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Analysis of the state of atmospheric air in the city of Aktobe according to stock materials

Abstract. *The article considers the influence of climatic factors on environmental indicators of the state of atmospheric air. The analysis of atmospheric air pollution in the city of Aktobe is carried out according to departmental organizations and stock materials. The dynamics and structure of pollutant emissions in recent years are presented. The authors carried out a comparative characteristic of the composition and structure of emissions depending on climatic conditions. The article focuses on patterns of changes in emissions of pollutants into the atmosphere. The article presents organizational and economic measures to prevent environmental pollution, including the tightening of environmental legislation and the introduction of methods of internalization of environmental damage.*

Keywords: *environmental situation, outdoor atmospheric pollution, stationary sources, environmental situation, the structure of emissions, analysis.*

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Introduction

In recent decades, there has been an increasingly close relationship between the development of the economy and changes in the environment, and the mutual impact of both the environment on economic development and the results of economic activity on the state of the natural environment is increasing, accompanied by significant negative changes in its quality. In turn, the impact of the environment on the health and quality of life of the population is increasing, which are important factors in human capital development and productivity growth that determine economic development [1-3].

The state of the environment is one of the basic parameters that characterize the quality of life of the population. In recent decades, there has been an increasingly close relationship between the development of the economy and changes in the environment, and the mutual impact of both the environment and the results of economic development on the state of the natural environment has increased [4, p. 125]. In a constantly deteriorating environmental situation, the impact of the environment on the health and quality of life of the population increases correspondingly. The health of the population as a whole and of the region, in particular, is an important factor in human capital development and productivity growth, which in turn have a direct impact on economic development.

An important factor that negatively affects both the health of the population and the economy is atmospheric air pollution. Therefore, there is a need for measures to analyze, predict and control the impact of transport and industry on the environment.

According to the annual bulletin of the RSE "Kazhydromet", the state of atmospheric pollution in the cities of the Republic of Kazakhstan, Aktobe has been among the five cities with the highest level of atmospheric air pollution for a long time and is included in the "Priority list of cities with the highest level of atmospheric air pollution".

Regular monitoring of the state of atmospheric air on the territory of the Republic of Kazakhstan is carried out by RSE "Kazhydromet" in 28 localities, including in the city of Aktobe [5,6].

Research area and methods

The condition of the air basin is assessed based on the results of the analysis and processing of air samples taken at observation posts. Observations of the state of atmospheric air in Aktobe are conducted at 5 observation posts, three of which are sampled in manual mode (discrete method), and two – in automatic mode (continuous) (Figure 1, Table 1).

Table 1. Location of observation posts and determinable impurities [6]

Post number	Selection Period	Conducting observations	Post address	Definable impurities
1	4 times a day	Manual sampling (discrete methods)	Aviagorok 14	Suspended Substances, Sulphur Dioxide, Sulphates, Carbon Oxide, Nitrogen Dioxide and Oxide, Hydrogen Sulfide, Formaldehyde, Chromium.
4	3 times a day	Manual sampling (discrete methods)	Belinskogo st, 5	
5			Lomonosova st, 7	
2	каждые 20 минут	In continuous mode	Ryskulova st, 4 «G»	Suspended particles RM-10, sulphur dioxide, carbon oxide, nitrogen dioxide and oxide, ozone, hydrogen sulfide, formaldehyde, sum of hydrocarbons, methane.
3			Eset-Batyr st, 109	

