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OPTIMIZATION OF THE PROCESS OF REDUCING THE ENVIRONMENTAL LOAD AND IMPROVING THE LIVING CONDITIONS IN THE PRODUCTION OF FERTILIZER MIXTURES

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ABSTRACT

The article provides information on the state of the environmental load, which has a significant impact on life and the environment in the industrial region of the south of the Republic of Kazakhstan. The results of the analysis and examination of the standards of maximum permissible emissions of one of the phosphorus enterprises, including the technological chain “raw material warehouse, crushing and drying department, preparation of raw materials, technological redistribution are given. The materials are presented that substantiate the need to optimize the process of reducing the environmental load and improving the living conditions in the production of fertilizer mixture, in connection with the need for the utilization and processing of various natural and man-made raw materials. The analysis and calculations of the identified parameters affecting the dust and gas emissions formed during the heat treatment of raw materials are presented, with the development of a functional dependence of the dust content reduction indicators.

Keywords: agro-industrial complex, efficiency, production of fertilizer mixtures, temperature, duration, roasting, mode, life safety, drum kiln.

INTRODUCTION

The industrial sector of the economy is a determining factor in the well-being of the population of any state. Food safety is becoming the most important problem of life support for humanity and its activities. Intensive use of fertile land for the cultivation of vegetables and fodder crops is not possible without the restoration of soil fertility. Therefore, the degree of development of the production and use of mineral fertilizers in the agro-industrial complex (AIC) is significantly increasing. Various types of fertilizers appear on the domestic and foreign markets.

It should be noted the growing need of the agricultural sector of the economy for phosphorus fertilizers, for the production of which the chemical method of processing phosphate raw materials is traditionally used, based on sulfuric acid leaching of P_2O_5 into extraction phosphoric acid, and then simple, complex and complex fertilizers are produced on its basis [1-5]. This process is based on the use of phosphate raw materials with a P_2O_5 content of at least 24.5% and crushed to a fineness of less than 0.1 mm, which is accompanied by the formation of a significant amount of dust and gas emissions, and phosphogypsum, one of the main industrial waste products. This requires its processing and disposal in order to improve the ecological situation in the industrial region.

The enterprise for the production of extraction acid from phosphorites by the dihydrate method is located on a site with a climatic feature of the region, characterized by the presence of turbulent air flows. This contributes to the development of stagnant zones due to insignificant atmospheric dynamics. It should be noted that the wind regime corresponds to the continental nature, with a predominance of the northwest direction. And this requires the development of environmental protection measures for the construction of a mini-shop for the production of complex fertilizers from solid materials of natural and technogenic origin, which will reduce the environmental load in the industrial region, as an alternative to the technology of obtaining complex fertilizers of prolonged action, using the acid-free method, in the form of a fertilizer mixture "ZHAMB-70" [6-10].

The proposed method includes mixing the components of the charge from the waste of various enterprises of natural raw materials, in certain proportions, and heat treatment at a temperature not exceeding 1223K. Therefore, the need arose to optimize technological processes, roasting of a charge of substandard natural phosphorite and vermiculite, components of the feedstock for obtaining fertilizer mixture "ZHAMB-70", ensuring the selection of the most efficient and rational version of the production cycle.

The study of the process of obtaining a fertilizer mixture of fertilizer "ZHAMB-70" was carried out in the laboratory "Chemical technology of inorganic substances" NJC SKU after M.Auezov. Studies have established that the temperature and time of the charge firing are the determining factors [6-9], therefore, the optimization of the technological process must be carried out according to the temperature-time regime, in order to obtain a multi-component complex fertilizer mixture of the desired activity in terms of digestibility and water solubility. This is important for the target product - the ZHAMB-70 multi-component fertilizer mixture, a phosphate-containing mineral fertilizer with microelements and moisture-retaining substances.

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The duration of firing is determined or regulated by the residence time of the charge in the roasting drum furnace and is ensured by the angle of inclination of the drum to the horizon within 3-4 degrees, as well as by the rate of flowability of the charge and the speed of rotation of the furnace drum from 2.3 to 2.7 rpm (0.045 s^{-1}):

An increase in temperature over 1223K leads to a decrease in the porosity of vermiculite, due to its sintering [6], since one of the important structural parameters of the main component of fertilizer mixture of fertilizer "ZHAMB-70" is the porosity of vermiculite, which has a moisture-retaining property.

