

Application of statistical analysis method to determine distribution of sulfur dioxide and phosphorus oxides emissions from industrial enterprise "KazFosfat"

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

1. Introduction

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

Over the last decades, ecological systems have come under a considerable influence of natural and, in particular, anthropogenous factors, changing in the direction undesirable to humankind. Therefore, research of the process of environmental pollution by emissions of waste of the industrial enterprises is an actual task [1-21].

Stability of an ecosystem, as we know, develops during interaction of two major factors: features of a local environment and resources, on the one hand, and sources of production pollution and non-productive character and intensity of their formation – on the other. The Republic of Kazakhstan has no quite powerful natural factors for counteraction to pollution forces. Its bio-geocenosis is insufficiently steady and differs by high vulnerability. In particular, it is poor in water resources and flora, the low-power soil cover is subject to influence of a wind and water erosion.



In this regard, studying of the influence of the industrial enterprise, processing phosphorites, located in the Republic of Kazakhstan on various weather conditions and mathematical modeling of environmental pollution is represented as especially important.

The main pollutant of the atmosphere of the considered region is the enterprises of chemical industry processing phosphorites. It is necessary to notice that gaseous impurity is most dangerous for environment.

Identification of tendencies of environmental pollution at a given time and during time among pollution sources of a ground layer of the atmosphere represents considerable interest during the solution of various problems concerning ecology-hygienic safety [14].

For these purposes, experimental-statistical methods, with the help of which the mathematical model is made, are successfully applied.

In the modern mechanical engineering, a significant number of parts are fabricated from lead-tin-base bronzes. They include a series of parts which should possess sufficiently advanced strength characteristics (sealings and piston rings, oil-seal and expander rings). In order to enhance tribotechnical characteristics, lead is introduced into these materials. Lead reduces the friction coefficient, enhances tribotechnical characteristics; however, it reduces strength significantly.

At present one of the promising trends of enhancing a set of service properties of such bronzes is alloying them with superdispersed powders (SDP). Introduction of their small amount into the melt before a crystallization process allows increasing strength properties of castings [1, 2]. But a mechanism of interaction with lead-tin-based bronzes, as well as the process regularities of such modification, is not studied profoundly. However, such modification of copper alloys is promising from several view points.

This paper presents an investigation of the influence of different content of additives of the pre-treated aluminium oxide powder on the structure of lead-tin-base bronze under formation.

2. Experimental Materials

As a material for the passive experiment, the collection of the initial statistical material in the normal operation mode at an industrial enterprise was used. Emissions of enterprises of the phosphorous industry are technological and aspiration gaseous emissions of sulfur dioxide are formed in the main production facilities of the enterprise [1-4]. The initial information for the quantitative assessment of the contamination of the surface layer of the atmosphere was the sampling of data representing the concentration of pollutants in the locations of the instrumentation stations, meteorological parameters (wind speed in the surface layer, wind direction), as well as data that determine the surface structure, physicochemical parameters of pollutants, various coefficients. In this paper, dispersion of aerosol of toxic substances released into the atmosphere by an enterprise for the processing of phosphate rock is considered.

3. Methods

The processing of experimental data to obtain a mathematical model was carried out by statistical methods. The methods of mathematical statistics allow in this case to extract a maximum of information from the available experimental data - to optimize the procedure for processing and analyzing the experiment. By the method of correlation-regression analysis, the equations of pollution of the environment are determined by the emissions of a chemical enterprise, depending on the volume of phosphorus produced. In practical terms, polynomial models are very useful and widely used in solving problems of optimization and management of chemical-technological processes.

4. Results and discussion

Research of distribution of aerosol in a ground layer in most cases does not allow one to make natural experiment. Therefore the great value gets a possibility of carrying out computing experiment, which requires creation of mathematical models, adequately enough investigated, natural processes and facilities realized on a modern computer.

In this work, dispersion of aerosol of the dioxide of sulfur released into the atmosphere by the enterprise for processing of phosphorites is considered.

For the purpose of assessment of environmental pollution, determination of dependence of the amount of the polluting substances on the volume of production released by the enterprise is necessary.

As initial statistical material for carrying out the analysis, the authors used selection of measurements in the mode of normal operation of the enterprise (measurements of concentration of the polluting substance in installation sites of control and measuring stations), meteorological parameters (speed of wind and its direction).

Every day the plant throws out a significant amount of the polluting substances. However, the increased ground concentration of these substances in the air environment of the city, which is at distance of 15 km from the enterprise, is not always observed. It is explained by impact of air streams on dispersion and ablation of emissions of the enterprise from the city aside.

Studying of an arrangement of sources of impurity emissions in the atmosphere showed that pollution of the city has to happen generally with western and N-W directions of wind.

Dependences of concentration of SO₂ sulfur dioxide on the direction of wind are given in fig. 1.