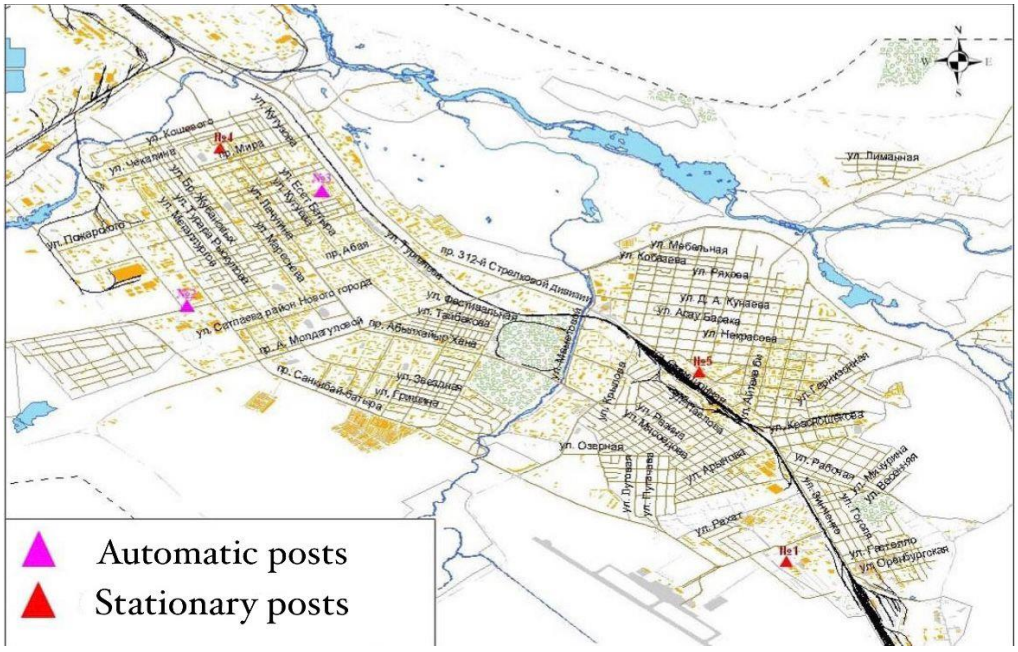

Figure 1 - Layout of air sampling stations in Aktobe

The quality criteria are the values of the maximum permissible concentrations (MPC) of pollutants in the air of populated areas. The level of atmospheric pollution is estimated by the value of the complex index of atmospheric pollution (ISA5), as well as by the excess of the MPC of individual pollutants by comparing the impurity concentration with the MPC (in mg/m3, mcg/m3). To assess the level of atmospheric air pollution for a month, there are used two air quality indicators such as:

• standard index (SI) – the highest impurity concentration measured in a short period of time, divided by MPC, from the measurement data at the post for one impurity, or at all posts for all impurities.

• greatest repeatability (NP) – the greatest repeatability of exceeding the MPC from the measurement data at the post for one impurity, or at all posts for all impurities [7].

The degree of atmospheric air pollution is estimated by four gradations of SI and NP values, which characterize the degree of short-term exposure to air pollution to public health (Table 2). If SI and NP fall into different gradations, then the level of air pollution is estimated by the highest value of these indicators [6].

Table 2 – Assessment of the degree of atmospheric pollution index

Gradation	Outdoor air pollution	Indicators	Assessments for the month
I	Low	SI	0-1
		NP, %	0
II	Increased	SI	2-4
		NP, %	1-19
III	High	SI	5-10
		NP, %	20-49
IV	Very High	SI	›10
		NP, %	›50

The value of the complex index of atmospheric pollution is calculated for five substances with the highest normalized values of MPC, taking into account their hazard class. In Aktobe IPA5 includes the following pollutants: nitrogen dioxide, sulfur dioxide, ammonia, dust, and carbon monoxide.

The criteria for the quality of atmospheric air by the value of IPA are presented in Table 3.