It should be noted that energy saving in technological processes and a decrease in water consumption for irrigating crops are important indicators of environmental protection. For this purpose, internal overburden of coal mining and natural vermiculite are introduced into the charge for burning phosphorite.

Internal overburden, containing about 35% of carbonaceous matter, in the course of heat treatment of the charge, due to the burning out of carbon from it, helps to reduce the consumption of natural gas used as a heat carrier, and porous vermiculite accumulates water in the pores during irrigation and provides a prolonged supply of moisture to the root system of plants.

EXPERIMENTAL PART

As an analogue of dust and gas formation, the process of preparation for the agglomeration of phosphate-siliceous raw materials, one of the phosphorus plants, was selected, the data of which on the maximum permissible emissions are given in Table-1.

Table-1. Standards for emissions of pollutants for crushing and drying and sintering processes.

Manufacturing workshop, area	**Emission source number**	**Pollutant emission standards**						
		current situation for 2015		**For 2016-2017 MPE**		**For 2018 – 2020 MPE**		**year of achievement of MPE**
Pollutant code and name		g / s	t / year	g / s	t / year	g / s	t / year	
1	2	3	4	5	6	7	8	9
ORGANIZED SOURCES								
Agglomerations	0070	0,00874	0,007928928	0,00874	0,007928928	0,00874	0,007928928	2016
Crushing dryer	6005	0,0146	0,010512	0,0146	0,1408	0,0146	0,1517	2016
Agglomerations	6013	0,001024	0,001904	0,000611	0,001467	0,000611	0,001467	2016

The results of laboratory studies: criterion functions and levels of limiting values of indicators of the optimization process - the technological process of roasting a charge from phosphate raw materials, vermiculite and internal overburden rocks, are shown in Table-2. The formation of emissions of dust, sulfur and fluorine during roasting at 1023, 1073, 1123, 1173 and 1223 K. To reduce the amount of calculated data, the article presents the results in full for a temperature of 1023 K with a firing time of 16, 18 and 20 minutes.

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Table-2. Values of indicators of optimization of the technological process at 1023K.

№	Temperature, K	Continue roasting, τ. min	Emissions					
			Dust		sulfur		fluorine	
			Δσ, kg·10^3 g/s	10^6	Δσ, kg·10^3g/s	10^6	Δσ, kg·10^3g/s	10^6
	X_1	X_2	$У_1$		$У_2$		$У_3$	
1	2	3	4	5	6	7	8	9
1	1023	16	55,7	5,8	3	0,31	0,0096	0,001
2	1023	16	50,9	5,3	2,9	0,30	-	Следы
3	1023	16	48	5,0	2,9	0,30	-	Следы
4	1023	16	49	5,1	3,037	0,32	-	Следы
5	1023	16	48	5,0	2,8	0,29	0,0096	0,001
average $τ^1_1$			50,32	5,24	2,93	0,304	0,00384	0,0004
6	1023	18	63,72	5,9	3,9	0,36	0,01	0,001
7	1023	18	61,7	5,7	3,7	0,34	-	Следы
8	1023	18	60,5	5,6	3,6	0,33	0,01	0,001
9	1023	18	62,64	5,8	3,7	0,34	-	Следы
10	1023	18	63,72	5,9	3,6	0,33	0,01	0,001
average $τ^1_2$			62,5	5,78	3,7	0,34	0,006	0,0006
11	1023	20	72	6,0	4,2	0,35	0,012	0,001
12	1023	20	74,4	6,2	4,56	0,38	-	Следы
13	1023	20	73,2	6,1	4,32	0,36	0,012	0,001
14	1023	20	74,4	6,2	4,44	0,37	0,012	0,001
15	1023	20	74,4	6,2	4,44	0,37	0,012	0,001
Average $τ^1_3$			73,7	6,14	4,4	0,366	0,0096	0,0008
Average			62,2	5,72	3,7	0,337	0,00648	0,0006

where:

Δσ – mass of dust, sulfur or fluorine in g / s

X_1 – firing temperature, K

X_2 – firing time, min.

