Technogenic impact assessment on the environment of Pavlodar region using GIS technologies

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Abstract. Pavlodar region is the largest industrial center of Kazakhstan. There are three cities with developed industries in the region: Pavlodar, Ekibastuz, and Aksu. A diversified industrial complex has developed in the region, which is focused on the production of electricity, alumina, oil products, mechanical engineering, the food industry, and building materials. The consequences of the rapid development of industry in the Pavlodar region were the highest rate of emissions of pollutants into the atmosphere in the Republic of Kazakhstan. According to the observations of environmentalists, the state of the atmospheric air in the region has deteriorated since the 1990s. Air pollution in industrial cities has a detrimental effect not only on human life, but also on animals, plants, and microorganisms, and also damages the economy of the region. Enormous damage to the waters of the Irtysh is caused by the enterprises of Pavlodar, as well as many enterprises of the East Kazakhstan region, the territory of which flows through most of the Irtysh River. Another no less significant environmental problem is the chemical pollution of the city of Pavlodar with mercury, associated with the Pavlodar chemical plant. Thus, one of the main tasks of the region is to improve the environmental situation.
Keywords: industry, sector, pollution, atmospheric air, substances, enterprises, production, environmental problems, impurities, gases, geoinformation systems, monitoring, sensing.

1 Introduction

Pavlodar city is a regional center of the Pavlodar Region, founded in 1861. Today the region is one of the developed industrial regions of Kazakhstan. Pavlodar region concentrates 7.8% of Kazakhstan's industrial production. According to the republican territorial labor division, the Pavlodar region accounts for 59% of mined coal, 40% of electricity generated, 65% of ferroalloy production, 41.8% of gasoline production, and 99.6% of alumina and raw aluminum. The leading industry is manufacturing - 62.3%, and in second place is mining - 21.4%.

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About 1000 industrial enterprises function in the Pavlodar region, however, 80% of industrial production is produced at 16 enterprises. The largest enterprises are JSC "Kazakhstan electrolysis plant", JSC "Aluminium of Kazakhstan", JSC "Pavlodar petrochemical plant", PF JSC "Kasting", and JSC "Pavlodar machine-building plant". It should be noted that most industrial enterprises are located in the industrial zones - central, northern, and eastern. Industrial zones are placed correctly, that is, on the leeward side.

One of the main industrial cities of the region is Ekibastuz, which is located in the west of the Pavlodar region. There are about 200 industrial enterprises in the city. The largest enterprises are Ekibastuz GRES-1, JSC "Station Ekibastuz GRES-2", LLP "Bogatyr Komir", which is one of the largest coal mines in Kazakhstan, JSC "Vostochny coal mine "EEC", LLP "Angrensor", LLP " Ekibastuz crushed stone mining Company".

The city of Aksu is located 50 km south of Pavlodar. The leading place in the structure of the industry is occupied by the manufacturing industry with 72.1%, the electric power industry accounts for 21.8%. The city-forming enterprises include the Aksu Ferroalloy Plant, a branch of JSC "TNC Kazchrome", and the power plant JSC "EEC". [1]

With the active development of industry, environmental problems in the Pavlodar region have become quite acute. Air pollution near industrial enterprises negatively affects the lives of humans, animals, plants, and microorganisms, and also harms the economy. Thus, the Pavlodar region ranks first among all regions of Kazakhstan in terms of the number of pollutants in the atmosphere. According to the data of 2020, industrial enterprises of the Pavlodar region accounted for 723 thousand tons of emissions.

176 enterprises of Pavlodar have autonomous boiler houses, while the emission limit for 2021 is 5,068 thousand tons.

There are 33 enterprises in Ekibastuz that have boiler houses on their balance sheet, and the emission limit for 2021 is 0.27 thousand tons

16 enterprises in the city of Aksu have autonomous boiler houses on their balance sheets. The emission limit of Aksu enterprises for 2021 is 0.236 thousand tons [2].

2 Materials and methods

Conducting industrial activity is regulated by the Law of Kazakhstan "On Licensing", dated 27.01.96, "On Subsoil and Subsoil Use, as well as by the President of the Republic of Kazakhstan decree dated 12.01.1998.

Observations were carried out at the posts installed in Pavlodar city and the predominant impurities in the atmospheric air were determined, the data are provided in table 1.

Table 1. Location of observation posts and determined impurities.

№	Sample selection	Post address	Determined impurities
1	Manual sampling	st. crossing Kamzin and Chkalova	suspended particles (dust), sulfur dioxide, carbon monoxide
2		Aimanova st., 26	hydrogen sulfide, phenol, chlorine, chloride, hydrogen.
3		Lomova st.	suspended particles PM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide, ozone (surface), and hydrogen sulfide.
4		Kaz-Pravdy st.	suspended particles PM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide, ozone (surface), and hydrogen sulfide.

