

Analysis and practice of reducing emissions of pollutants from road transport into the atmospheric air of the city of Almaty

Yerkin A. Jailaybekov¹, Galym D. Berkinbayev², Natalia A. Yakovleva³

¹Academy of Logistics and Transport, Almaty, Republic of Kazakhstan

^{2,3}LLP “ECOSERVICE-C”, Almaty, Republic of Kazakhstan

¹Corresponding author

E-mail: ¹erkin.j@mail.ru, ²galymkz65@mail.ru, ³nat_alb@mail.ru

Received 28 December 2022; received in revised form 17 January 2023; accepted 22 January 2023

DOI <https://doi.org/10.21595/vp.2023.23143>



62nd International Conference on Vibroengineering in Almaty, Kazakhstan, February 10-11, 2023

Copyright © 2023 Yerkin A. Jailaybekov, et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract. The key environmental problem of the city of Almaty is atmospheric air pollution. The objective of the study was to forecast changes in emissions of pollutants in the city of Almaty, taking into account various scenarios for the development of motor transport. Based on research and calculations, environmental quality targets for Almaty for the period up to 2025 on emissions of pollutants from motor vehicles have been compiled and approved. The analysis of quantitative and qualitative indicators of vehicle emissions in the city in 2017 and 2022 is given. Measures have been developed to reduce emissions of pollutants by road into the environment of the city of Almaty.

Keywords: vehicles, atmospheric air, pollutants, calculation of emissions, forecast, targets, measures.

1. Introduction

According to the review of effectiveness of Kazakhstan environmental activity prepared by the UN European Economic Commission, the serious problems were found out in the sphere of achievement of coordination between the social-economic development and the environmental protection in the country, as well as, in the frames of the international obligations, in the sphere of environmental protection and sustainable development. It was pointed out on the necessity to strengthen the measures in order to achieve target parameter 11.6 of the Agenda 2030 concerning the unfavorable environmental impact of the cities, and target parameter 3,9 – reduction of mortality and disease rate caused by the air pollution [1]. Recently the followers of the opinion that ecological compatibility in all spheres of the activities is the main condition of the mankind' sustainable development are gaining more and more strength [2].

In accordance with the opinion of the international and Kazakh experts, the increasing number of vehicles in the Republic of Kazakhstan together with the problems related to the fuel quality for the motor transport in the country results in the extreme air pollution and in risks for the population health, especially in the cities. Constant worsening of the air quality in the big cities is the long-standing concern of the public society. Public society more and more often requires the stronger interference of the Government and other interested parties into this situation [3].

The city of Almaty is the largest economic, cultural and scientific center of the Republic of Kazakhstan, megalopolis with population of almost two million persons (about 10 % of total population of the country) [4], with the developed industry, transport and infrastructure.

The atmospheric air pollution is the key environmental problem of the city. According to the data of observations on the air quality at the gauging stations of “Kazhydromet” network, high level of the atmospheric pollution is regularly registered in the city [5].

Specific character of formation of the atmospheric air pollution in Almaty is stipulated by the city geographic location in foothills of the northern slope of Zailiisky Alatau mountain ridge.

Recurrence of the calm situations (wind velocity up to 1 m/sec) is estimated as being 71 % during summer, in winter it amounts to 79 % [6]. The pollutants are mainly borne out of the city by local (mountainous and valley) winds [7].

Based on the results of complex environmental investigations conducted in Almaty in 2017, it was found out that the emissions of the fixed sources of the thermal power plants, which use coal, heating devices of the private sector, which also use solid fuel, as well as the motor transport emissions are the main sources of the atmospheric air pollution. At that, the share of the latter is more than 60 % of total gross emissions in the city. It was shown that maximum polluted sites of the city mainly coincided with the areas of intensive vehicle traffic [8].

