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# ATMOSPHERIC PRECIPITATION IMPACT ON $SO_2$ CONCENTRATION IN THE ATMOSPHERE OF ALMATY CITY, KAZAKHSTAN

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*The author investigates the dependence of the sulfur dioxide concentrations from the characteristics of Almaty city's precipitation level. Meteorological values and levels of air pollution by sulfur dioxide have been examined during five years of research (2007 to 2011.) By using analysis of variance the authors have studied and evaluated the reliability of this factor's influence and highlighted the correlation coefficients between the content of sulfur dioxide in ambient air and levels of precipitation in different seasons.*

## INTRODUCTION

The main air pollutants in urban areas are the so-called "classical pollutants" as well as sulfur dioxide (Arystanbekova, 2011). Globally sulfur dioxide emissions add up to a total number of 160-180 million tons per year (Denisov, 2008). The share of sulfur dioxide ($SO_2$) takes up to 95% of the total amount of sulfur compounds which enter the atmosphere from anthropogenic sources. Up to 70% of $SO_2$ emissions are produced by burning coal, and about 15% from fuel oil (Stolberg, 2000), which means that the main sources of sulfur dioxide in urban air are the power plants, boilers and metallurgical enterprises. According to WHO, the impact of sulfur dioxide in concentrations that exceed accepted limits can lead to a significant increase in various respiratory diseases, affect the mucous membranes, cause throat inflammations, bronchitis, cough, hoarseness and sore throat (WHO, Europe). In Almaty the largest enterprises of sulfur dioxide emissions are the thermal power plants that run on solid and liquid fuels.

It is known that the air quality in the city is formed by a complex interaction of natural and anthropogenic factors. The natural topography of the terrain and climatic factors are important conditions that create a "foundation" of air quality conditions and prerequisites for future high pollution. There are cities with favorable conditions for dispersion of substances emitted into the atmosphere, and on other hand there are cities like Almaty with atmospheric layers thick enough to restrain diffusion. The city's location in the foothills leads to formation of climatic features unique to Almaty and creates very unfavorable conditions for transferring and dispersing pollutants in the atmosphere (Akhmedzhanov et al., 1985). We know that meteorological conditions play an important role in shaping the level of contamination (Bezuglaya et al., 1983, 1971; Berlyand, 1985). In Almaty precipitation is one of the main natural air purifiers. Therefore, while studying the conditions that form the average level of air pollution, we should take into account their intensity and quantity. Atmospheric precipitations contributes to cleansing the atmosphere from impurities, and their intensity determines the speed of this process (Berlyand, 1985, Gorbarenko et al., 1998).

## MATERIALS AND METHODS OF RESEARCH

The state of air pollution by sulfur dioxide in Almaty is the object of this investigation. Methods of research are a comparative-analytical statistical analysis of empirical data. Observations regarding levels of city's atmospheric pollution have been performed at 5 fixed locations.

Depending on the street area's load by various vehicles, location of industrial factories, heating sources, main streets, area relief and other factors, several fixed "Kazgydromet" stationary observation posts have been set-up in Almaty city:

- Post 1 is located in the central part of city;

- Post 12 is the site with highest traffic load;

- Post 16 is the site where most of pollution is observed in winter and summer season, mostly from household waste;

- Post 25 is the site where most of pollution comes from boiler plants of the western thermal complex;

- Post 26 is a site with heavy traffic load.

## RESULTS OF RESEARCH

Our explorations revealed the following dependency of sulfur dioxide distribution from precipitation. For example Figure 1 shows the average annual course of sulfur dioxide concentrations and precipitation during 2007 - 2011.

Figure 1 shows that maximal value is clearly associated with the winter period, especially with January when sulfur dioxide pollution level is on the rise and reaches 0.024 mg/m$^3$. The fact that the main maximum occurs in winter can be explained by the work of thermal power plants because minimum level of pollution is observed during warm season when the central heating is off. It is especially noticeable in April and May during which large amounts of precipitations above 100 mm take place while the mean concentration of sulfur dioxide is equal to 0.009-0.012 mg/m$^3$.

Let us consider this dependence in detail by using analysis of variance and Fisher's criterion for statistical significance (F) (Danylina et al., 1976). Table 1 shows the values that reveal the relationship between the concentration of sulfur dioxide and amount of precipitation in different seasons over the five year period (2007- 2011).