$У_1 У_2$ $uУ_3$ – the amount of dust, sulfur and fluorine emitted, respectively.

Having data on emissions of dust, sulfur and fluorine according to the formula below, we calculate their surface concentration, depending on the temperature and duration of the process.

$$C_M = \frac{A \cdot M \cdot F \cdot m \cdot n \cdot \eta}{H^2 \cdot \sqrt[3]{V_1 \cdot \Delta T}} \tag{1}$$

The maximum value of the ground-level concentration of a harmful substance Cm (mg / m³) for the emission of a gas-air mixture from a single source is determined by formulas (1) for heated emissions and (2) for cold emissions.

For heated emissions (ΔT> 0); and for cold emissions (ΔT = 0):

$$C_M = \frac{A \cdot M \cdot F \cdot m \cdot n \cdot \eta}{H^{4}/_{3}.} \tag{2}$$

Since the emissions are heated at a certain temperature, the calculation is carried out according to the 1st formula, where: A is the coefficient depending on the temperature a ratification of the atmosphere, given for different territories in Table-3.

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Table-3. Temperature ratification.

Discharge source location	Coefficient A
Regions of Central Asia south of 40 ° n. l., Chita region and Buryatia	250
For the European territory of Russia, for areas south of 50 ° n. l., the lower Volga region, the Far East and the rest of Siberia	200
For the European territory of Russia and the Urals, from 50 to 52 ° n. l., with the exception of the above-listed areas falling into this zone	180
for the European territory of Russia and the Urals north of 52 ° n. l., with the exception of the Central European territory	160
For Moscow, Tula, Ryazan, Kaluga, Vladimir, Ivanovo regions	140

For the conditions of Central Asia, and we take A = 250, the values given in the formula correspond to:

M (g / s) is the mass of a harmful substance emitted into the atmosphere per unit of time (for the power of the source, see Tables (1 and 2);

F is a dimensionless coefficient that takes into account the sedimentation rate of harmful substances in the atmosphere (F = l for gases and fine dust);

m, n are coefficients that take into account the conditions for the exit of the gas-air mixture from the mouth of the source.

The coefficient m is found from the expression:

$$m = \frac{1}{0{,}67 + 0{,}1 \cdot \sqrt{f} + 0{,}34 \cdot \sqrt[3]{f}}$$

where $f = 1000 \cdot \frac{\omega_0^2 \cdot Д}{H^2 \cdot \Delta T}$

ω_0 - ejection speed, m / s; we accept ω_0= 10 m/s;

Д - source mouth diameter, m; we accept D = 1.8 m

H - source height, m; we accept H = 50 m

ΔT - the difference between the temperature of the discharged gas-air mixture (T_g) and the temperature of the ambient atmospheric air (T_v) is taken as 20^0C.

The coefficient n is found from the range of values given below:

$$n = \begin{cases} 1, & V_м \geq 2 \\ 0{,}532 \cdot V_м^2 - 2{,}13 \cdot V_м + 3{,}13, & 0{,}5 \leq V_м < 2 \\ 4{,}4 \cdot V_м, & V_м < 0{,}5 \end{cases}$$

where:

V_M - parameter that determines the average wind speed, m / s.

At an altitude of 60 m, the wind speed is always more than 2 m / s, therefore n = 1.

V_1 - the flow rate of the gas-air mixture, m^3 / s is determined by the formula:

$V_1 = \frac{\pi \cdot Д^2}{4} \cdot \omega_0$=25,4469 m^3 /s

m = 1,1866

η - dimensionless coefficient taking into account the influence of the terrain. If the height difference does not exceed 50 m per 1 km, then η is taken equal to 1.

Using the obtained values, we build a graph of the dependence of C_m (surface concentration) on the holding time τ (min) and the temperature of the process T°, °C in the form of a volumetric figure.