5	in continuous mode - every 20 minutes	Estaya st., 54	suspended particles PM-2.5, suspended particles PM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide, ozone (surface), ammonia.
6		Zaton st, 39	particulate matter PM-2.5, particulate matter PM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitric oxide, hydrogen sulfide, ozone (surface), ammonia.
7		Toraigyrova – Dyusenova st.	suspended particles PM 2.5, suspended particles PM 10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide, hydrogen sulfide, ozone (surface), ammonia.

According to the observations of posts in Pavlodar city, the level of atmospheric air pollution according to SI = 3.5 i.e. elevated level. The indicator for suspended particles is PM-2.5 in the area of post No. 5 (Estay St. 54).

Exceeding the maximum permissible concentrations was not observed, and there was no extremely high and high pollution. The number of recorded excesses is shown in Table 2.

Table 2. Characteristics of atmospheric air pollution.

Impurity	**Average concentration**		**Maximum single concentration**		**HR**	**The number of cases of exceeding the MS-MPC**	
	mg/m3	Multiplicity of average daily MPC	mg/m3	Multiplicity of maximum single-MPC	%	MPC	>5 MPC
Suspended particles (dust)	**0,05**	**0,33**	**0,30**	**0,60**	**0,00**		
Suspended particles PM-2,5	0,01	0,31	0,56	3,48	0,40	35	
Suspended particles RM-10	0,04	0,59	0,90	2,99	1,76	167	
Sulphur dioxide	0,01	0,18	0,49	0,97	0,00		
Carbon monoxide	0,32	0,11	10,97	2,19	0,08	6	
Nitrogen dioxide	0,02	0,59	0,33	1,63	1,06	106	
Nitric oxide	0,01	0,14	0,38	0,96	0,00		
Ozone (surface)	0,02	0,81	0,16	0,98	0,00		
Hydrogen sulfide	0,00		0,01	1,53	0,42	30	
Phenol	0,00	0,31	0,01	0,80	0,00		
Chlorine	0,01	0,29	0,06	0,60	0,00		
Hydrogen chloride	0,03	0,35	0,18	0,90	0,00		
Ammonia	**0,00**	**0,05**	**0,03**	**0,13**	**0,00**		

Geoinformation and mathematical modeling of mercury contamination of underground waters of the region were carried out on the territory of the Pavlodar region. The simulation was performed to assess the risk of pollution to the environment. The source of pollution is

a soda and chlorine production facility. The plant of JSC "Khimprom", in which the chlorine and soda production shop operated, worked from 1975 to 1990. Groundwater was polluted with mercury as a result of accidents that occurred in the workshop. Thus, 4 variants of the forecast for the next 30 years were carried out. The first option assumed the preservation of the source of pollution, that is, JSC "Khimprom", the second option involves the demercurization of the territory of the plant. The third option is to stop the supply of water to the northern industrial complex and the fourth option is to localize the two main sources.

During the monitoring of air quality, it was revealed that the level of atmospheric air pollution in Pavlodar city for the 1st quarter of 2017-2021 changed significantly.

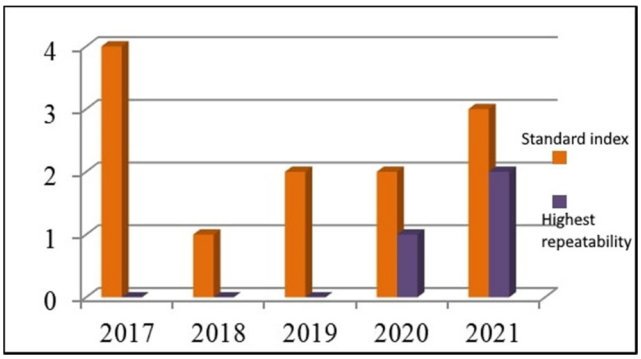

Fig. 1. Comparison of air pollution for the 1st quarter of 2017-2021 in Pavlodar.

According to the schedule, the pollution level in Pavlodar for 2017-2021 tends to increase. The air quality of the city of Pavlodar has deteriorated in comparison with the 1st quarter of 2020. The dynamics of the increase indicate that there are suspended dust particles in the air from the soil, that is, of natural origin, and from emissions from boilers, furnace heating, and transport, that is, of anthropogenic origin.

Studies were conducted on the concentration of pollutants in the Northern Industrial Zone of Pavlodar City. The research data is shown in Table 3.

Table 3. Results of expedition measurements of atmospheric air quality.