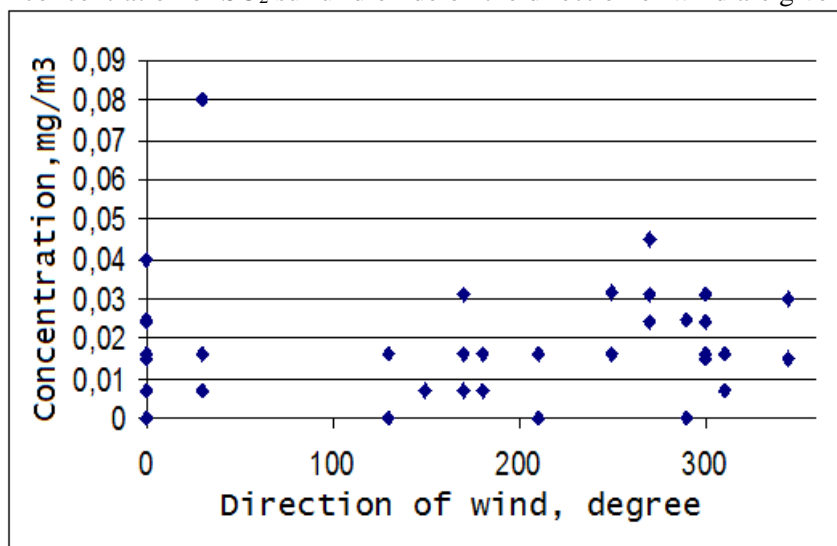


Figure 1. Dependence of pollution of the atmosphere with sulfur dioxide on the wind direction.

It is visible that the maximum permissible concentration (MPC) is allocated. This excess of maximum concentration limits occurs at the northern direction and makes 0.08 mg / m³ that there is more than average daily maximum concentration limit - 1.6 times. A certain amount of sulfur dioxide dissipates in the southern direction of the wind and its concentration makes from 0.01 to 0.03 mg / m³. Atmospheric pressure, SO₂ (0.004 - 0.045 mg / m³) is close to the maximum concentration limit (0.05 mg/ m³) by dispersion of harmful substances in the ground. Change in the sulfur concentration over three days, when the speed of wind changes from calm to 2 m / s, is shown in fig. 2.

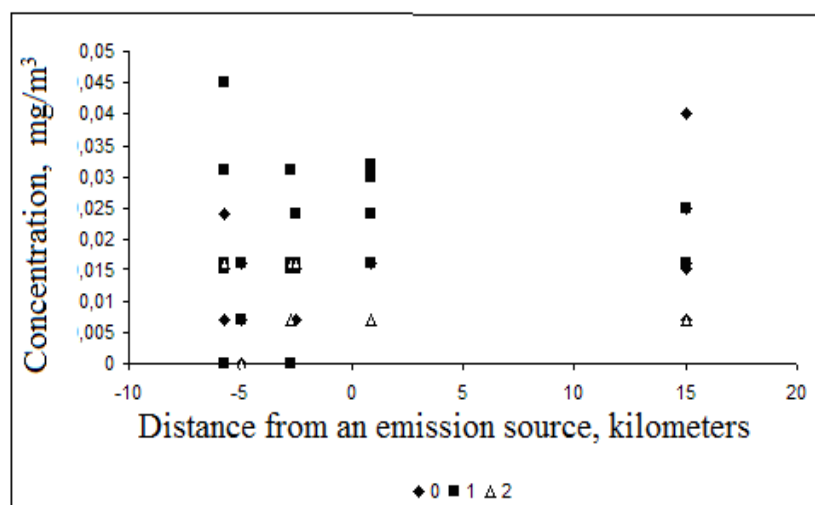


Figure 2. Dependence of distribution of emissions concentration of sulphurous gas on the distance to an emission source at various wind speeds: 0 m/s, 1 m/s and 2 m/s.

From the data given in fig. 2, it is visible that when it is calm there is the greatest pollution of the city and concentration of SO_2 makes 0.04 mg/m^3 , whereas with a wind of 1 m/s speed the content of dioxide of sulfur decreases twice and makes $0.015\text{--}0.025 \text{ mg/m}^3$. At a speed of wind of 2 m/s , the maintenance of SO_2 in the point of supervision of the city is insignificant (0.007 mg/m^3), whereas in an active zone of a kernel the maximum concentration makes 0.08 mg/m^3 .

For this purpose, it is necessary to define the distance from a torch axis to a sampling point. Previously, distances from a conditional point of the gravity center of organized sources to a sampling point of the polluting substances were determined by the card.

The assessment of diffusion of the polluting substances in the direction perpendicular to the direction of a stream of the polluting substances according to supervision on stationary posts is of a certain theoretical and practical interest.