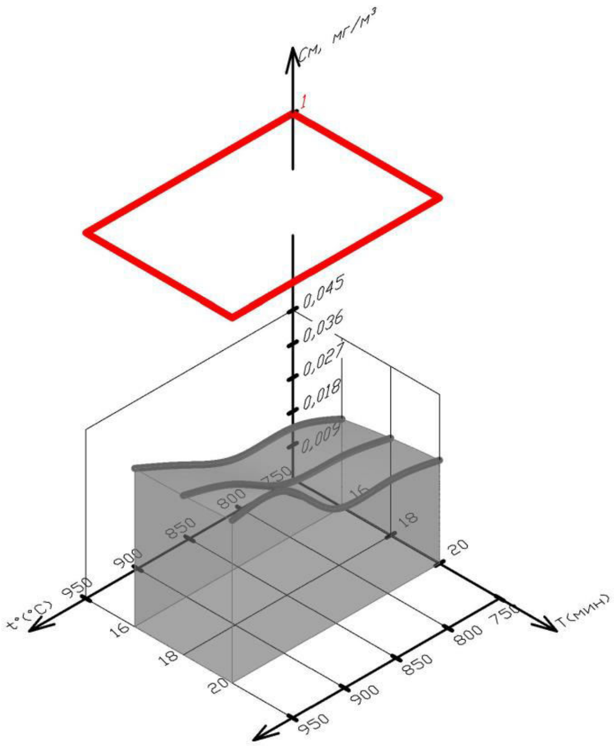

Figure-1. 3D plot of surface dust concentration versus firing time and temperature.

Knowing the MPC of dust (1 mg / m3), we cut off the volumetric figure. The area at the clipping point will be the area of unacceptable process parameters for dust. Since the MPC line is much higher than the upper point of the volumetric figure, then all the process modes indicated in Table-1 are permissible.

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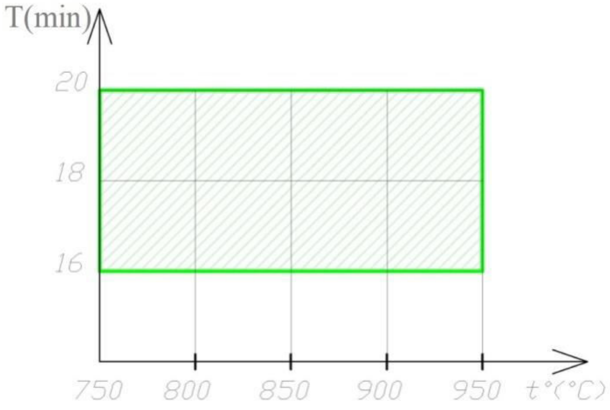

Figure-2. The area of permissible process parameters (hatching is directed to the right) according to the MPC for dust.

In this case, there are no invalid process parameters.

Similarly, to the method for calculating the range of permissible parameters of the dust release process, we determine the values for sulfur and fluorine. The obtained values are shown in figures 3, 4, 5 and 6, respectively, for sulfur and fluorine.

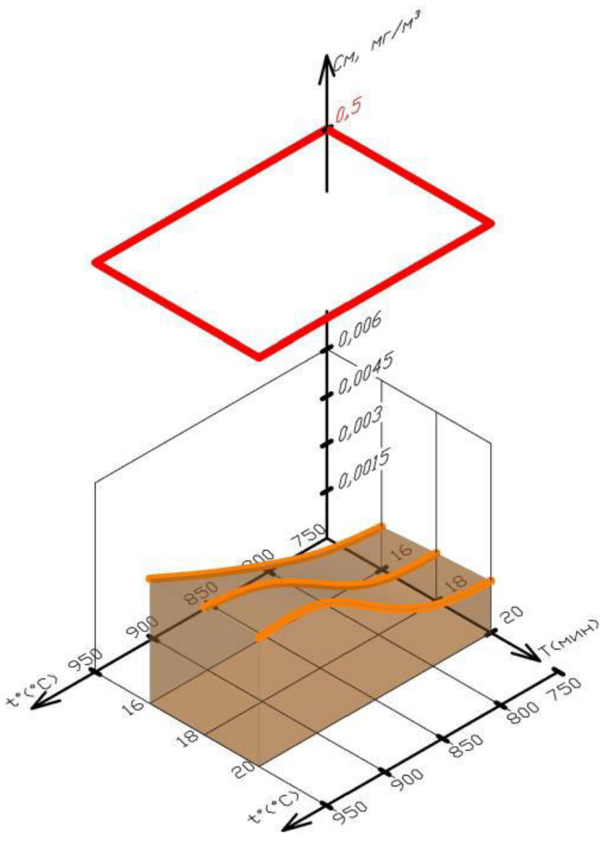

Figure-3. Three-dimensional graph of the dependence of the surface concentration of sulfur dioxide on the duration and temperature of firing.