Table 3 - Air pollution quality criteria by IPA value

IPA - < 5 -	The level of pollution is below the average in cities
IPA - > 5, < 8	The level of pollution is average in cities
IPA - > 8, < 15	The level of pollution is above the average in cities
IPA - 15 and highest	The level of pollution is significantly higher than the average in cities

The quality of atmospheric air in an urban environment depends not only on the volume of gross emissions, but is formed under the influence of a complex interaction of natural and anthropogenic factors. With constant emission parameters, the level of pollution directly depends on climatic conditions: temperature, wind speed, and direction, solar radiation intensity, air humidity, amount and duration of precipitation. It is also important to take into account the parameters of the dispersion of impurities. In an urban environment, the dispersion features are influenced by the layout of streets, their width, direction, and height of buildings. In large cities, with prolonged weather clearings (anticyclonic type of weather), prerequisites are created for the formation of a "heat island", where the highest concentrations of pollutants are observed [8].

Natural and climatic conditions largely determine the potential for atmospheric pollution (APP). The transport and dispersal of impurities entering the city's air basin emitted by industry and motor vehicles depends on the APP. A low APP (favorable dispersion conditions) is observed in North and Central Kazakhstan. The most unfavourable dispersion conditions (very high APP) occur in Eastern and Southern Kazakhstan [9]. The urban agglomeration «Aktobe City» is located in the Western part of the Republic of Kazakhstan, in the central part of the Podralskaya plateau, raised by 200-400 m. The terrain within the city is diverse, absolute marks range from 200 to 210 m [9].

The western part of Kazakhstan in the cold season is under the influence of a vast area of the Siberian anticyclone [10]. The climate of Aktobe is assessed as sharply continental, characterized by negative values of the average annual temperature (+5 ° C), a significant difference between average temperatures in winter and summer (30 °, -40 ° C), sharp temperature fluctuations (10 ° C or more) during the day, relatively little precipitation (350 mm in a year). The average annual wind speed is 2.4 m/s, and the average annual humidity is 68 % [10].

Throughout the year, the wind of the western, north-westerly direction prevails (22-27%). The anticyclone dominating the city in winter causes the predominance of calm or with weak winds weather. From November to March, the wind speed of 0-1 m/s is recorded in 82-89% of cases. The displacement of cyclones leads to a significant increase in wind from March to May. The main direction of the wind in the city of Aktobe is the west (17%). In addition, the prevailing wind directions can be called southeast (17%) and south (15%). The rarest wind in the city of Aktobe is northeast (6%) (Figure 2). The wind speed in this period can reach 15-18 m /s, sometimes its gusts are recorded at the level of 20-25 m/ s, which, combined with intense evaporation from the surface of sandy soil, is the cause of increased natural dustiness of the air basin.

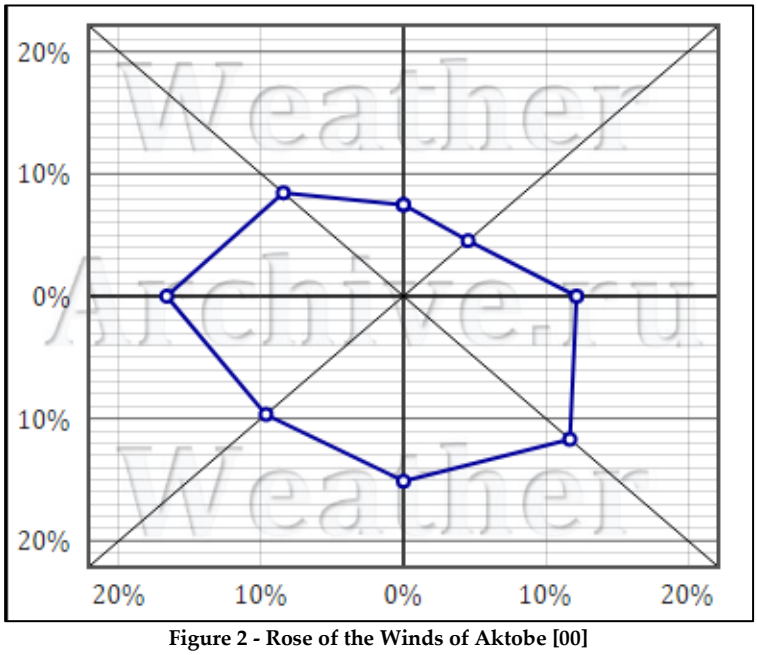

Figure 2 - Rose of the Winds of Aktobe [00]

The city is dominated by a fairly low relative humidity (40-50%). Precipitation is distributed unevenly throughout the year: during the cold period, their monthly amounts are insignificant (25-30 mm), the minimum falls in December-January (17 mm), and the maximum is in June, less often in July. The city has an average of about 148-170 days with snow cover.