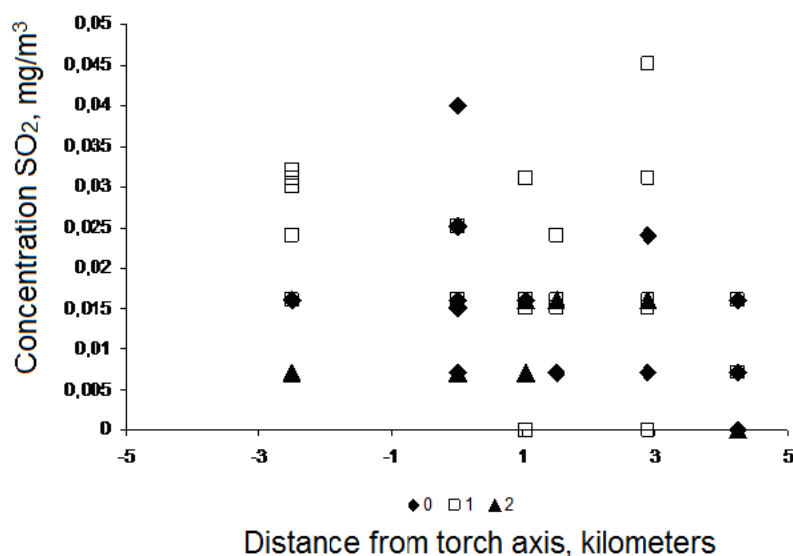


Figure 3. Concentration of SO_2 at various distances from a torch axis

It is visible that the greatest pollution by sulfur dioxide is observed in a kernel zone, in its active zone, in which industrial constructions and objects of the enterprise are located. In an active subband,

the processes making direct impact on environment components proceed. Here the greatest specific loads of environment are observed. The border of a sanitary protection zone of the enterprise and a zone of an arrangement of stores of waste of productions (5-6 km) is characterized apparently from the schedule, by high concentration of dioxide of sulfur though specific loadings are lower here than in an active subband. In this subband, the weakened activity and peripheral subband processes of diffusion, evaporation, etc. are observed at a temperature and pressure of environment, but at the increased concentration of the polluting substances. The zone of indirect influence, where the nearby city (15 km) is located, is affected by the polluting substances during their migration in mobile components of the environment. Here the average annual content of dioxide of sulfur makes 0.016 mg/m^3 .

The statistical analysis was carried out by a correlation and regression method [19, 20]. In fig. 4 the correlation field of dependence of emission of dioxide of sulfur on the volume of the phosphorus released by the enterprise is presented. The received results indicate existence between the number of emissions of sulphurous gas and output pronounced positive, close to linear functional correlations. The view of the received field of correlation allowed one to choose the regression equation of a look:

$$y = b_0 + b_1 x,$$

where x - production of phosphorus; y - emission of the polluting substance.

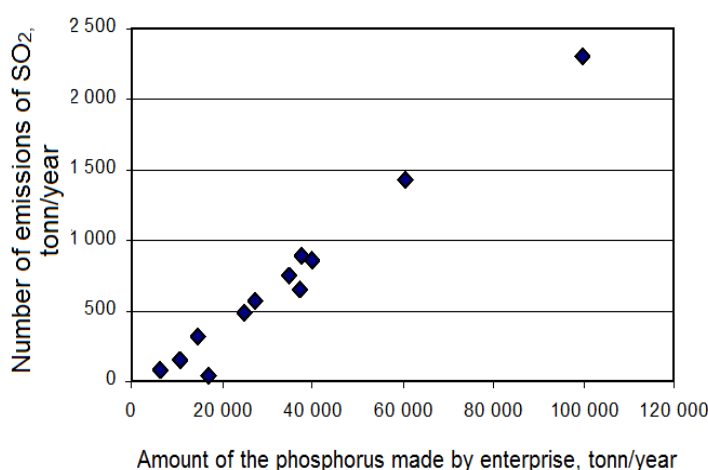


Figure 4. Correlation field of dependence of the amount of SO_2 gas emissions on output from the phosphorus amount made by the enterprise

Coefficients of the linear equation of regression are determined by a method of the smallest squares. After finding the linear equation of regression, the statistical analysis of results consisting in check of the importance of all coefficients in comparison with an error of reproducibility and adequacy of the equation is carried out. The assessment of the importance of coefficients is carried out in terms of Student's criterion: $t_{st} = b_j / S_{bj}$, where b_j - j -y regression equation coefficient; S_{bj} - an average square deviation of j -go of the coefficient. The results received by a statistical method are presented in table 1.