In order to improve the environmental situation, the Environmental Department and the City Administration performs the wide range of different measures directed on reduction of negative environmental impact of the motor transport, industrial enterprises and private sector. But, notwithstanding the taken measures, the atmospheric air pollution remains the most important environmental problem in the city of Almaty. The motor transport emissions continue to be the most important source of the atmospheric air pollution in the city. That fact was confirmed by the significant improvement of the atmospheric air quality in Almaty during lock-down established due to COVID-19 pandemia [9].

The aim of the present study is to forecast the changes in the pollutants emissions in Almaty taking into account different scenarios of the motor transport development. The study is conducted within the frames of development of the target indexes of the environmental quality in the city of Almaty up to the year 2025 [8].

2. Methods

Quantitative data on motor transport by types, categories, used fuel, year of manufacturing and other characteristics are determined based on the electronic database of the vehicles registered in Almaty, according to the data of the Department of Administrative Police of Almaty Department of Interior.

Motor vehicles (hereinafter - vehicles), in accordance with the ecological parameters, was divided into 7 (seven) ecological classes: Euro-0, Euro-1, Euro-2, Euro-3, Euro-4, Euro-5, Euro-6 [10].

Calculations of the pollutants' emissions into the atmosphere by the vehicles are done in accordance with the methods developed on the basis of the international methods of the pollutants emissions' inventory EMEP/ EEA (CORINAIR). Calculations are performed taking into account the peculiarities of the motor vehicles structure and status as well as the road-climatic conditions of its operation in the Republic of Kazakhstan and in the city of Almaty [11, 12]. Calculations were performed for the following pollutants: CO (carbon oxide), CH (hydrocarbons), NO_x (nitrogen oxides), PM (solid particles), SO₂ (sulphur dioxide), etc.

3. The study' results

In 2017 in Almaty 522804 vehicles were registered. Including: passenger cars - 473688 units (90,6 % of total number of vehicles), buses - 9405 units (1,8 %), trucks - 32721 units (6,2 %), special machinery - 1744 units (0,33 %) and motorcycles - 5068 units (1,0 %).

The vehicle ecological class shows its technological level by the pollutants emissions into the environment. The higher is the ecological class, the lower are the emissions [10]. It is found out that the fleet of vehicles in the city contains the large number of vehicles, which do not correspond to the requirements of Euro-standards on the pollutants emissions. Such vehicles belong to ecological class Euro-0. Thus, 32,56 % of trucks, 26,05 % of buses and 17,25 % of passenger cars were referred to the given ecological class.

Conducting the calculation number of vehicles was increased by 40 % of the registered number due to the vehicles entering the city (daily entrance of 200 thousand vehicles – determined based

on the field investigations).

According to the performed calculations, total amount of the pollutants emitted by the motor transport in the city of Almaty for the year 2017 was 79486 tons. The main amount of pollutants was emitted by the passenger cars - 77,1 % of total amount. Gross amount of pollutants emitted by trucks was 12,5 %, by busses - 9,39 % (Table 1).

Amount of pollutants emitted by the vehicles in the city, by Euro ecological classes. Amount of pollutants emitted by the vehicles by ecological class Euro-0 was 43421 tons (63,6 % of total amount), ecological class Euro-1 – 10419 tons (15,3 %), ecological class Euro-2 – 6747 tons (9,9 %), ecological class Euro-3 - 4101 tons (6,0 %), ecological class Euro-4 - 1554 tons (2,2 %), ecological class Euro-5 - 1986 tons (2,9 %). So, maximum share of emissions belongs to the pollutants emitted by the vehicles of Euro-0 ecological class.