Table 1. The values of Fisher's criteria within data ranks of mean seasonal concentrations of sulfur dioxide for the period 2007 - 2011

The studies reveal that spring and fall have the lowest correlation coefficients between the content of sulfur dioxide in the air and amount of precipitation: F = 0.19 in spring and 1.47 in fall. Index of factorial variable's influential power ( $^2$) on the result was 7% and 35% showing the share of the studied factor among all other factors. Table 1 shows that the largest correlation coefficients between the content of sulfur dioxide in the air and precipitation amounts have been observed in winter time: F equal to 2.98 and index of the factorial variables influence power ( $^2$) reaching 53%.

The linear correlation coefficient was applied for comparison. The following months were selected for processing the data: January, April, June and October. Qualitative assessment of a close connection of these quantities has been found by applying correlation analysis scales (Makarova et al., 2002), (Figures 2 to 5).

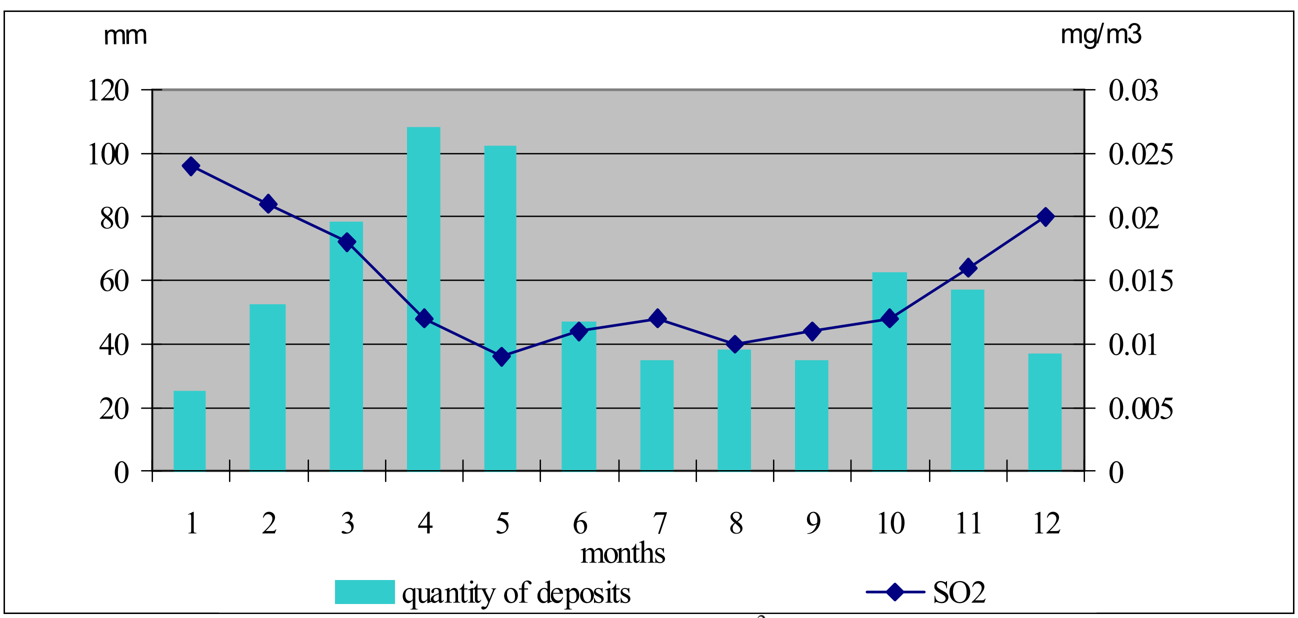


Figure 1. Mean annual course of sulfur dioxide values in mg/m$^3$ and precipitation level in mm (2007-2011).