Detectable impurities	**$q_m$mg/ m^3**	**q_m/MPC**
Ammonia	0,0005	0,003
Benzene	0,0585	0,20
Ethylbenzene	0,0145	0,73
Formaldehyde	0,0	0,0
Gasoline	1,569	0,3
Phenol	0,0005	0,048
Hydrogen fluoride	**0,0007**	**0,04**

In general, the concentrations of impurities contained in the air did not exceed the limits of the norm. Monitoring of atmospheric air quality in Ekibastuz. Monitoring of atmospheric air quality in Ekibastuz is carried out at two posts.

Results of monitoring of atmospheric air quality in Ekibastuz for the 1st quarter of 2021. According to the results of observations of posts in Ekibastuz, a low level of atmospheric air pollution was recorded.

No exceedances of the Mand PC were recorded. The average concentration is shown in Table 5.

Table 4. Location of observation posts and detectable impurities.

№	Sampling	Post address	Detectable impurities
1	manual sampling	Berkimbayev and Satpayev str.	Suspended particles (dust), sulfur dioxide, carbon monoxide, nitrogen dioxide.
2	in continuous mode - every 20 minutes	Mashkhur Zhusupa str. 118/1	Suspended particles RM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide.

Table 5. Characteristics of atmospheric air pollution.

Impurity	Average concentration		Maximum single concentration		HR	The number of cases of exceeding the MS-MPC		
	mg/m3	The multiplicity of average daily MPC	mg/m3	The multiplicity of maximum single-MPC	%	>MPC	>5 MPC	>10 MPC
Ekibastuz city								
Suspended particles (dust)	0,03	0,21	0,20	0,40	0,00			
Suspended particles RM-10	0,00	0,00	0,05	0,15	0,00			
Sulfur dioxide	0,00	0,08	0,08	0,15	0,00			
Carbon monoxide	0,91	0,30	5,09	1,02	0,03	2		
Nitrogen dioxide	0,01	0,17	0,12	0,60	0,00			
Nitric oxide	0,00	0,02	0,07	0,18	0,00			

As shown in the graph, the level of pollution in the 1st quarter of the period from 2017 to 2021 has not changed.

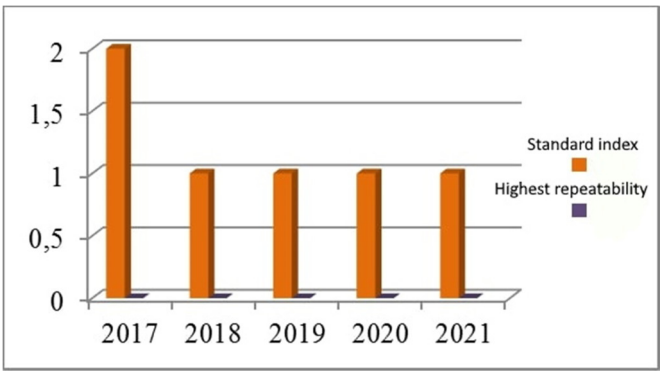

Fig. 2. Comparison of the air pollution level for the 1st quarter of 2017-2021 in Ekibastuz.

There were no exceedances of the standards of average daily concentrations. Monitoring of atmospheric air quality in Aksu. Monitoring of the state of atmospheric air in Aksu is

carried out at one post. The locations of the monitoring posts and the detected impurities are shown in Table 6.

Table 6. Location of observation posts and detectable impurities.

Sampling	Post address	Detectable impurities
In continuous mode - every 20 minutes	Auezova str., 4	suspended particles RM-10, sulfur dioxide, carbon monoxide, nitrogen dioxide, and nitrogen oxide.

Results of monitoring of atmospheric air quality in Aksu for the 1st quarter of 2021. As a result of observations, a low level of atmospheric air pollution was recorded. The excess of the MPC was recorded only in one case - nitrogen dioxide. The average concentration, the maximum single concentration, and the number of cases exceeding the MPC are shown in Table 7.

Table 7. Characteristics of atmospheric air pollution.

Impurity	Average concentration		Maximum single concentration			HR	The number of cases exceeding the MS-MPC	
	mg/m 3	A multiplicity of average daily MPC	mg /m 3	The multiplicity of maximum single-MPC			mg/m3	The multiplicity of average daily MPC
	Aksu city							
Suspended particles RM-10	0,01	0,21	0,0 2	0,08		0,00		
Sulfur dioxide	0,01	0,23	0,1 5	0,29		0,00		
Carbon monoxide	0,11	0,04	2,4 7	0,49		0,00		
Nitrogen dioxide	0,05	1,20	0,2 5	1,24		0,20	13	
Nitric oxide	0,01	0,15	0,2 6	0,65		0,00		

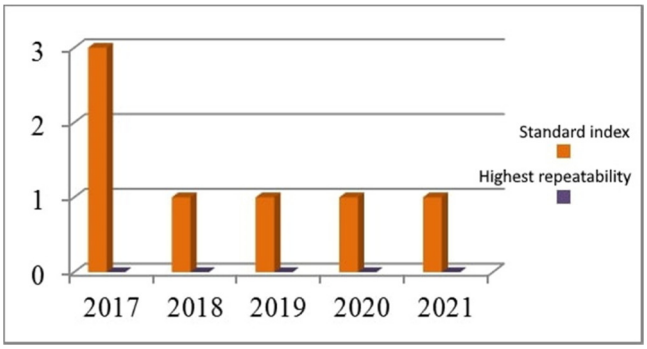

Fig. 3. Comparison of air pollution for the 1st quarter of 2017-2021 in Aksu.

