DISTRIBUTION OF SULFUR DIOXIDE AND PHOSPHORUS PENTOXIDE IN AN AIR POOL OBTAINED BY CORRELATION AND REGRESSION ANALYSIS

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ABSTRACT

Results of studying an aerosol of sulfur dioxide and phosphorus pentoxide released to the atmosphere by a chemical company processing phosphorites are presented. The effect of wind direction and speed on sulfur dioxide and phosphorus pentoxide distribution in a ground layer of the atmosphere is studied. The points of wind direction leading to pollution of the nearby city atmosphere are allocated. The statistical analysis of the environmental pollution is carried out by method of correlation and regression analysis. The dependence of the amount of sulfur dioxide and phosphorous pentoxide reaching the atmosphere on the volume released by the enterprise producing them is defined. The results obtained are recommended for environmental control, regulation and management.

Keywords: phosphorus oxide, atmosphere, correlation regression analysis, industrial enterprise, sulfur dioxide, phosphorous pentoxide, statistical correlation regression analysis, equation.

INTRODUCTION

A modern chemical industry produces several tens of thousands of products. In the laboratories hundreds of new technological processes are developed. It is unrealistic to set the task of studying the mechanism of the course of all these processes, whereas the task of their optimization and management must be solved.

In the last decades the ecological systems are under considerable effect of natural and, in particular, anthropogenic factors changing in a direction undesirable to mankind. Therefore the study of the processes of environmental pollution by emissions of industrial enterprises wastes is an actual task [1 - 19].

The stability of an ecosystem, as we know, develops because of the interaction of two major factors: features of a local environment and resources, on one hand, and sources of pollution of production and non-productive character and intensity of their investigation – on the other. The Republic of Kazakhstan has no powerful natural factors to counteract the pollution forces. Its biogeotsenosis is insufficiently steady and is characterized by high vulnerability and vulnerability. In particular, it is poor in water resources and flora, while the low-power soil cover is subjected to wind and water erosion.

In this regard, studying of effect of the Kazakhstan industrial enterprises processing phosphorites under various weather conditions and mathematical modeling of the environmental pollution is of great importance. The main atmospheric pollutant of the considered region refers to the phosphorites processing enterprises. It is worth noting that the gaseous impurities are the most dangerous to the environment. These are technological and aspiration gaseous emissions of sulfur dioxide, formed in the main production facilities of the enterprise [1 - 4].
The identification of the environmental pollution tendencies of a ground layer of the atmosphere as at a given time, and in the course of a given period of time from sources of pollution represents considerable interest for the solution of various problems concerning the ecology-hygienic safety [14]. Statistical methods providing the elaboration of mathematical models are successfully applied in this aspect. In fact this is the aim of the present communication.

**EXPERIMENTAL**

**Materials**

An initial statistical material referring to the normal operation mode of the industrial enterprise chosen was used as a material for the passive experiment. The initial information contained a quantitative assessment of the contamination of the atmospheric lowest layer, i.e. data on pollutants concentration and physicochemical parameters, surface structure, meteorological parameters (wind speed and direction), various coefficients.

**Methods**

The processing of the experimental data was carried out by statistical methods. They provide to extract maximum information. The method of correlation-regression analysis was applied to derive the equations of environmental pollution depending on the volume of the phosphorus produced. Polynomial models were developed.

**RESULTS AND DISCUSSION**

The dependence of the polluting substances amount on the volume of the production released by the enterprise has to be determined.

Every day the plant throws out a significant amount of polluting substances. However, the ground concentration of these substances in the air of the city which is located 15 km away from the enterprise is not always increased. It is explained by the impact of the air streams on the dispersion and ablation of the enterprise emissions. The study of the emissions sources arrangement shows that the city pollution happens generally in case of western and north-western directions of wind.

The dependence of $SO_2$ concentration on the wind direction is given in Fig. 1.

It is evident that a maximum permissible concentration (MPC) is allocated. It occurs in case of northern wind and amounts to 0.08 mg/m$^3$. The latter value is 1.6 times higher than the average daily maximum. A certain amount of sulfur dioxide dissipates in southern direction. Its concentration is within the limits of 0.01 mg/m$^3$ to 0.03 mg/m$^3$. It is worth noting that $SO_2$ maximum concentration limit is equal to 0.05 mg/m$^3$. The variation observed within three days, when the wind speed changes from calm to 2 m/s, is shown in Fig. 2.

Fig. 2 shows that the greatest pollution of the city is observed when the wind is calm. The value observed is 0.04 mg/m$^3$. Sulfur dioxide concentration decreases twice reaching 0.015 mg/m$^3$ - 0.025 mg/m$^3$ at a wind speed of 1 m/s. The value recorded at a wind speed of 2 m/s amounts to 0.007 mg/m$^3$, whereas the maximum in the active zone refers to 0.08 mg/m$^3$.

It is evident that the distance from the torch axis to the point of sampling has to be defined. Previously this was done using a map of the region. Nowadays supervi-
sion is carried out using stationary posts located in a direction perpendicular to the polluting substances stream.