Table 1. The values of Fisher's criteria within data ranks of mean seasonal concentrations of sulfur dioxide for the period 2007 - 2011

| Periods | Used formulas and symbols | |
|---|---|---|
| | Index of factorial variable's influential power ($\eta^2$) to the result | Fisher's criteria |
| winter | 53% | 2,98 |
| spring | 7% | 0,19 |
| summer | 43% | 1,9 |
| fall | 35% | 1,47 |

Thus, Figures 2 and 4 show that the closeness between the values is accepted as reasonable. In this case the correlation coefficient in January was r = - 0.507, and in the month of June r = - 0.485. For October (Figure 5), the correlation coefficient was r = 0.652. But it suggests that with an increase of one magnitude, precipitation in this case, the other one also increases (the sulfur dioxide concentration), and this fact shows that the relationship between two variables is not observed in this period. In April (Figure 3) closeness of the connection is not observed at all since the correlation coefficient was r = 0.086. This fact can be explained as follows: in April there is a larger amount of precipitation than in other seasons, thus the sulfur dioxide concentration is quite low compared to other seasons of the year. Therefore, when precipitation amount was 223 mm in 2009, the average sulfur dioxide concentrations were 0.012 mg/m$^3$, and in 2007 the sulfur dioxide concentration was 0.013 mg/m$^3$ while precipitation value was 110 mm (Information bulletin, 2007-2011, Weather in Almaty, website http://pogoda.ru.net/).

In 2010 the precipitation amount was only 78 mm, while the level of the same pollutant reached 0.011 mg/m$^3$, which is slightly below the previous values with exception of the year 2008 when precipitation amounted to 53 mm and sulfur dioxide concentration rose to 0.014 mg/m$^3$. This suggests that during the spring period (April), characterized by large amount of precipitation, the concentration of pollutant varies slightly and is poorly correlated.

There is also another way to explain the traced link in October. The increase in precipitation amount increases the sulfur dioxide concentration. The thing is that in 2010 the amount of precipitation was quite large - 117 mm, while the level of pollution $SO_2$ was 0.015 mg/m$^3$, but the bulk of precipitation occurred during four days (20, 21, 22, 23 October) and totaled 93 mm. During those days the concentration of the pollutant was low but in the rest of the period was quite high because the middle of October is the time when thermal power stations start operating and the private sector of the city uses coal, which together boost pollution levels compared to the previous warmer months. In October 2011 the concentration of $SO_2$ was 0.010 mg/m$^3$, with the precipitation level three times less compared to year 2010 - 44 mm, but the precipitation amount was more or less evenly distributed over the entire period.

In January, when thermal power stations operate at full capacity and other adverse meteorological conditions add-up to the rise of atmospheric pollution, the precipitations in this case, play an important role in reducing levels of pollution. Thus, even small increases in precipitation tend to decrease concentrations of sulfur dioxide.

## CONCLUSIONS

The data suggest that precipitation in the studied area contributes to the atmosphere's purification from sulfur dioxide. During rainfall pollutant concentrations repeatedly decrease and subsequently have values close to zero. Thus, the atmospheric self-cleaning capacity increases

