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THE SPATIAL DISTRIBUTION OF NITROGEN DIOXIDE IN ATMOSPLERIC SURFACE LAYER OF ALMATY CITY

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Absrract: *The level of air pollution by nitrogen dioxide in Almaty city has been monitored over the past five years (2009 - 2013). The distribution characteristics of impurities' concentrations in the air basin of urbanized area are reviewed with regard to space and time. It's been revealed that the level of city's air pollution varies depending on the season.*

Key words: *atmosphere, air pollution, the level and degree of pollution by nitrogen dioxide.*

Introduction

Air pollution is one of the major problems in large cities. Air pollution in Almaty city is an environmental problem that is compounded by the climatic and physiographic conditions. The city atmosphere is polluted by various substances but nitrogen dioxide is among the key atmospheric pollutants in Almaty.

Nitrogen oxides (NO_X) are formed during combustion process at high temperatures by oxidation of nitrogen present in the atmosphere. Under the general formula NO_X amount usually is meant the sum of NO and NO_2 [1] . Nitrogen oxide and dioxide play an important and complex role in photochemical processes in troposphere and stratosphere under the influence of solar radiation [2]. Most of the atmospheric NO_2 initially comes as NO, which is rapidly oxidized by ozone to NO_2. In the presence of hydrocarbons and UV radiation, nitrogen dioxide is the main source of tropospheric ozone and nitrate aerosols, which form a significant part of atmospheric mass [3]. Nitrogen dioxide, as its been said, plays an important role in the formation of photochemical smog, contributing to climate change as a greenhouse gas. Therefore, data from permanent monitoring measurements and mathematical modeling will provide detailed information on nitrogen dioxide the content in

various regions taking into account topographic and climatic conditions throughout the defined period [4].

At low concentrations of nitrogen dioxide we observe impaired breathing and coughing. With an average annual concentration of 30 mcg/m^3, we see an an increased number of children with rapid breathing, cough and bronchitis patients. WHO recommended 40 mcg/m^3 as annual standard for nitrogen dioxide concentrations, because higher concentrations lead to painful symptoms in patients with asthma and other groups of people with high sensitivity [5].

Therefore, the issue of reducing the amount of nitrogen oxides in emissions from mobile and stationary sources is acute and relevant.

Materials and methods of research

The state of air pollution by sulfur dioxide in Almaty is the object of investigations. Methods of research are comparative-analytical, statistical analysis of empirical data. The stationary observation posts have been setup depending on how loaded is the street area with different types of vehicles, location of industrial enterprises, sources of heating system, main streets, landscape, etc.

Results

Over the past years, the task of comprehensive environmental improvement is always in the spotlight. So a few long-term comprehensive programs were developed and adopted to improve the current environmental situation. That's why its interesting to consider the distribution of nitrogen dioxide in different seasons and areas of the city over recent years.

With regard to this our goal was set to examine the annual variation of nitrogen dioxide concentration using statistical characteristics of air pollution. The observations' timeframe took 5 years from 2009 - 2013. The last few years i.e. 2011, 2012 and 2013 have particular interest they show the dynamics of reducing the concentration of pollutants in relation to the implementation of programs that reduce air pollution.

The seasonal changes in concentration of impurities have been studied to identify patterns of air pollution by nitrogen dioxide. We also revealed the pattern of nitrogen dioxide's increasing concentrations in winter in contrast to of other impurities, in particular formaldehyde, which has higher concentrations during summer season [6]. We calculated the average monthly and yearly concentrations. All this made possible to allocate such months in which there were deviations from the mean and relate them to meteorological conditions in a given month.

The chart of nitrogen dioxide distribution for the period from 2009 to 2013 is shown below (Fig. 1).