Knowing the maximum permissible concentration of sulfur dioxide (0.5 mg / m^3), we cut off the volumetric figure. The area at the cut-off point is an area of unacceptable process parameters for sulfur dioxide. Since the MPC line is much higher than the upper point of the volumetric figure, then all the process modes indicated in Table-1 are permissible.

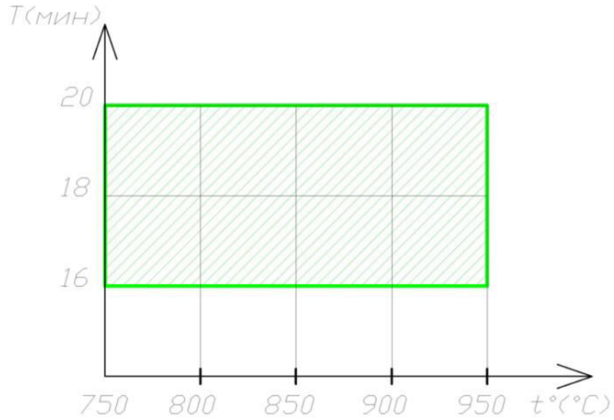

Figure-4. The area of permissible process parameters (hatching is directed to the right) according to the MPC for sulfur dioxide

In this case, there are no invalid process parameters.

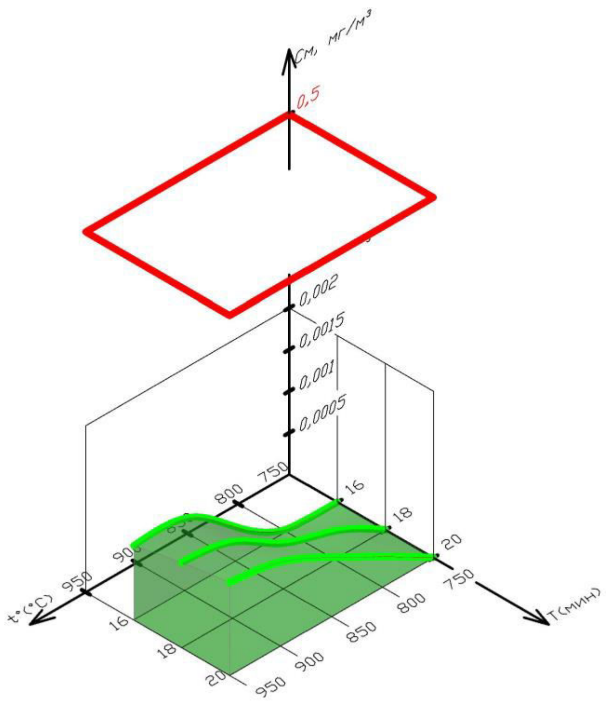

Figure-5. 3D plot of surface fluorine concentration versus firing duration and temperature.

Knowing the MPC for fluorine (0.5 mg / m^3), we cut off the volumetric figure, the area at the cut-off point

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and will be the area of unacceptable process parameters for fluorine. Since the MPC line is much higher than the upper point of the volumetric figure, then all the process modes indicated in Table-1 are permissible.

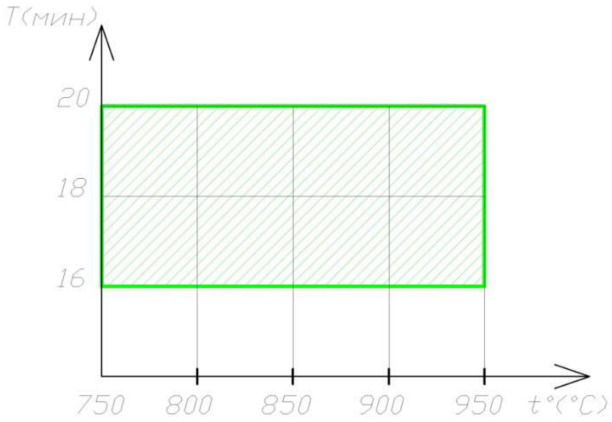

Figure-6. The range of permissible process parameters (hatching is directed to the right) according to the MPC for fluorine.