The natural topographical features of the location of the city and its individual districts are important factors in determining air quality. In conditions of local terrain, with frequent stagnation of air

masses, emissions from industrial enterprises dissipate slowly, while high concentrations of pollutants are created in the surface layer of the atmosphere. According to the zoning of the country's territory according to the climatic conditions of the dispersion of impurities from low emission sources, the city belongs to the fifth zone (with a high potential for atmospheric pollution).

Results and discussion

According to the index of atmospheric pollution in 2020, Aktobe was in 11th place among other cities of Kazakhstan – 4.2, which characterizes the level of air pollution in the city as "below average" (Figure 3) [3].

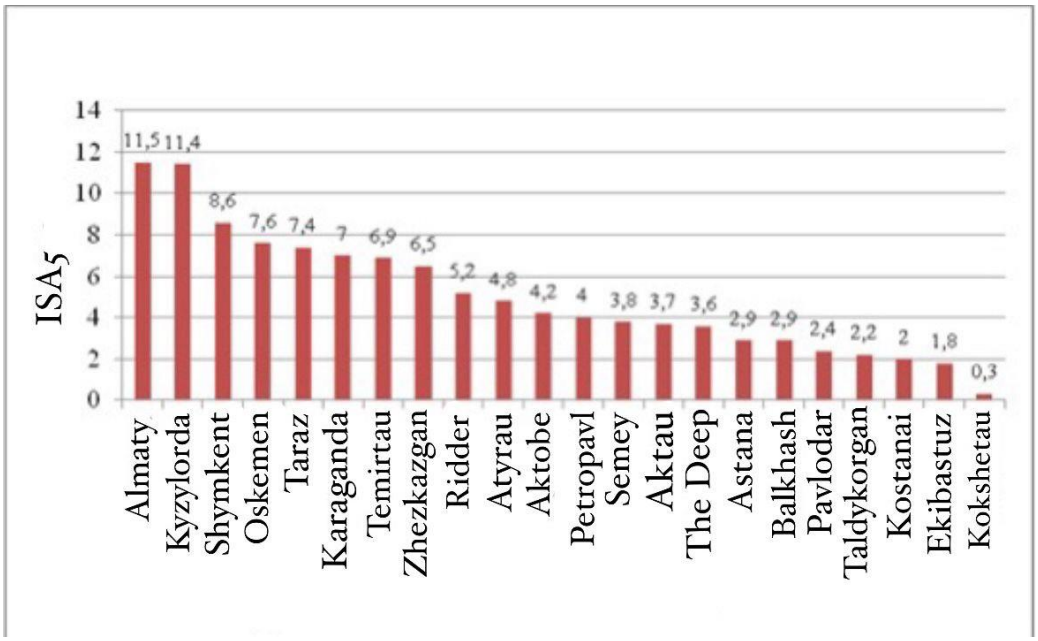

Figure 3 - Comparison of the Air pollution index (ISA) by cities of the Republic of Kazakhstan for 2020

Analysis of changes in the average long-term (for 2015-2021) value of the air pollution index in the city of Aktobe by month showed the following (Figure 4).