Table 1. Pollutants emission of motor vehicles in Almaty (the year 2017)

Vehicle type	Pollutants emissions, tons per a year						
	Carbon oxide CO	Hydro-carbons CH	Nitrogen oxides NO _x	Sulphur dioxide SO ₂	Solid particles PM	All pollutants	
						Tons	%
Passenger cars	50660	5589	4290	620	20.8	61289	77,1
Trucks	7437	738	1599	85	46.1	9963	12,5
Buses	5668	747	885	95	16.8	7469	9,4
Special machinery	614	49	89	4	2.5	763	0,2
Total	64380	7124	6866	805	86	79486	100
Share, %	81,0	8,9	8,6	1,0	0,1	100	

Amount of pollutants emitted by the vehicles in the city, by types of used fuel. Amount of pollutants emitted by gasoline (petrol) vehicles - 64824 tons (95,0 % of total amount), diesel vehicles – 2655 tons (3,8 %), gas-tank vehicles - 232 tons (0,4 %) and vehicles, in which mixed fuel is used - 517 tons (0,8 %). The given information is the evidence of the fact that the main share of the emitted pollutants belongs to the vehicles, for which gasoline fuel is used.

Based on the long-term official statistic data on availability of vehicles [13] as well as on the materials of Almaty Department of Administrative Police, number of vehicles is forecasted up to the year 2025. This forecast takes into account the character of the city development and changes in population.

In accordance with the forecast data, number of vehicles in 2020 should be 540,0 th. units, in 2022 - 610,0 th. units and in 2025 - 700,0 th. units.

Based on the forecast of number and anticipated structure of motor transport, gross (annual) amounts of emitted pollutants were calculated till the year 2025. The years 2020, 2022 and 2025 are defined as the control periods. Calculations were done for three scenarios of the motor transport development: inert, active and intensive.

The scenario of the inert development of motor transport– increase of the vehicles’ number by the years according to the forecast without changes in the motor transport’ content and structure.

Active scenario of the motor transport development - increase of the vehicles’ number by the years according to the forecast and changes in the vehicles’ content as regards the years of manufacturing and ecological level.

Intensive scenario of the motor transport development - increase of the vehicles’ number by the years according to the forecast, changes in the vehicles’ content as regards the years of manufacturing and ecological level, and decrease of use of certain categories of vehicles (passenger cars, trucks and buses) due to anticipated optimization of the municipal transport (development of public transport, rapid bus service, light-rail tram and the underground), based on the data of adopted “Strategy on stable transport of the city of Almaty” [14].

The results of calculations of the forecast levels of the vehicles emissions under different scenarios of the motor transport development in Almaty are given in table 2 and on the Fig. 1.

According to the calculations it was anticipated that under the inert development and unchanged structure of the vehicles, the amounts of all emitted harmful substances would increase

to 86746 tons up to the year 2020. Under the active development the emissions will decrease to 66564 tons, and under the intensive development – to 60422 tons.

Table 2. Forecast amounts of pollutants emitted by the vehicles in Almaty under different scenarios of the motor transport development (up to the year 2025)

Years	Scenario	Pollutants emissions, tons per a year					
		Carbon oxide CO	Hydro-carbons CH	Nitrogen oxides NO _x	Sulphur dioxide SO ₂	Solid particles PM	All pollutants
2017	actual	64380	7124	6866	86	805	79486
2020	inert	70234	7769	7524	95	877	86746
	active	53984	5523	5912	74	867	66564
	intensive	48955	5009	5414	69	786	60422
2022	inert	76826	8495	8247	105	959	94902
	active	50090	4990	5481	67	941	61768
	intensive	43158	4291	4785	60	809	53278
2025	inert	87861	9717	9421	120	1097	108525
	active	44339	4336	5082	57	1068	55076
	intensive	30583	2978	3640	43	733	38122