In this case, there are no invalid process parameters.

The values shown in Figures 2, 4 and 6 show that the process at any operating parameters: holding time τ (min) and the temperature of the process T^o,^{o}C, pass through the MPC.

Based on the obtained experimental results, a graphical analysis was carried out, response surfaces (frame surfaces) were constructed, and statistical processing of experimental results was performed with verification of their adequacy using known methods using scientific works on statistical processing of research experiments [11-16].

The dependences shown in Figures 1-6 show the areas of optimal temperature and time characteristics, providing the least emission of dust, sulfur and fluorine in relation to the maximum permissible concentrations, in the working rooms of the components for quartzite dust 1, mg / nm^3 phosphorite 2 mg / nm^3; 0.05 for SO2 and 0.05 mg / m^3 for fluorine.

RESULTS AND DISCUSSIONS

The temperature limitation is due to the fact that at temperatures less than 1023 K and time less than 16 minutes. No significant release of carbonates (CO_2) from $CaCO_3$ and $MgCO_3$ of natural phosphorite, as well as an increase in the porosity of vermiculite, is not observed.

A temperature value of more than 1223K leads to the melting of vermiculite and the formation of cakes that violate not only the porosity of vermiculite, but also the entire technological process, with significant emissions of sulfur and fluorine.

The main purpose of joint firing of natural phosphorite and vermiculite is dust and gas removal and increasing the porosity of vermiculite. In addition, thermal treatment of phosphorus provides an increase in the amount of phosphorite pentoxide in water-soluble and assimilable forms for plants [17].

To substantiate the technological modes of obtaining fertilizer mixtures of the complex fertilizer "ZHAMB-70", a mathematical analysis was carried out based on experimental results and production tests.

The main tasks of the mathematical analysis of experimental results are selected:

- minimum dust and gas emissions that pollute the environment at optimal performance and maximum load on technological equipment;
- identification of parameters influencing the formation of dust and gas emissions during the production of multi-component fertilizers;
- development of functions Δσ = (T, τ) (Δσ - amount of dust, kg) by the method of quadratic interpolation, depending on the existing conditions of the model, if the determining parameter is the reduction of dust and gas emissions, in order to reduce the environmental load on the environment;
- search for an optimal solution, with the calculation of an extremum and determination of the most effective for a specific situation technological process for the production of complex-mixed multi-component fertilizer fertilizer mixture "ZHAMB-70", which allows you to obtain finished products containing P_2O_5 in a more digestible and water-soluble form, in the temperature range 1023-1173K , as indicated in the works [11-12];
- search for an extremum for $F_{(X)}$ by varying the predetermined values of X within the range of assumptions: Δσ = (T, τ), using the following parameters:
- $F_{(X)}$ – used function (obtained by interpolation);
- X – vector of variables;
- firing temperature T;
- the duration of the process τ [11], the choice of an individual parameter that corresponds to the given process conditions.

In this case, this is the smallest emission of dust and harmful substances that damage the environment, i.e. fauna, flora and people at the maximum possible productivity and given conditions of phosphorite raw materials necessary for obtaining finished products - a multi-component mineral fertilizer in a more assimilable form.

One or more criteria can be used as methods for optimizing technological processes. The work uses various parameters of multi-criteria optimization with the development of one compromise criterion that takes into account several selected parameters at once, the so-called E_i-local criteria (E_1, E_2, E_3, ... E_r) [11].

For each such criterion, the optimization problem for the development of technological processes was solved, with the calculation of the extreme value for Δσ.

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The deviation equation for the criterion can be written in the following form:

$Q_i = E_i - E_{i*}$.

Separately, for each of these criteria, it is necessary to calculate the weight coefficient $\lambda_i (0 < \lambda_i < 1$ and $\Sigma\ \lambda_i = 1)$, in order to identify the importance of the desired parameter in the technological process.

The results of determining the technological characteristics of the process of firing the mixture of fertilizers are shown in Table-4.

Table-4. Technological characteristics of the optimization of the firing process.