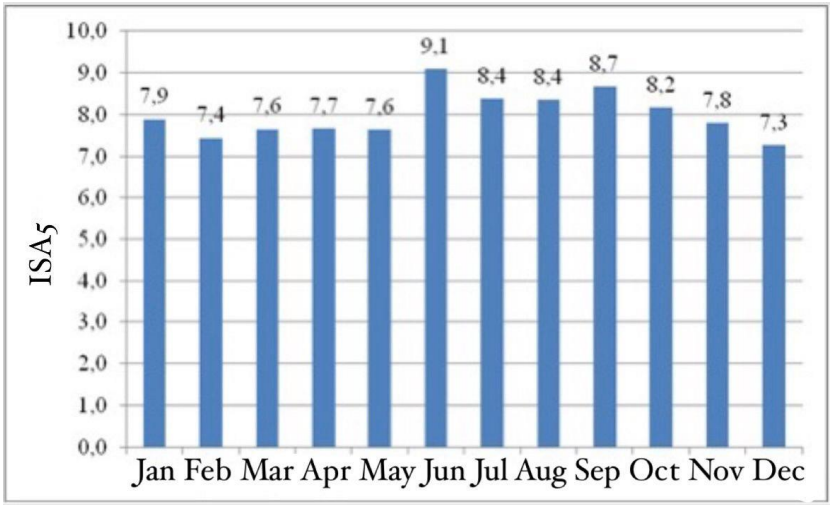

Figure 4 - Comparison of the average long-term value of the atmospheric pollution index (IPA5) in the city of Aktobe by month.

The average long-term value of IS5, as a rule, reaches the highest values in the summer, especially the level of pollutants in the atmosphere of the city in June is high. In autumn, the level of atmospheric air pollution decreases reaches its minimum value in December, and then stabilizes at relatively low levels of 7.5-7.6.

The analysis of the level of air pollution in Aktobe in 2021 by the maximum permissible concentrations of pollutants in the air of populated areas showed that for a number of impurities, there are exceedances of both average and maximum regulatory values. If in the first case the excess was registered for only one substance – formaldehyde (2.3 MPC), then in the second for five: chromium – 31.5 MPC, suspended solids – 8.6 MPC, carbon monoxide – 6.2 MPC, formaldehyde – 2.6 MPC, hydrogen sulfide – 2.1 MPC, nitrogen dioxide – 2.0 MPC ◎5◎. In comparison with the nature and level of atmospheric air pollution in 2020 [00], the average content of the main pollutants in the air in 2021 varies slightly. On the other hand, there are reasonable concerns about a sharp increase in atmospheric pollution with suspended substances and, in particular, chromium.

In total, 19 cases of high pollution (EW) and 4 cases of extremely high pollution (EW) were noted in the city of Aktobe in 2021 (Table 4).

Table 4 – Information on cases of extremely high pollution and high pollution in atmospheric air [5]

Impurity	Day, Month, Year	Time, Hour	Posts Number	Concentration		Wind		Temperature, ^{0}C	Atmospheric Pressure
				mg/m^3	Exceedance, MPC	Direction, grad	Speed, m/c		
В3									
Hydrogen Sulfide	23.02. 2021	12:40 19:00 19:20	№ 2	0,1 0,0838 0,0857	12,5 10,48 10,71	East South East	0,1 0,1 0,1	-3,9 -9,6 -10,2	744,7 746,3 746,6
Hydrogen Sulfide	24.02. 2021	09:00	№ 2	0,0854	10,68	East	0,1	-21,7	752,2
Hydrogen Sulfide	15.03. 2021	00:00	№ 2	0,1014	12,68	North	0	- 1,2	742,7
Hydrogen Sulfide	23.04. 2021	23:40	№ 3	0,1521	19,01	East	0	16,4	731
Hydrogen Sulfide	24.04. 2021	00:20	№ 3	0,0919	11,5	East	0	15,7	730,9
Hydrogen Sulfide	24.04. 2021	02:20 03:00	№ 3	0,0869 0,1559	10,86 19,49	East	0	14,8 14,5	731,4 731,6
Hydrogen Sulfide	04.07. 2021	08:40 23:00 23:20	№ 3	0,1057 0,1443 0,1246	13,2 18,0 15,6	North	Calm	18,3 22,4 21,5	740,3 740,1 740,2
Hydrogen Sulfide	10.07. 2021	04:00 07:40	№ 3	0,1073 0,1011	13,4 12,6	Northwest	Calm	23,4 21,4	732,6 732,4
Hydrogen Sulfide	13.07. 2021	07:40 08:00	№ 3	0,0885 0,1191	11,1 15,0	Northeast	Calm	14,9 15,9	730,5 730,5
Hydrogen Sulfide	26.07. 2021	22:20 22:40	№ 3	0,0868 0,1017	10,85 12,7	East	Calm	25,9 24,6	730,0 730,1
Chromium (+6)	07.10. 2021	13:00	№ 4	0,016	10,7	West	2-6	1,7	745,9