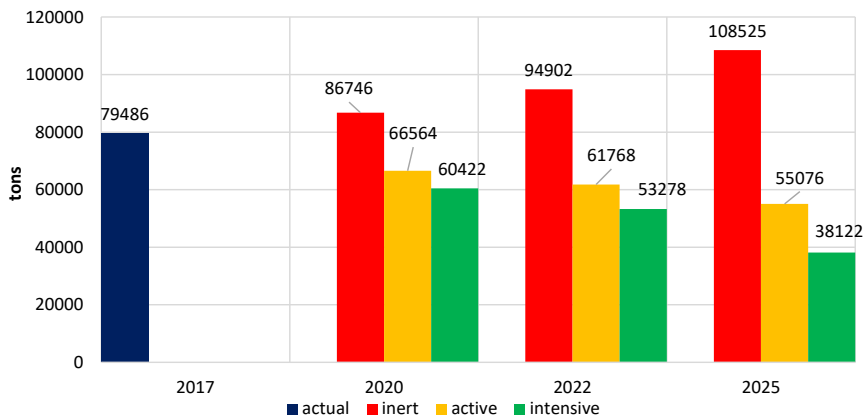


Fig. 1. Forecast of the amounts of pollutants emitted by the vehicles for the years 2020-2025, tons/year

In 2022 under the inert development and unchanged structure of the vehicles, the amounts of all emitted harmful substances will increase to 94902 tons. Under the active development the emissions will decrease to 55076 tons (by 22,2 % in comparison with the year 2017), and under the intensive development – to 53278 tons (32,9 % in comparison with the year 2017).

In 2025 under the inert development and unchanged structure of the vehicles, the amounts of all emitted harmful substances will increase to 108525 tons. Under the active development the emissions will decrease to 61768 tons (by 30,7 % in comparison with the year 2017), and under the intensive development – to 38122 tons (52,0 % in comparison with the year 2017).

Based on the results of the performed forecast on the motor transport' emissions in the city it may be pointed out that under the unregulated development of motor transport (inert scenario) in 2025 the natural increase of the vehicles' number will result in increase of gross emissions of harmful substances by 36,6 % in comparison with the level registered in 2017. This will considerably worsen difficult environmental situation in the city.

Therefore, improvement of the ecological structure and reduction of use of the vehicles' fleet (first of all, passenger cars) is the most important condition for the atmospheric air rehabilitation in the city of Almaty. On the basis of the performed forecast calculations, the target parameters for the quality of environment in Almaty were proposed for the period till the year 2025 as regards the pollutants emitted by the vehicles: the year 2020 – 67000 tons, the year 2022 – 54000 tons and the year 2025 – 38000 tons [8]. According to the acting Environmental Code of the Republic of

Kazakhstan, target parameters of quality of the environment are the parameters, which characterize maximum level of the rated parameters of the environment for the certain period of time, taking into account the necessity of gradual improvement of the environment' quality [15]. Target parameters of the vehicles' emissions, proposed by us, were approved by the Decision of Maslikhat of the city of Almaty in 2019 [16]. The established target parameters for the pollutants emitted by the vehicles may be achieved only as a result of the serious measures on improvement of the transport structure, fuel quality, hardening of the standard emissions [17].

The actual state of road transport and emissions of pollutants from it in Almaty for 2022 and comparison with the forecast.

As of May 2022, 547834 units of motor vehicles were registered in the city. The basic data of motor transport is determined by the number of 538544 units of motor vehicles. Of these: passenger cars 491861 units and make up 91.3 % of the total number of PBX, buses 8150 units, make up 1.6 %, trucks 32113 units make up 5.9 %, special equipment 582 units, is 0.1 % and motor vehicles 5838 units, is 1.1 %.

Vehicles of Euro 0 ecological class include 12.6 % of the total, Euro 1 class – 10.4 %, Euro 2 class – 10.4 %, Euro 3 class – 10.3 %, Euro 4 class – 20.7 %, Euro 5 class – 23.4 % and Euro 6 class – 12.1 %.

The amount of emissions of pollutants from road transport in the city of Almaty for 2022 (the annual estimated amount of emissions) will be 48697.3 tons. The main amount of harmful emissions falls on the share of passenger cars - 35610.4 tons, which is 73.3 % of the total. Trucks emit 8260.3 tons (17.0 %) and buses 4569.2 tons (9.4 %) of emissions (Table 3).