№	Technical specifications (TS)		Values of T.S.				
1	Temperature, K	X_1	1023	1073	1123	1173	1223
Batch composition							
2	phosphorite, (in%%):	X_2	50	52	55	57	59
	vermiculite,%	X_3	10	10	10	10	10
3	Firing time, min.	X_4	16,0	17,0	15,0	17,5	15,0

The amount of dust and sulfur emitted into the exhaust gases from the heating unit (mg / s) will be:
- dust:
- $У_1$=6,0 $У_2$ = 6,8 $У_3$ = 7,0 $У_4$ = 10,2 $У_5$ = 10,4
- SO_2containing gases:
$У^1_1$ = 3,5 $У^1_2$ = 4,3 $У^1_3$ = 6,4 $У^1_4$ = 9,2 $У^1_5$ = 9,9
$У^{II}_1$ = 0,001 $У^{II}_2$ = 0,008 $У^{II}_3$ = 0,015 $У^{II}_4$ = 0,024 $У^{II}_5$ = 0,026

An example of calculating the variance of the distribution of results and the standard deviation is presented below:

D - variance distribution of experimental results
σ - standard deviation

Table-5. Disperse distribution and standard deviations for dust.

1	Results	$У_1$	$У_2$	$У_3$	$У_4$	$У_5$	t^0 = 1023
2	Dust, g	55,7	50,9	48	49	48	τ = 16 мин

Average value 49.63 = 49.6 mathematical expectation, and the probability of events P_i0,1+0,2+0,21+0,28+0,21=1;
$M = M_{(Y)}$ mathematical expectation equal = 49,6

$D_{(Y1-5)} = \sum_{i=0}^{n}(Y - M)^2 P_i = \sum_{i=0}^{n}(Yi - M)^2 Pi$ = $(55{,}7 - 49{,}6)^2 \cdot 0{,}1 + (50{,}9-49{,}6) \cdot 2{,}20 + (48-49{,}6)^2 \cdot 0{,}21 + (49-49{,}6)^2 \cdot 0{,}28 + (48-49{,}6)^2 \cdot 0{,}21 = 5{,}2371 = 5{,}2$

The dispersion of the distribution of the results turned out to be significant. The reason can be explained by the large deviation of Y1 and caused by a possible dust residue from previous experiments at the facility. Therefore, the first result is discarded as an accidental release of additional dust from previous studies. After eliminating Y1, we get the variance.
$D_{(Y1-4)}$ = 1,549 = 1,55

Standard deviation in experiments 1-5:

$\sigma_{1-5} = \sqrt{n \cdot D} = \sqrt{4 \cdot 1{,}55} = 2{,}4899 = 2{,}5$

$D = \frac{G^2}{n}$ [11 стр. 124, ф. (17)], $\sigma^2 = n \cdot D$;
$\sigma = \sqrt{n \cdot D}$

$D_{(Уi)}$ - variance of distribution of experimental results;
$У_i$ - the value of the result of the i-th experiment;
M - mathematical expectation of the result, equal to the average value of all data of experimental studies with the specified technological parameters shown in Table-8.

Table-6. Results of statistical processing of experimental data

T, K	τ, min	$D_{(Уi)}$	$M_{(У)}$	G
1023	16	1,55	49,6	2,5
1073	16	0,2196	63,2	0,468
1123	16	0,4984	65,14	0,706
1173	16	1,684	80,1	1,3
1223	16	0,0737	97,92	0,272

The largest values of the dispersion and standard deviation of the experimental data are observed at 1023 K and 1173 K, which indicates the instability of the firing process at these temperatures. At a temperature of 1023 (750°C), due to the greater flowability of the charge components, intensive abrasion of the main components of phosphorite and vermiculite occurs. At more than 1173K, it softens and melts, and at more than 1223K, as indicated above, it leads to its sintering.

To get a mathematical description of the function $П_{(T)} = F_{(T,\tau)}$ apply the interpolation method. Example:

h – table step ($x_0 \ldots. x_1 \ldots. x_2$) $h = (x_i - x_{i-1})$
к – angle coefficient $k = \frac{у_1 - у_0}{h} = \frac{\Delta у_0}{h}$

$У = Y = У_0 + \frac{\Delta y_0}{h}(x - x_0)$ (ruler interpolation)
entering $\frac{x - x_0}{h} = t$, then the formula is ruler interpolation or can be written as:
$y = y_0 + t\,\Delta y_0$
$\Rightarrow y \rightarrow X(y_0 \leq\ y \leq y_1)$
$t = \frac{y_1 - y_0}{\Delta y_0}$.