ЭВЗ									
Hydrogen Sulfide	24.04. 2021	00:00	№ 3	0,2384	29,8	East	0	16	731
Hydrogen Sulfide	24.04.	02:40	№ 3	0,2285	28,56	East	0	14,5	731,5
Hydrogen Sulfide	26.07.	23:00	№ 3	0,1834	23,0	East	Calm	25,3	730,1
Chromium (+6)	10.10.	19:00	№ 4	0,0473	31,5	Southwest	2-11	11,0	753,0

In May 2021, at the time of the preparatory work within the framework of these studies, the state of atmospheric air pollution in the city of Aktobe according to the stationary observation network of RSE "Kazhydromet" was characterized by a very high level of pollution. It was determined by the SI value of 14.9 (very high level) for hydrogen sulfide in the area of the industrial zone, the NP of this substance was 5.2% (elevated level).

The high level of atmospheric air pollution was recorded in the 5th District at Station 3 (109 Eset Batyra Str.) *by hydrogen sulfide*, it was determined by the SI value of 6.2, NP was 3.5%. Also in the area of the railway station at station 5 (st. Lomonosova, 7) was noted high content of *formaldehyde*, with values SI 5.8, NP=12.5%.

An increased level of atmospheric air pollution was observed in the area of Zhilgorodok at post No. 4 (Belinsky str., 5) *for hydrogen sulfide and nitrogen dioxide*, NP is equal to 1.4, SI = 1.1. Also, in the area of the railway station at post No. 5 (Lomonosov str., 7*), elevated suspended matter contents were noted* (SI= 2, NP=1,4) and carbon monoxide (NP =8,3, SI = 1,8). In the 5th micro district at post No. 3 (109 Eset-Batyr Street), *increased content of sulfur dioxide, nitrogen dioxide and formaldehyde were registered* (SI was 1.1-2.4, NP< 0.1%).

The concentrations of sulfates, nitric oxide, and chromium were at a low level: SI ≤1, NP = 0%.

The formation of the level and duration of atmospheric air pollution can be significantly influenced by meteorological conditions, especially the wind and temperature regimes of the studied territories [3].

The diffusion capacity of the atmosphere depends on the vertical temperature distribution and wind speed. If the temperature drops at an altitude, intensive turbulent exchange conditions are created. The most volatile state of the atmosphere occurs during the summer during the daytime. Under such conditions, there are large concentrations of contaminants on the Earth's surface and there may be large variations over time. If in the surface air the temperature rises with height (temperature inversion), then the dispersion of impurities decreases. In the case of strong and long-term ground-level inverses with low, in particular disorganized, emissions, impurity concentrations may increase significantly [9].

In the case of elevated inversions, surface concentrations depend on the height of the location of the source of pollution relative to their lower boundary. If the source is located above the elevated inversion layer, then the admixture to the earth's surface comes in small quantities. If the source is located below the elevated inversion layer, then the bulk of the impurity is concentrated near the earth's surface.

The change in the temperature regime in Aktobe is shown in Figure 5.