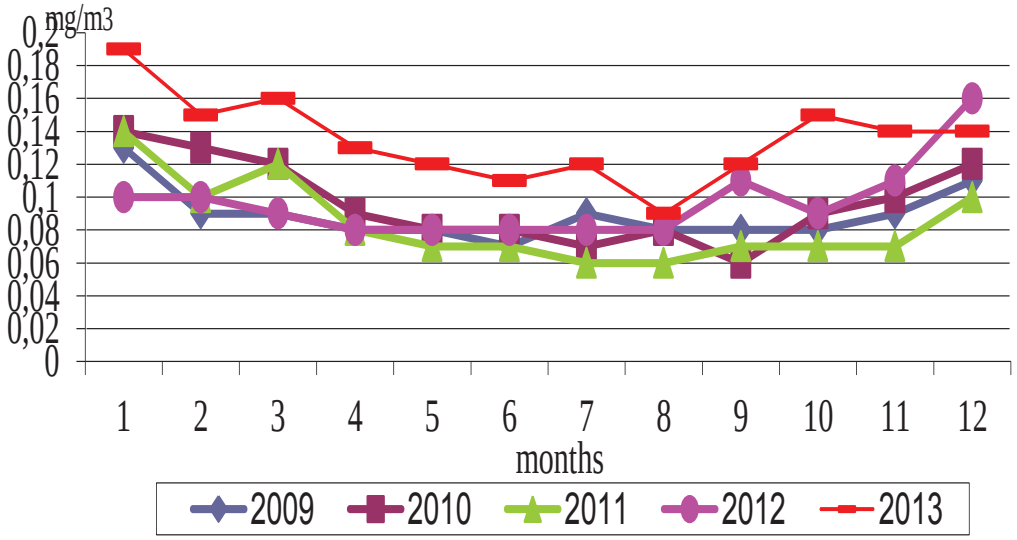

Figure 1. Distribution of nitrogen dioxide's average concentrations during the period from years 2009 to 2013

The graph (Figure 1) shows that distribution of nitrogen dioxide concentration has a well defined maximum which comes to winter time, when concentrations reach 0.10 to 0.19 mg/m^3. Also there's a defined minimum value in summer, when concentrations of nitrogen dioxide are reduced from 0.06 to 0.08 mcg/m^3. Such a distribution is primarily due to work of thermal power plants that emit more pollutants into the atmosphere in winter time and also due to imposition of specific meteorological conditions.

Average annual values of nitrogen dioxide remain almost the same during the study period and change slightly from year to year. The exception is year 2013 when emissions' concentrations increased in all seasons. This can be seen from the graph (Fig. 1) where the changes range 0.07-0.09 mg/m^3 in summer during years 2009 - 2012 and 0.09 - 0.12 mg/m^3 in 2013. In winter the changes range 0.14 - 0.19 mg/m^3, which is significantly higher as compared to previous years, when values ranged 0,11-0,14 mg/m^3. Also we can distinguish September 2010, when there was a decrease of nitrogen dioxide concentrations up to 0.06 mg/m^3. But such deviations are petty and chart looks quite natural with clear highs and lows.

Also we highlighted the main most polluted parts of the city. Thus, the stationary observation posts have been setup depending on how loaded is the street area with different types of vehicles, location of industrial enterprises, sources of heating system, main streets, landscape, etc. The following posts have been used to monitor environmental pollution:

- post № 1, located in central part of the city; - post №12, the CHP-1 area; - post №16, the highest pollution is observed in winter and summer periods, mainly by household waste; - post №25, the surroundings of this post are polluted by boilers of western thermal compound; - post №26 is loaded by different types of transport.

Let's consider what is the spread pattern of nitrogen dioxide by city districts [7]. The highest concentrations of nitrogen dioxide occur in the first quarter, and the lowest concentrations in the third quarter (Table 1). This is due to the mode of power plants operation. Therefore, the table includes data precisely of these periods.

Table 1. Values of nitrogen dioxide's mean concentrations by the posts during years 2010 -2011

Post number	Average concentration		Maximal concentration		Repeatability of impurities' concentrations higher than the MPC in %
	mg/m^3	Multiplicity in excess of MPC	mg/m^3	Multiplicity in excess of MPC	
1^{st} quarter of 2010 – 11					
1	0,134	3,4	0,30	3,5	83,4
12	0,157	4,0	0,29	3,4	95,9
16	0,104	2,6	0,24	2,8	63,3
25	0,099	2,5	0,24	2,8	58,3
26	0,084	2,1	0,27	3,2	40,1
3^{rd} quarter of 2010 - 11					
1	0,065	1,6	0,19	2,3	28,4
12	0,133	3,3	0,23	2,7	89,4
16	0,056	1,5	0,17	2,0	21,2
25	0,063	1,6	0,17	2,0	21,0
26	0,053	1,3	0,15	1,8	7,1

The table shows that Almaly district is the most polluted one with post №12. In 1^{st} quarter average concentration of nitrogen dioxide at this post was 0,157 mg/m^3, exceeding MPC by 4.0 times. At the same time there's a significant difference between 1^{st} and 3^{rd} quarter at other posts. Post №1 (Bostandyk district) showed 0,134 mg/m^3 as average concentration of nitrogen dioxide in 1^{st} quarter, while in 3^{rd} quarter the average concentration reduced by 2 and showed 0,065 mg/m^3, with MPC excess by 1.6 times. Same trend was observed at post №16 (Zhetisu district): high average concentration in 1^{st} quarter ranging from 0,092 to 104 mg/m^3, and reduced value in 3^{rd} quarter ranging between 0,056-0,063 mg/m^3. At the same time the maximum single concentration of this substance in various posts of the city is not much different.