Table 3. Pollutants emission of motor vehicles in Almaty (the year 2022)

Vehicle type	Pollutants emissions, tons per a year						
	Carbon oxide CO	Hydro-carbons CH	Nitrogen oxides NO _x	Sulphur dioxide SO ₂	Solid particles PM	Non-methane hydrocarbons NMVOC	All pollutants
Passenger cars	27206,6	2885,2	2221,4	461,7	60,0	2775,5	35610,4
Trucks	5341,5	574,2	1595,2	131,4	65,2	552,8	8260,3
Buses	2044,5	303,6	1688,5	200,6	88,5	243,5	4569,2
Special machinery	53,1	4,9	4,6	0,4	0,4	4,8	68,2
Motorcycles	72,5	9,9	0,6	0,2	0,2	9,2	92,6
Total	34718,2	3774,7	5610,7	794,6	213,4	3585,7	48697,3

Emissions of pollutants from motor vehicles for 2022, taking into account incoming vehicles (about 250,000 units), will amount to 72140.2 tons.

According to the approved environmental quality targets for the city of Almaty until 2025, the target for emissions of pollutants from motor vehicles for 2022 is set at 54,000 tons per year. The actual emission of vehicles for 2022 will amount to 72140 tons and exceeds the target by 33.6 %

Compared to 2017, in 2022, vehicle emissions decreased by 15,725 tons and 17.9 %.

Achieving the targets for air pollution by motor transport would be possible if the conditions of intensive development of transport were met [14].

Reasons for not achieving the vehicle emissions targets for 2022.

1) There is a slow increase in the environmental classes of cars. In 2017, the share of Euro 0 class vehicles was 29.3 %, Euro 5 and 6 was 27.1 %. In 2022, the share of Euro 0 class vehicles is 23.0 %, Euro 5 and 6 is 35.5 %.

2) Limiting the use of passenger cars of Euro 0 - 3 environmental classes and replacing them with environmental classes Euro 5-6 is not held.

In order to further reduce the pollutants emissions into the atmospheric air by the motor transport, the following measures are proposed:

1) Increase of the ecological level of motor transport used in the city:

- increase of share of the improved ecological classes Euro-5 and Euro-6 in the vehicles fleet up to 50 % in the year 2025;

- limitation in use of vehicles belonging to the ecological class Euro-0;
- strengthening of control on harmful emissions and black smoke of the vehicles' exhaust gases, introduction of multimode control.

2) Regulation of the vehicles' use within the city:

- decrease of the passenger cars' use within the city due to development of public transport;
- increase of use of large municipal buses, implementation of the passengers transportation based on the rapid bus service' system, public transport development.

3) Further increase of use of compressed natural gas and liquefied oil gas as the fuel for vehicles.

4) Development of electric transport:

- use of electric vehicles, hybrid – electric vehicles and electric buses.

4. Conclusions

Emissions of the motor transport are the most important source of the pollutants entrance into the atmosphere of the city of Almaty. Depending on realization of different scenarios of the motor transport development in the city till the year 2025 (in comparison with the input year 2017), the increase of gross emissions of harmful substances (by 36,6 %) is possible as well as the decrease (by 52,0 %). The developed target parameters of the environmental quality for Almaty for the period till the year 2025 as regards the pollutants' emissions produced by the vehicles foresee the realization of the active and intensive scenarios. These scenarios of development will support the reduction of the emissions. Development of the given scenarios is possible under condition of realization of effective measures on increase of the vehicles' ecological level and regulation of the motor transport' use within the city.

Achievement of the established target parameters for the pollutants emissions produced by the motor transport is the essential condition for provision of good quality of the atmospheric air in the city of Almaty.