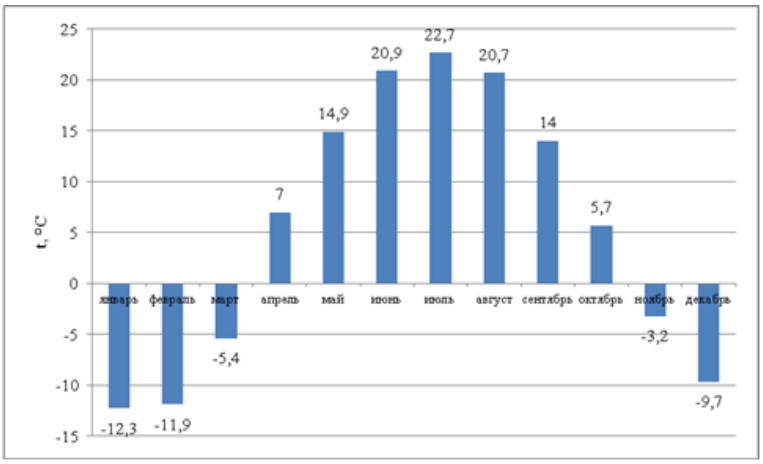

Figure 5 – Change in the average monthly air temperature in Aktobe in 2021

The wind speed contributes to the transfer and dispersion of impurities, as the intensity of the mixing of air layers increases with increasing wind. With a weak wind in the area of high emission sources, the concentrations of SV near the ground decrease due to an increase in the rise of the torch and the entrainment upward. The rise of impurity is especially significant with heated emissions. With a strong wind, the initial rise of the impurity decreases, but the impurity transfer rate increases over considerable distances. Maximum impurity concentrations are usually observed at a certain rate, which is called dangerous. The dangerous wind speed depends on the emission parameters. For powerful emission sources with a large overheating of flue gases relative to the surrounding air, for example, for thermal power plants, it is 5-7 m/s. For sources with relatively low emissions and low gas temperature, for example, for chemical industry enterprises, it is close to 1-2 m/s [5]. For G. Aktobe is characterized by winds of up to 3 m/s, therefore, dangerous winds may occur for metallurgical enterprises located in the city, however, the probability of such winds for the city's energy supply enterprises is low.

Solar radiation causes photochemical reactions in the atmosphere and the formation of various secondary products, which often have more toxic properties than substances coming from emission sources. Thus, in the process of photochemical reactions in the atmosphere, sulfur dioxide is oxidized to form sulfate aerosols. As a result of the photochemical effect, photochemical smog is formed in polluted air on clear sunny days.

With fogs, the concentration of impurities can greatly increase. Fogs are associated with smog, in which high concentrations of harmful impurities are retained for a long time. The greatest probability of smog formation in Aktobe exists in the cold period of the year – late autumn, winter, and early spring.

The spread of impurities is influenced by ordered vertical movements due to the heterogeneity of the underlying surface (terrain and the presence of large reservoirs).

In urban conditions, the dispersion of impurities is also significantly affected by the layout of streets, their width, direction, the height of buildings, the size of green areas, and water bodies that form, as it were, different forms of ground obstacles to airflow and lead to the emergence of special meteorological conditions in the city.

Thus, the analysis of the measurement results of the RSE "Kazhydromet" indicates that since 2017 in Aktobe there has been a systematic decrease in the level of pollution according to ISA5, in recent years this indicator has decreased by more than 2 times. An analysis of the values of I-5 calculated for each month in the period from 2015 to 2021 shows that the value of I-5 increases from June to September of each analyzed annual period.

At the same time, despite the general decrease in the level of air pollution in Aktobe, in 2021, excess amounts of chromium, hydrogen sulfide, suspended solids, carbon monoxide, formaldehyde, and nitrogen dioxide were recorded in the city. In addition, cases of high and extremely high atmospheric air pollution are noted for two substances – hydrogen sulfide and chromium.