The value of x is unknown, knowing the time τ, we find the value of x

$x = x_0 + t \cdot h$ quadratic intercom
$y = y_0 + t\,\Delta\, y_0 + \frac{t(t-1)}{2}\Delta^2 y_0$
$\Delta y = (y_1 - y_0)$
$\Delta^2 y_0 = (y_1 - y_0)^2$
$П(т) = \Delta\,\sigma_0 + \left(\frac{T-1023}{50}\right)\boldsymbol{\Delta\sigma} + \frac{\left(\frac{T-1023}{50}\right)\left(\frac{T-1023}{50}-1\right)}{2}(\sigma_i\ -50)$
$П(т) = 50{,}32 + \frac{\Delta\sigma_i \cdot T_i}{50} - \frac{1023\Delta\sigma_i}{50} + \frac{T_i^2}{}$

1	T,K	1023	1073	1123	1173	1223	at τ = 16 min
2	Δσ	50,32	63,20	65,14	80,10	97,92	

We choose a step of the temperature gradient equal to h = 50, те (1073-1023) = 50.

$t = \frac{T-T_0}{50} = \frac{T-1023}{50} = \frac{T_i}{50} - \frac{1023}{50} = \frac{1}{50}(T_i - 1023) = 0{,}02T_i - 15$

$\Delta\sigma = 22{,}9 - 0{,}3476T_i + 0{,}0002T^2_i = \frac{\Delta\sigma = 0{,}0002T_i^2 - 0{,}3476Ti - 22{,}9}{\Delta\sigma(Ti) = (T_i^2 - 1{,}738Ti - 114{,}5)x10^{-4}}$

We check T_i at 1073 K and obtain the value of $\Delta\sigma(T_i)$ from the expression $\Delta\sigma\ (T_i)$ = (640000 - 1390,4 – 114,5) = 63,8495

$$\boldsymbol{\Delta\sigma}_{\text{расч.}} - \boldsymbol{\Delta\sigma}_{\text{экс.}} = 63{,}8 - 63{,}2 = 0{,}6$$

Checking the adequacy of the mathematical model $\Delta\sigma_{theor.}$ with experimental data allows us to conclude that the obtained model is adequate, since the error of the calculated value is:
$\Delta\sigma_{cal.} - \Delta\sigma_{ex.} = 0{,}6 \cdot 10^{-3}$ kg., i.e. less than 1.0%

CONCLUSIONS

Based on the above, the following conclusions can be drawn:

An analytical review of the state of the ecological situation in an industrial region for the production of phosphorus-containing products for the agricultural sector of the economy and with a tendency to increase is carried out.

To reduce the environmental load and increase the output of fertilizers, it is proposed to create a mini-shop for the production of fertilizer mixture and "ZHAMB-70" with prolonged action, in addition to a method that differs from the traditional acid-free method.

Research has been carried out to determine the standards for emissions of pollutants in the production of sub-preparation of raw materials to obtain pure phosphorus, which are as of 2018-2020. Within the range of 0.0015 - 0.008.

The values of dust and gas emissions in the process of identifying indicators of optimization of the technological process at 1023-1223K and time of 16-20 minutes were determined, which amounted to (g / s) for: dust from 50.32 to 62.5; sulfur from 2.93 to 3.7 and fluorine from 0.0038 to 0.0096.

On the basis of the above values, the determination of their compliance with the maximum permissible concentrations by graphic-analytical means was made. It was revealed that the MPC values for dust, sulfur and fluorine compounds correspond to the normative and technical documentation in the working room.

The numerical conclusions of the technological characteristics of the process parameters and the amount of dust, sulfur and fluorine compounds released at these values, as well as dispersed indicators and deviations of characteristics from them, have been determined.

The verification of the adequacy of the mathematical model $\Delta\sigma_{theor}$ has been carried out. From the experimental values and it was found that the error of the calculated value is less than 1%. This indicates that the resulting model is adequate.

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