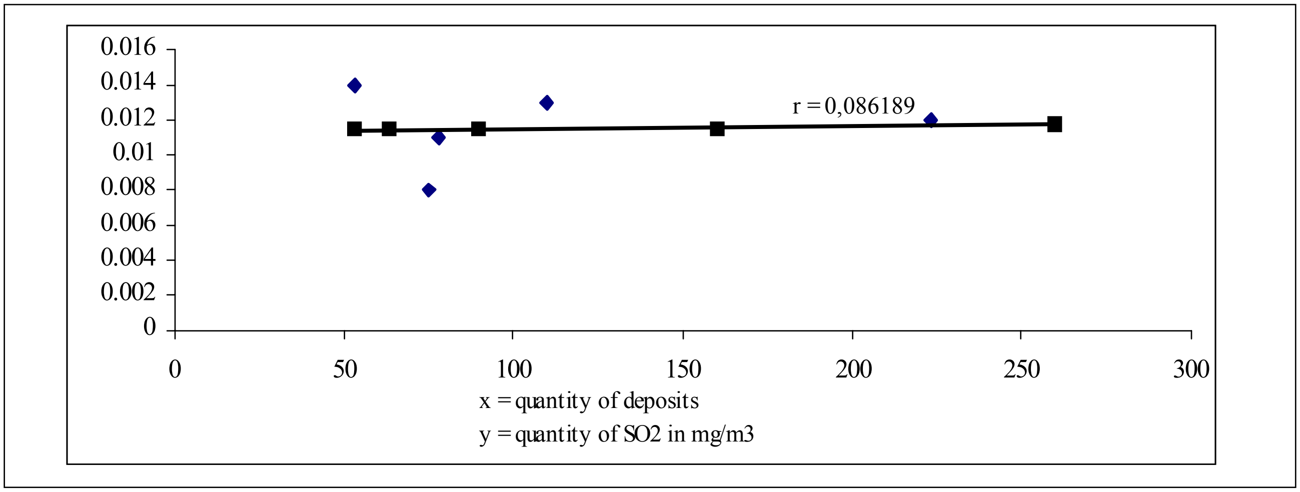


Figure 2. The linear regression of correlation between the level of atmospheric pollution by sulfur dioxide and the amount of precipitation in Almaty city in January.

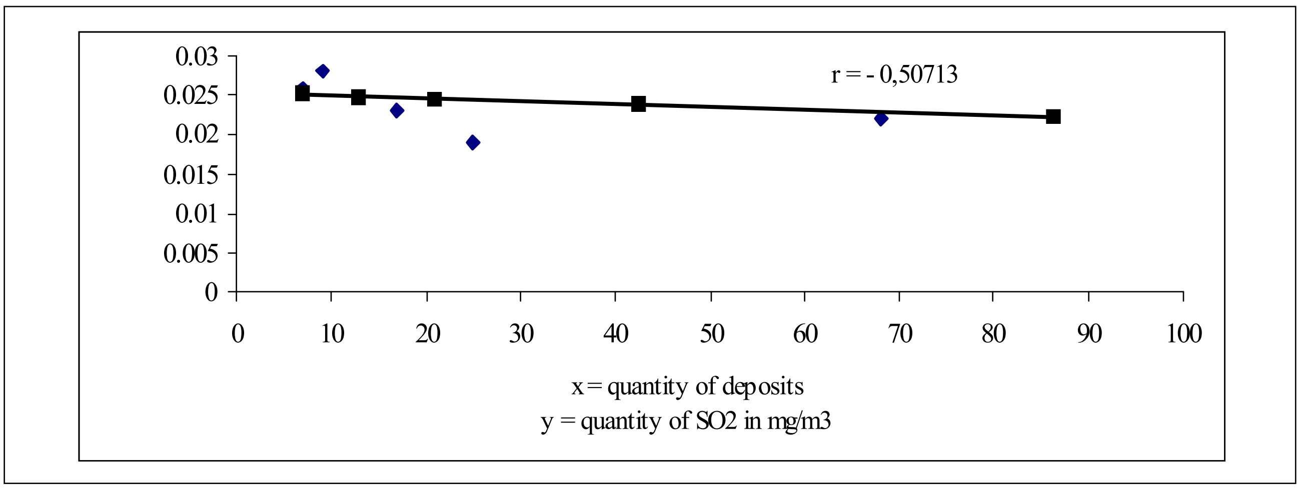


Figure 3. The linear regression of correlation between the level of atmospheric pollution by sulfur dioxide and the amount of precipitation in Almaty city in April.