Conclusion

According to the data obtained from the results of regular monitoring of the state of atmospheric air in Aktobe, the level of pollution of the urban atmosphere, calculated on the basis of the complex index of atmospheric pollution (ISA5), from 2015 to 2021, i.e. over the past 7 years, has steadily decreased by an average of 0.7 points, and in 2021, it was 4.2, i.e. "below average", which allowed Aktobe to take 11th place among other cities of Kazakhstan in this indicator. Despite this, the ecological state of atmospheric air in the city cannot be called favorable due to the fact that the value of the complex index of atmospheric pollution is calculated only for five substances with the highest normalized MPC values, taking into account their hazard class and, accordingly, cannot fully characterize the ecological state of atmospheric air. This is confirmed by the fact that analyzing the level of atmospheric pollution of Aktobe in 2021, in terms of the maximum permissible concentrations of impurities in the air of populated areas, cases of excess of 6 pollutants - chromium, suspended solids, carbon monoxide, formaldehyde, hydrogen sulfide, and nitrogen dioxide - were identified, of which only three are considered in the formula for calculating ISA5 in Aktobe.

The formation of the level and duration of atmospheric air pollution can be significantly influenced by meteorological conditions, especially the wind and temperature regimes of the studied territories. Thus, when the temperature level decreases with the height, conditions of intense turbulent exchange are created, and, conversely, in the case of an increase in temperature (temperature inversion), the dispersion of impurities weakens. Unlike the temperature, the wind definitely contributes to the transfer and dispersion of impurities. If with a weak wind in the area of high emission sources, the concentrations of SV near the ground decrease due to an increase in the rise of the torch and the entrainment upward, then with a strong wind, the impurity transfer rate increases over considerable distances.

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Анализ состояния атмосферного воздуха города Актобе по фондовым материалам

Аннотация. В статье рассмотрено влияние климатических факторов на экологические показатели состояния атмосферного воздуха. Проводится анализ загрязнения атмосферного воздуха в городе Актобе по данным ведомственных организаций и фондовым материалам. Представлены динамика и структура выбросов загрязняющих веществ за последние годы. Проведена сравнительная характеристика состава и структуры выбросов в зависимости от климатических условий. Сделаны выводы о закономерностях изменения выбросов загрязняющих веществ в атмосферу. Предложены организационные и хозяйственные меры по предотвращению загрязнения окружающей среды, включающие ужесточение экологического законодательства и введение методов интернализации экологического ущерба.

Ключевые слова: экологическая ситуация, загрязнение атмосферного воздуха, стационарные источники, динамика выбросов, структура выбросов, анализ.

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Ақтөбе қаласының атмосфералық ауасының құралық материалдар бойынша

Аннотация. Мақалада климаттық факторлардың атмосфералық ауа жағдайының экологиялық көрсеткіштеріне әсері қарастырылады. Ведомстволық ұйымдардың мәліметтері және қор материалдары бойынша Ақтөбе қаласының атмосфералық ауасының ластануына талдау жүргізілуде. Соңғы жылдардағы ластаушы заттардың шығарындыларының динамикасы мен құрылымы берілген. Климаттық жағдайларға байланысты шығарындылардың құрамы мен құрылымының салыстырмалы сипаттамасы жүргізілді. Атмосфераға ластаушы заттардың шығарындыларының өзгеру заңдылықтары туралы қорытындылар жасалады. Қоршаған ортаның ластануының алдын алу бойынша ұйымдық-экономикалық шаралар ұсынылды, оның ішінде табиғатты қорғау заңнамасын қатайту және қоршаған ортаға келтірілген залалды интернационализациялау әдістерін енгізу.

Түйін сөздер: экологиялық жағдай, атмосфералық ауаның ластануы, стационарлық көздер, эмиссия динамикасы, эмиссия құрылымы.

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