In 1st quarter, one that shows the highest concentrations, post №1 showed 0,30 mg/m^3 as maximum single concentration value, post №12 – 0,29 mg/m^3, post №26 showed 0,27 mg/m^{3}for nitrogen dioxide concentration, while MPC excess was between 3.2 – 3.5 times.

The lowest average concentrations of nitrogen dioxide was at post №26: 0,084 mg/m^{3}in 1st quarter and even lower value of 0,053 mg/m^3 in 3rd quarter with MPC excess by 1.3 times.

At the same time the highest repeatability of concentrations above the MPC in percentage falls on post № 12, and they remain high throughout the year from 89.4 to 95.9%. The lowest level of repeatability is at post №26, ranging from 7.1 to 40.1%.

According to data from five posts we constructed the maps of nitrogen dioxide spatial distribution during the study period [8]. Consider the structure, distribution of nitrogen dioxide fields spread around the city in 1st and 3rd quarter during years 2010- 2011 (Figure 2.3). Maps show that the field structure varies little in all seasons with the axis usually stretching from north- west to south - east. But 1st quarter shows how nitrogen dioxide concentrations are increasing in northern direction. And 3rd quarter shows a rapid decline in concentrations and slight change of direction, while the maximum concentration is observed in central part of the city.

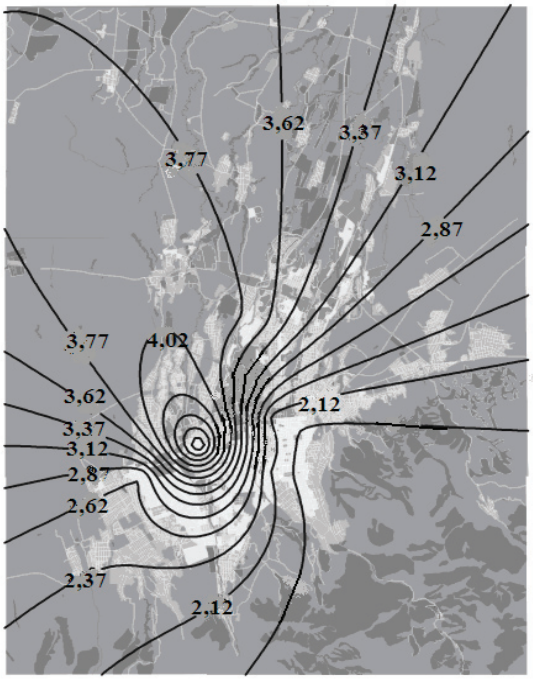

Figure 2 Structure of nitrogen dioxide spread in the city for the 1st quarter in excess of MPC

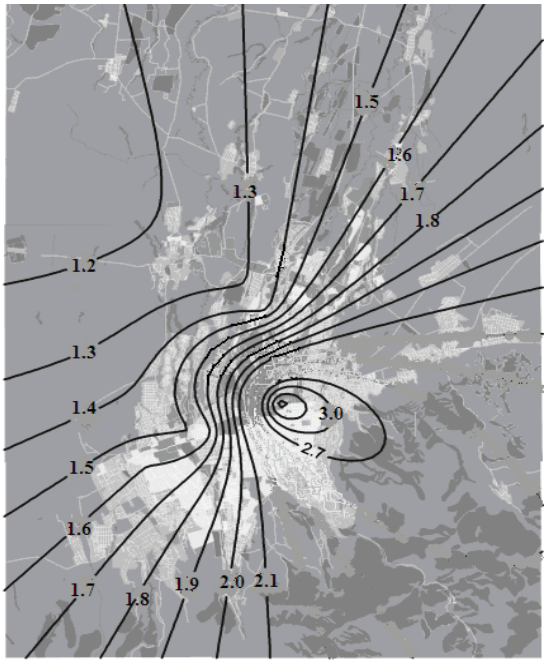

Figure 3 Structure of nitrogen dioxide spread in the city for the 3rd quarter in excess of MPC

This field distribution suggests that the formation of nitrogen dioxide concentrations is affected by almost the same set of factors. The ratio of these factors varies slightly from season to season, which leads to field's stability. In general, concentration values change much from season to season. So the greatest concentrations occur in the 1st quarter, i.e. in cold season. And the smallest concentrations take place in the 3rd quarter, where the MPC excess is 1.5-2 times lower than usually.

Conclusion:

Maximum average concentrations occur in the 1st quarter, which is quite typical for Almaty city, because as a rule, in January there is the highest repeatability and duration of anticyclonic weather, which contributes to the accumulation of pollutants in the city. Also, such a distribution can be attributed to increased operational load of thermal power plant. Besides the expected reduction of nitrogen dioxide is not observed, and instead we found a significant increase in all seasons of 2013.

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