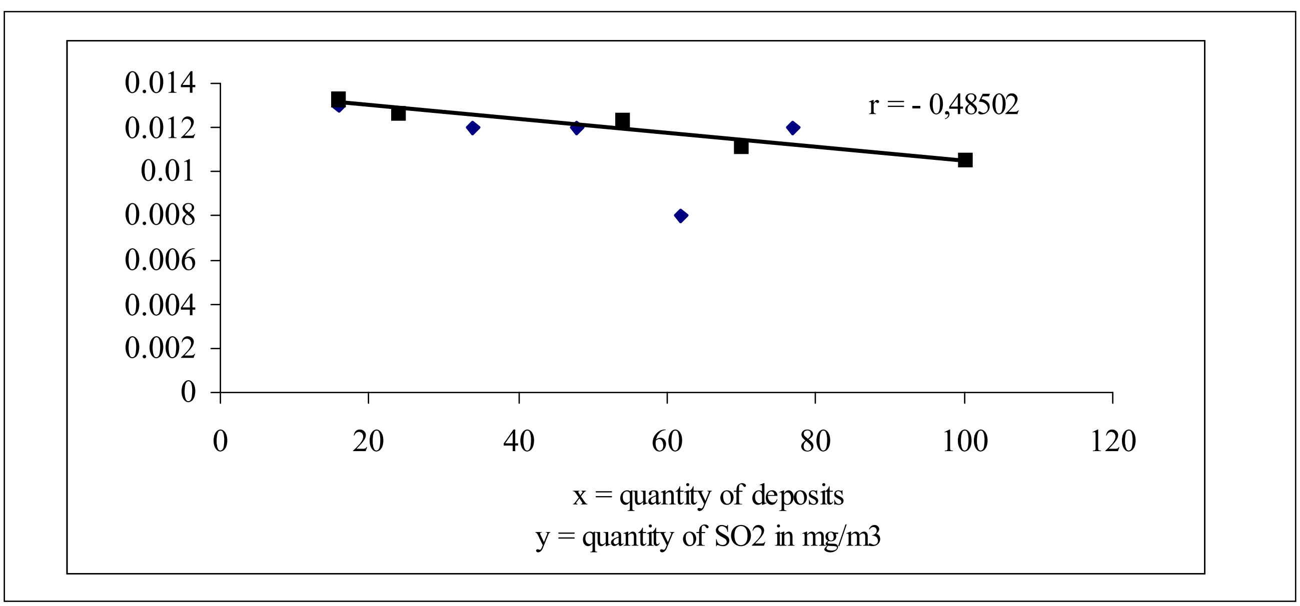


Figure 4. The linear regression of correlation between the level of atmospheric pollution by sulfur dioxide and the amount of precipitation in Almaty city in June.

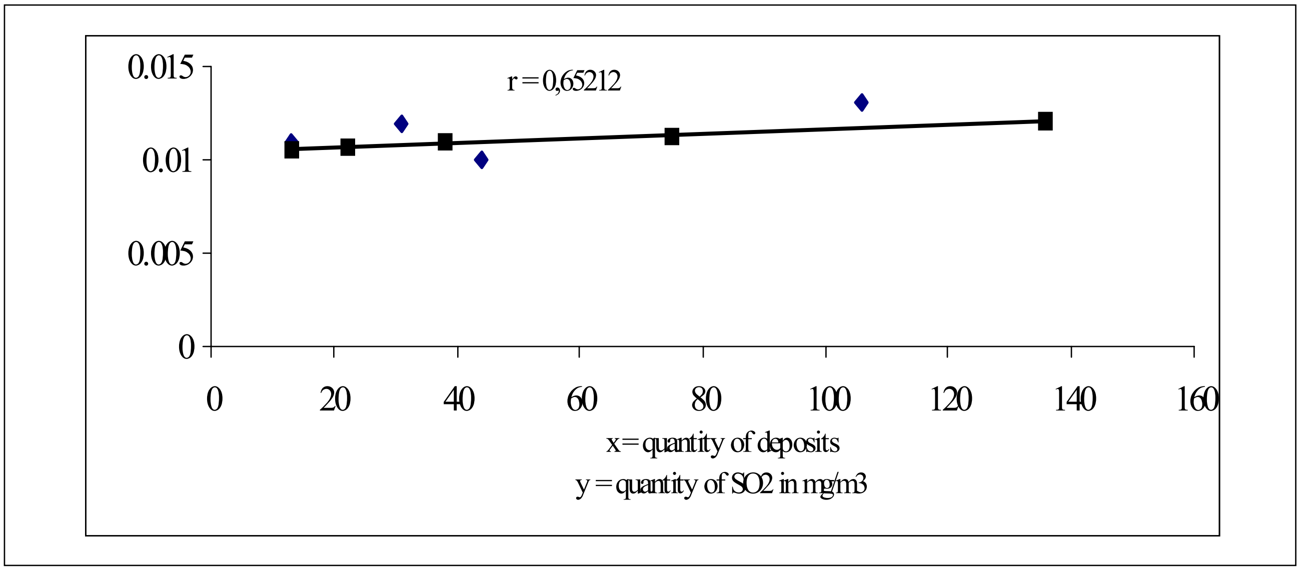


Figure 5. The linear regression of correlation between the level of atmospheric pollution by sulfur dioxide and the amount of precipitation in Almaty city in October.

with increasing frequency and intensity of precipitation in the city. Correlation analysis in general has shown that significant ties do exist between the concentration of sulfur dioxide in the urban atmosphere and the meteorological parameters such as precipitation, but their magnitude varies considerably depending on the season of the year.

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