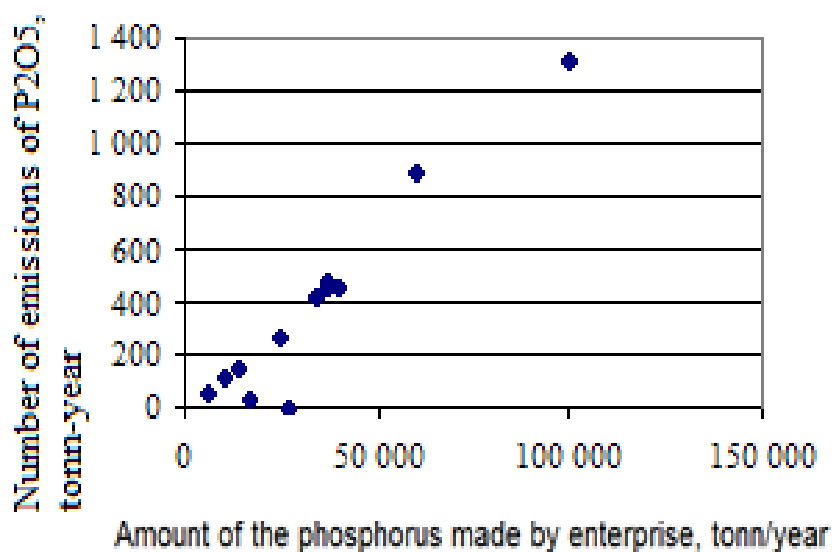


Figure 5. Correlation field of dependence of number of emissions of SO₂ gas on output from amount of the phosphorus made by the enterprise

It is visible that for sulfur dioxide emissions, the amount of the let-out phosphorus within an interval of the importance of 95% is statistically significant (Student's criterion makes 20.39) whereas at the same intervals of confidence (95%) and number of degrees of freedom is $f=11$, the tabulated value = 2.2. The equation coefficients determined by this method make: $b_0 = -135.16$; $b_1 = 0.25$.

The size R-square for emissions of SO₂ is close to 1 (0.98) that testifies to linear nature of dependence between the number of emissions and phosphorus volume made by the enterprise. The criterion size of Fischer makes 415.9 whereas with the number of freedom steps, $f_1=11$ and $f_2=10$ F_{tabl} , value = 2.95 that indicates that the equation corresponds to the experiment and has an appearance:

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

where x - the volume of phosphorus; y - amount of dioxide of sulfur.

Statistical calculation of these emissions in the atmosphere of phosphorus oxide has shown that the volume of the produced phosphorus is also of statistically significant size as $t_{\text{st.}} = 10.93$, that there is a more tabular value ($t_{\text{st.}} = 2.2$) at intervals of confidence of 95% and size of $f = 11$. The size R-square for P₂O₅ emissions is close to a unit and makes 0.92 that indicates almost linear dependence of the number of phosphorus oxide emissions on phosphorus production. The calculated coefficients of the equation make $b_0 = 112.3$; $b_1 = 0.0145$. The equation of linear regression of dependence of quantity of P₂O₅ on the amount of the produced phosphorus is described by dependence:

$$y = 112.30 + 0.0145x,$$

where x - the volume of phosphorus; y - amount of oxides of phosphorus.

The criterion value of Fischer makes 119.5 that testifies to compliance of the received equation to an experiment as with the number of freedom steps of $f_1=11$ and $f_2=10$, size is $F_{\text{tabl}} = 2.95$.

Table 1. Values of correlation coefficients of emissions and criteria of their assessment.

Name of emission	R -sq	Coefficients		t_{ct} Student's criterion	F , Fischer's criterion
		b_0	b_1		
Sulfur dioxide	0,98	-135.16	0.0247	20.39	415.88
Phosphorous pentoxide	0,92	112.30	0,0145	10.93	119.5

It is visible that for SO_2 and P_2O_5 emissions, the amount of the let-out phosphorus is statistically significant.

The generalized regression equation describing communication of volume of the produced phosphorus with the amount of the substances polluting the environment is received and has the following appearance:

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

where x_1 , x_2 - amounts of sulfur oxide, phosphorous oxide, respectively; y – phosphorus volume.

The calculated value of criterion size of Fischer of $F = 61.3$ defines compliance of the equation to an experiment as it is higher than the tabulated value $F = 5.9$ at confidence intervals of 95% and the size of the number of freedom degrees $f_1 = 11$ and $f_2 = 4$. The size of the R-square makes 0.99 that defines the linear nature of dependence of phosphorous production on emissions of pollutants.

5. Conclusion

1. It is shown that by production of phosphorus from phosphorites, sulphurous gas is more significant in environmental pollution in comparison with phosphorous oxide.

2. The method of the correlation and regression analysis defined the equations of environmental pollution by emissions of the chemical company depending on the volume of the made phosphorus.

3. The mathematical equations, revealed by the method of the classical correlation and regression analysis, can be recommended for environmental impact assessment of gaseous waste, both at acting and at the designed industrial enterprises aimed at phosphorus production.

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