	*	-

* – data are not available in open sources; ** – excluding emissions from mobile sources

Various factors influence the composition and amount of emissions of pollutants from motor vehicles, namely: the life of the car and the technical condition of its engine; the speed of the car and the operating mode of its engine; the quality of the fuel used.

As the mileage of the car increases, the components and units wear out, which leads to an increase in toxic emissions into the atmosphere. Only in the first three years of their operation can the maximum allowable content of pollutants in exhaust gases be maintained.

In order to determine the impact of motor vehicles on certain parts of the city, three streets with the highest traffic intensity were chosen: st. Volgogradska, intersection of Metalurhiv avenue and Nikopol highway, str. Lermontova. During one hour, traffic intensity was monitored in these areas, the number and type of road traffic was determined. The results of the observations are summarized in Table 2.

Table 2 – Intensity of motor vehicle traffic in the studied areas

Type of vehicles	Number of vehicles per hour, unit		
	St. Volgogradska	the intersection of Metalurhiv avenue and Nikopol highway	St. Lermontova
Light-duty	3332	2372	1144
Heavy duty	252	368	312
Buses	720	596	180
Motorcycles	80	132	12
Together	4384	3468	1648

The observation was carried out from 8:00 to 10:00 in the morning and reflects the peak loads on the transport infrastructure due to the movement of the population from home to the place of work, the intensity of traffic in other hours decreases.

In order to determine the amount of emissions, the distance traveled by each type of motor vehicle along the studied area was determined. The distance traveled was calculated according to the formula:

$$L = N \times l, \quad (1)$$

where N – the number of cars;

l – the distance that the cars traveled during the study (conditionally 250 m).

The results of the calculations are summarized in Table 3.

Table 3 – Distance traveled by each type of motor vehicle on the studied area during an hour

Type of vehicles	The path traveled by motor vehicles during the study, km		
	St. Volgogradska	the intersection of Metalurhiv avenue and Nikopol highway	St. Lermontova
Light-duty	833	593	286
Heavy duty	63	92	78
Buses	180	149	45
Motorcycles	20	33	3
Together	1096	867	412

Pollutant emissions are calculated according to the methodology EMEP/EEA air pollutant emission inventory guidebook 2019 [15].

For calculations, it is assumed that light-duty vehicles and motorcycles run on petrol, and heavy duty vehicles and buses run on diesel fuel.

The methodology takes into account fuel consumption by different categories of vehicles and their emission standards. According to the reports of the National reports on the state of the natural environment in Ukraine, it is known that the average age of vehicles is 10-20 years [16].

The emission coefficients separately by type of motor vehicle (according to the data of tables 3.17, 3.18, 3.21-3.25 of the specified methodology [15]) are given in Table 4.

Table 4 – Emission factors for different types of transport

Type of transport	Release of pollutants, g/km					
	CO	NMVOC (CH4)	NO_x (NO_2)	N_2O	NH_3	PM
Passenger Cars (Petrol Medium)	3,92	0,53	0,485	0,01	0,0922	0,0022
Heavy duty (Diesel 7.5 - 16 t)	1,02	0,326	5,31	0,008	0,0029	0,201
Buses (Urban Buses Standard)	2,71	0,706	10,10	0,012	0,0029	0,479
Motorcycles (2-stroke >50 cm³)	16,3	5,82	0,028	0,002	0,0019	0,064

Emissions of pollutants (except for SO_2 , the emissions of which are determined by formula (3)) are calculated by the formula:

$$E_i = k_i L \quad (2)$$

where E_i – emissions of the ith substance during the study period, g;

ki – emission factors for different types of transport, g/km;

L – the distance traveled by vehicles during the study, km.

SO_2 emissions are calculated assuming that all sulfur in the fuel is completely converted to SO_2 by the formula:

$$E_{SO2,m} = 2 \cdot k_{S,m} \cdot FC_m \quad (3)$$

where $E_{SO2,m}$ – SO_2 emissions for the mth fuel, g;

$k_{S,m}$ – relative mass content of sulfur in m-type fuel (g/g of fuel);

FC_m – fuel consumption of the mth fuel, g.

Typical values of the sulfur content in fuel are taken according to the standard sulfur content in fuel (according to table 3.14 of the specified methodology [15]), for petrol it is 40 ppm, for diesel fuel it is 8 ppm (1 ppm = 10-6 g/g of fuel).

The results of the calculations are given in Table 5.