Acknowledgements

The authors have not disclosed any funding.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

References

- [1] "3rd Environmental performance review of Kazakhstan," United Nations, Geneva, 2019.
- [2] A. Nurgalieva, D. Ismailova, G. Abisheva, L. Taukenova, P. Hajek, and E. S. Balapanova, "Ecology as a basic principle of sustainable development," *NEWS of National Academy of Sciences of the Republic of Kazakhstan*, Vol. 1, No. 439, pp. 164–171, Feb. 2020, <https://doi.org/10.32014/2020.2518-170x.20>
- [3] "Vehicle emissions, fuel quality standards and fuel economy policies in Kazakhstan: Stocktaking analytical report," United Nations Environment Programme, 2013.
- [4] "... Agency for Strategic planning and reforms of the Republic of Kazakhstan Bureau of National statistics. <https://stat.gov.kz/official/industry/61/statistic/6>

- [5] “National report on the state of the environment and the use of natural resources of the Republic of Kazakhstan for 2019,” (in Russian), Ministry of Ecology, Geology and Natural Resources of Kazakhstan, <http://ecogofond.kz/orhusskaja-konvencija/dostup-k-jekologicheskoy-informacii/jekologijaly-zha-daj/r-orsha-an-ortany-zhaj-k-ji-turaly-ltty-bajandamalar/>, 2019.
- [6] V. V. Chernonozhkina, “Analysis of natural and climatic features of the area contributing to air basin pollution in Almaty,” (in Russian), *International Research Journal*, Vol. 1, No. 8, pp. 73–74, 2013.
- [7] T. Dedova, E. Zakarin, B. Mirkarimova, N. Yakovleva, and E. Sadvakasov, “Numerical analysis of the impact of mountain-valley circulation on atmospheric air pollution in Almaty,” (in Russian), Vol. 2, pp. 7–24, 2018.
- [8] “ECOSERVICE-S Setting environmental quality targets for Almaty,” (in Russian), <https://ecoservice.kz/projects/target-values-almaty>, 2017.
- [9] A. Kerimray et al., “Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan,” *Science of The Total Environment*, Vol. 730, p. 139179, Aug. 2020, <https://doi.org/10.1016/j.scitotenv.2020.139179>
- [10] “Technical Regulations of the Customs Union "On the safety of wheeled vehicles",” (in Russian), TR CU 018/2011, 2011.
- [11] “EMEP/EEA Air Pollutant Emission Inventory Guidebook,” <https://www.eea.europa.eu/publications/emep-eea-guidebook-2013>, 2013.
- [12] Y. A. Jailaubekov, “Calculation and analysis of emissions of harmful pollutants by motor vehicles into the atmospheric air in the Republic of Kazakhstan,” (in Russian), Almaty, 2010.
- [13] “Transport in the Republic of Kazakhstan. Statistical bulletin,” (in Russian), Committee on Statistics of the Republic of Kazakhstan, <https://stat.gov.kz/>.
- [14] “Sustainable transport of the city of Almaty,” (in Russian), UNDP GEF Project 2011-2017, <https://alatransit.kz/ru/content/proekt-ustoychivyy-transport-galmaty>, 2017.
- [15] “Environmental Code of the Republic of Kazakhstan.”. <https://adilet.zan.kz/rus/docs/k070000212>
- [16] “On approval of target indicators of environmental quality for the city of Almaty until 2025,” (in Russian), The decision of the extraordinary LII session of the maslikhat of the city of Almaty of the VI convocation of August 9, 2019.
- [17] L. R. Sassykova et al., “Norms of emissions of harmful substances generated from vehicles in the different countries of the world,” *NEWS of National Academy of Sciences of the Republic of Kazakhstan*, Vol. 2, No. 434, pp. 181–190, Apr. 2019, <https://doi.org/10.32014/2019.2518-170x.53>
- [18] “Recommendations for green and healthy sustainable transport – "Building forward better",” United Nations Geneva, <https://thepep.unepc.org/events/fifth-high-level-meeting-transport-health-and-environment-0>, 2021.