As can be seen from the graph, the level of pollution in the 1st quarter over the past five years has remained at the same level and is low. Compared to the 1st quarter of 2020, the

air quality of the city of Aksu has not changed. Exceedances of the maximum single MPC were noted for nitrogen dioxide (13). Exceedances of the standards of average daily concentrations were observed for nitrogen dioxide. This pollution is typical for the spring-winter season, accompanied by the influence of emissions from thermal power plants and heating of the private sector [3].

Table 8. Results of expedition measurements of atmospheric air quality.

Detectable impurities	$q_m$mg/m^3	q_m/MPC
Ammonia	0,0010	0,0048
Benzene	0,233	0,777
Ethylbenzene	0,033	1,7
Formaldehyde	3,05	0,609
Gasoline	0,003	0,4
Phenol	0,34	-
Hydrogen fluoride	0,0009	0,043

3 Conclusions

It can be concluded that in order to stop mercury contamination of groundwater, it is necessary to install a filtration curtain. So, in the coming decades, mercury does not pose a danger to residents of the Pavlodar Industrial Hub.

Observations of posts of industrial cities of the Pavlodar region provide information about the level of air pollution. Being in an industrial city, any of us can get information about the degree of atmospheric air pollution, as well as about the content of impurities in it. To do this, Kazhydromet has created an application called "Air Kz". The application is available for free download [4].

One of the problems of the Pavlodar region, which arose as a result of the development of industry, is the deterioration of water quality. This applies primarily to the East Kazakhstan region since most of the Irtysh passes through this territory. Non-ferrous metals mining enterprises are located in the East Kazakhstan region.

Within this territory, there are six large industrial centers that have a negative impact on water quality. The first source of pollution is Mykolaiv, a branch of Vostokkazmed located here. Thus, there is a significant content of iron, cadmium, copper, and lead in the waters. The next source of pollution is Leninogorsk. It includes the Tishinsky, Ridder-Sokolny, and Altai mines, as well as the Kazzinc zinc plant. Waste from these enterprises causes significant harm to water quality. The third - the Krasnoyarsk hearth includes the Irtysh mine and the Berezovskaya concentrating plant. The consequence of the functioning of the Belousovsky mine is the excess of the MPC in terms of content, manganese, cadmium, zinc, copper, etc. The enterprises of the Ust-Kamenogorsk source of pollution have a negative impact on the waters of the Irtysh. These include JSC "Kazzinc", "Ulba Metallurgical Plant", "and Ust-Kamenogorsk titanium and magnesium combined [5].

The consequence of the influence of these pollution foci is that in some tributaries of the Irtysh River, exceedances of MPC of some heavy metals are recorded. However, a significant amount of Irtysh runoff, as well as the use of self-purification mechanisms, allows restoring the quality of the river. According to 2018 data, the water quality of the Irtysh is assessed as moderate. But it is worth noting that a decrease in the level of runoff will lead to a significant deterioration in water quality.

One of the environmental problems of the Pavlodar region is chemical mercury pollution.

Mercury pollution was associated with the Pavlodar Chemical Plant, which produced chlorine and caustic soda. In 1994, it was decided to close production by the mercury method and carry out demercurization [6].

Human has a significant impact on the environment as a result of economic activity. Man creates various chemicals that are constantly accumulating in nature. Chemical pollution is attributed to one of the global problems of mankind. The consequence of this is a decrease in biological diversity, climate change, and water problems. The consequence of environmental degradation is every fourth death in the world, which means 12.6 million people a year [7-9].

To improve the state of the environment, Kazakhstan signed the Aarhus Convention in 2001. The Convention provides citizens with the opportunity to solve environmental problems [10].

Recently, the number of people fighting for environmental improvement has increased. Industrial enterprises of the Pavlodar region actively carry out environmental protection measures. JSC "Aluminum of Kazakhstan" is a leader, filters are installed, and environmental costs are billions. The Pavlodar region is constantly monitoring compliance with environmental legislation. So, the youth squad "Zhasyl El" on a regular basis conducts subbotniks on Goose flight. In schools, special attention is paid to environmental problems, which educates children with a caring attitude to the environment.

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