Table 5 – Emissions of polluting substances in the studied areas during the hour

Research place	Emissions of pollutants							
	CO	NMVOC (CH_4)	NOx (NO_2)	N_2O	NH_3	PM	SO_2	Unit of measurement
St. Volgogradska	0,004143	0,00071	0,0026	1,1E-05	7,75E-05	0,000102	6,2E-09	t
	1,15095	0,195974	0,710304	0,003065	0,02154	0,028332	1,73E-06	g/s
the intersection of Metalurhiv avenue and Nikopol highway	0,00336	0,000642	0,002282	8,52E-06	5,54E-05	9,33E-05	4,7E-09	t
	0,933358	0,178204	0,633875	0,002367	0,015399	0,025911	1,3E-06	g/s
St. Lermontova	0,001372	0,000226	0,001007	4,03E-06	2,67E-05	3,81E-05	2,2 E-09	t
	0,380981	0,062844	0,279854	0,001119	0,007425	0,010571	6,1E-07	g/s

As we can see from the above calculation results, the following pollutants are the largest emissions: CO, NO_2, NMVOC. With an increase in the number of motor vehicles, there is an increase in the intensity of emissions of pollutants into the atmospheric air, which leads to an increase in the concentration of pollutants in the atmosphere and the formation of background pollution in the city. The dependence of emissions on the number of motor vehicles is shown in Figure 1.

The highest intensity of traffic was recorded on Volgogradska Street and amounted to 4,384 vehicles per hour, the amount of pollutants from these sources amounted to 0.008563 tons.

This indicates the need to implement complex measures to solve this problem.

Measures to improve the environment caused by road transport include:

- organizing and streamlining the road infrastructure by building bypasses, increasing car lanes, building underground pedestrian crossings, etc.;
- development and popularization of public transport;
- improvement of environmental indicators of vehicles, high-quality maintenance and control;
- improving the quality of fuel and fuel-lubricants;
- use of environmentally friendly fuels and electric vehicles;
- during the operation of vehicles, it is necessary to carry out work on dedusting roads in order to reduce the concentration of dust;
- greening of city streets - creation of "green screens", helps to reduce traffic noise and atmospheric air pollution in roadside areas, increases the aesthetic appeal of the city.

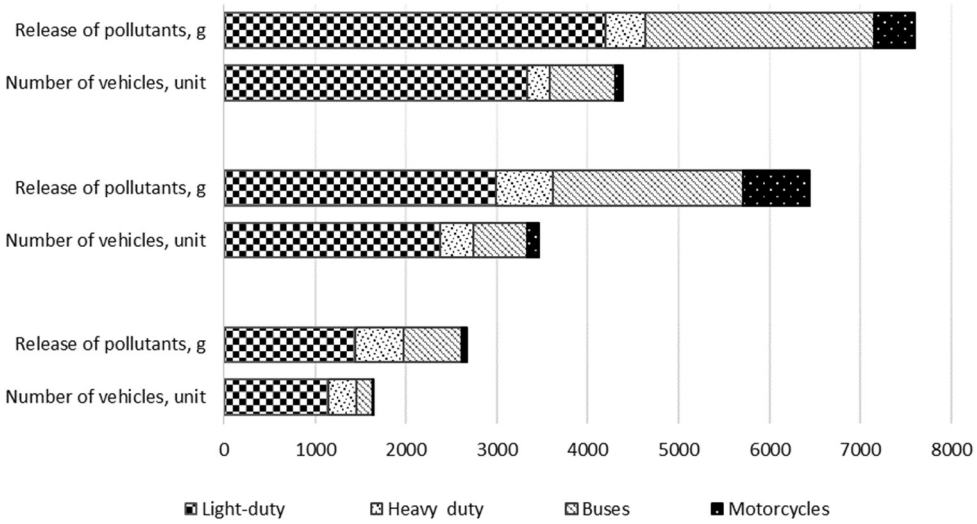

Figure 1 – Dependence of emissions on the number and type of motor vehicles

Conclusions

According to the results of the conducted research, it was established that the air quality of the city of Kryvyi Rih, in addition to industrial enterprises, is also significantly affected by road transport. During the research, it was determined that during peak hours on highways, emissions increase and lead to deterioration of the atmospheric air in the immediate vicinity of highways and at intersections. An increase in the intensity of motor vehicle traffic leads to an increase in emissions of pollutants, which in turn affects the quality of atmospheric air, which is already loaded with industrial facilities in the city. Therefore, we consider it necessary to implement the proposed environmental protection measures to improve the ecological situation in the city of Kryvyi Rih. We also consider it necessary to create and implement a system for monitoring emissions from motor vehicles.

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