It is seen that the greatest pollution is observed in the kernel zone, i.e. the active zone where the industrial enterprise is located. Processes making direct impact on the environment components take place in the active subband. Here the greatest specific loads of the environment are observed. The border of a sanitary protection zone of the enterprise including the zone where the wastes of the productions are stored (5 km - 6 km) is characterized, apparently depending on the schedule, by a high concentration of sulfur dioxide though the specific loadings are lower here than those in the active subband. The zone of indirect influence nearby the city (15 km) is affected by polluting substances because of their migration. Here the average annual content of sulfur dioxide is 0.016 mg/m$^3$.

The statistical analysis is carried out on the ground of a correlation and regression method [19, 20]. Fig. 4 shows the correlation field of the dependence of sulfur dioxide emission on the volume of the phosphorus released by the enterprise. The results indicate a nearly linear correlation described by:

$$y = b_0 + b_1 x,$$

where $x$ stands for the production of phosphorus, while $y$ designates the emission of the polluting substance.

The coefficients of the linear equation of regression are determined by the Least squares method. The statistical analysis of results obtained consists in checking the importance of all coefficients in comparison with the error of reproducibility and adequacy of the equation. The assessment of the coefficients importance is carried out using the Student’s test $t_{oj} = bj/j-y$, where $bj$-j-y is the regression equation coefficient, $Sbj$ is the mean squared deviation of j-go of the coefficient. The results obtained are presented in Table 1.

It is evident that sulfur dioxide emissions are statistically significant (Student’s test makes 20.39) within an interval of the importance of 95 %. In the same confidence interval (95 %) and number of degrees of freedom $f = 11$, while the tabulated $t_{oj}$ value $= 2.2$. The equation coefficients determined by this method make refer to $b_0$

![Fig. 3. Concentration of SO$_2$ at various distances from the torch axis.](image)

![Fig. 4. A correlation field of the dependence of SO$_2$ gas amount on phosphorus output.](image)

Table 1. Values of the coefficients of correlation and criteria referring to sulfur dioxide and phosphorous pentoxide emissions.

<table>
<thead>
<tr>
<th>Name of emission</th>
<th>$R$-sq</th>
<th>Coefficients</th>
<th>Student's criterion</th>
<th>Fischer's criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$b_0$</td>
<td>$b_1$</td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>0.98</td>
<td>-135.16</td>
<td>0.0247</td>
<td>20.39</td>
</tr>
<tr>
<td>Phosphorous pentoxide</td>
<td>0.92</td>
<td>112.30</td>
<td>0.0145</td>
<td>10.93</td>
</tr>
</tbody>
</table>
$a = -135.16$ and $b_1 = 0.25$.

The $R^2$ of the coefficient of multiple correlation for SO$_2$ emissions is close to 1 (0.98) verifying the linear dependence between the emissions amount and that of phosphorus produced by the enterprise. The Fischer’s test has a value of 415.9, whereas at number of steps of freedom $f_1 = 11$ and $f_2 = 10$, $F_{tabl} = 2.95$ indicating that the equation corresponds to the experiment. It is presented by:

$$y = -135.16 + 0.025x,$$

where $x$ is phosphorus amount, while $y$ is that of sulfur dioxide.

The statistical calculation of these emissions shows that the amount of the phosphorus produced is also statistically significant as $t_\text{s} = 10.93$ (the latter value is higher than the tabular one of 2.2) in an interval of confidence of 95 % and $f = 11$. The $R^2$ value referring to P$_2$O$_5$ emissions amounts to 0.92 indicating almost a linear dependence of P$_2$O$_5$ amount on that of phosphorus produced. The calculated coefficients of the equation are: $b_0 = 112.3; b_1 = 0.0145$. The corresponding linear regression equation is described by:

$$y = 112.30 + 0.0145x,$$

where $x$ is the amount of phosphorus, while $y$ is that of phosphorus oxide.

The Fischer’s test value is 119.5. It verifies the compliance of the equation obtained to the real data used as $F_{tabl} = 2.95$ in case of $f_1 = 11$ and $f_2 = 10$.

It is evident from Table 1 that the amount of the phosphorus produced is statistically significant for emissions of SO$_2$ and P$_2$O$_5$.

The generalized regression equation describing the relation between the amount of the phosphorus produced and that of the substances polluting the environment is presented by:

$$y = 11084.82 + 5.85 x_1 + 0.01 x_2,$$

where $x_1, x_2$ are the amounts of sulfur dioxide and phosphorous pentoxide, respectively, while $y$ is that of the phosphorus produced.

The calculated Fischer’s test is 61.3. It verifies the compliance of the equation it is higher than the tabulated value of 5.9 in case of a confidence interval of 95 % and $f_1 = 11$ and $f_2 = 4$. The $R^2$ value is equal to 0.99, which verifies the linear relation between the phosphorous produced and the pollutants emissions.

**CONCLUSIONS**

- It is shown that emissions of gaseous oxides of phosphorus and oxides of sulfur in a ground layer of the atmosphere are the most significant sizes and it needs to be considered at assessment of environmental pollution by production of phosphorus from fosforits ores.

- The method of the correlation and regression analysis provides equations describing environmental pollution by chemical company emissions in dependence of the amount of the phosphorus produced.

- The mathematical equations obtained can be recommended for assessment of the environmental impact of gaseous wastes, both in case of acting and designed industrial enterprises producing phosphorus.

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