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Planning An Experiment To Assess The Illumination In The Production Area.

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ABSTRACT

This article presents the results of a multifactor experiment to assess the level of illumination in the conditions of the action of controlled disturbances. A statistical processing of the results obtained. It has been established that the level of illumination at the workplace can be described by a linear model, with the prevailing influence of such factors as the power of the lighting device and the supply voltage. The degree of interaction of factors with each other can be ignored.
Keywords: lighting, experiment, statistical processing of results, regression equation.

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INTRODUCTION

At present, a large-scale system of measures for the rational use of energy resources is being carried out in our country. Energy saving policy is a state priority and determines the state security of the country.

An important role in solving this problem belongs to the lighting systems. If we take into account that in lighting installations of our country 14% of all electricity produced at power plants is spent, careful and more efficient use of it is a significant task for the state.

The main areas of energy savings for lighting systems are as follows [1]:

- use of the most economical light sources and special fixtures with the necessary characteristics of light distribution and the necessary design;
- organization of effective lighting control;
- the right choice and rational placement of lamps;
- improving the quality of operational activities.

On the other hand, energy savings in lighting installations should not be achieved by disabling part of the lighting fixtures or avoiding the use of artificial lighting in low light conditions. Since electric lighting creates a comfortable environment for workers, the struggle for energy saving in lighting systems should not significantly reduce the illumination at workplaces and worsen other indicators of the quality of lighting, significantly affecting labor productivity.

It is known that illumination at workplaces is standardized and periodically monitored by labor protection specialists. At the same time, such an important indicator as illumination, which determine comfortable working conditions for personnel, depends on a number of destabilizing factors [1].

MATERIAL AND METHODS

In order to assess the influence of these factors on the amount of light, a multifactorial experiment was performed. The following factors were considered as controllable factors: the power of the lighting device (x_1); supply voltage (x_2); suspension height (x_3) [2].

Factor levels were considered in the following range (table 1).

Table 1: Factor levels

Factors	Level factors			
	0_{x_i}	μ_i	+ 1	− 1
x_1	150	50	200	100
x_2	220	20	240	200
x_3	75	25	100	50

To assess the linearity of the regression equation, the y0 output at the zero level was determined three times, y_0 values were obtained = 157.1; 139.1; 165.4.

In the course of the experiment, three series of experiments were performed (k = 3). The experiment planning matrix and the results of parallel experiments are shown in Table 2.

Table 2: Matrix planning three-factor experiment

Experience number	Factor level				Estimates				Output parameter			
	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	y_m^I	y_m^{II}	y_m^{III}	$\bar{y}_m$
1	+	–	–	–	+	+	+	–	54,3	49,5	39,6	47,8
2	+	+	–	–	–	–	+	+	148,8	151,4	119,0	139,7
3	+	–	+	–	–	+	–	+	102,1	94,2	75,3	90,5
4	+	+	+	–	+	–	–	–	275,5	273,3	218,6	255,8
5	+	–	–	+	+	–	–	+	80,4	68,7	54,9	68,0
6	+	+	–	+	–	+	–	–	221,2	196,8	157,4	191,9
7	+	–	+	+	–	–	+	–	153,4	133,2	105,7	130,7
8	+	+	+	+	+	+	+	+	410,9	368,4	380,1	358,0

RESULTS AND DISCUSSION

According to the data obtained, the regression coefficients were calculated and we managed to get the regression equation in the following form

$$\hat{y} = 160{,}3 + 76{,}0x_1 + 48{,}4x_2 + 26{,}8x_3 + 22{,}1x_1x_2 + 11{,}7x_1x_3 + 8{,}7x_2x_3 + 3{,}8x_1x_2x_3.$$

Next, a statistical analysis of the regression equation was carried out in three stages: estimation of the variability of reproducibility (estimation of the experimental error), assessment of the significance of the coefficients of the regression equation, and verification of the model adequacy.

Before calculating the error of the experiment, the uniformity of dispersions was checked $S^2(y_m^k)$ по критерию Кохрена $G_p = S^2(y_m^k) / \sum S^2(y_m^k)$.

The calculations made it possible to establish the value G_p = 0,5, which is less than the table value G_n = 0,52. Thus, the hypothesis of dispersion homogeneity was confirmed.

The dispersion of reproducibility was determined as the arithmetic average of the line-by-line dispersions. The resulting value of her $S^2(y) = 854{,}8$. After that, the calculation of the variance of the average value $S^2(\bar{y}) = 284{,}9$, calculation of the dispersion of the regression coefficients $S^2(b_i) = 35{,}6$ and estimated regression coefficient error $S(b_i) = 6{,}0$.

The calculations made it possible to proceed to the verification of the significance of the regression coefficients by the criterion of Student. As a result of the calculations, the following was obtained:

b_0 = 160,3 > 12,7;
b_1 = 76,0 > 12,7;
b_2 = 48,4 > 12,7;
b_3 = 26,8 > 12,7;
$b_{1,2}$ = 22,1 > 12,7;
$b_{1,3}$ = 11,7 < 12,7;
$b_{2,3}$ = 8,7 < 12,7;
$b_{1,2,3}$ = 3,8 < 12,7.

Thus, the regression coefficients $b_{1,3}$, $b_{2,3}$ and $b_{1,2,3}$ are not significant and the regression equation can be written as

$$\hat{y} = 160{,}3 + 76{,}0x_1 + 48{,}4x_2 + 26{,}8x_3 + 22{,}1x_1x_2 .$$

Testing the adequacy of the model usually involves testing the accepted hypothesis of linearity of the system and is carried out in two stages: assessment of the possibility of describing the process by an equation without quadratic terms and the possibility of using an equation without paired terms [2].

To assess the significance of the regression coefficients with higher-order terms, experience at the zero level was performed several times and the average value of the output parameter was calculated $\bar{y}_0 = 153{,}8$. Difference $|\bar{y}_0 - b_0|$ turned out to be statistically insignificant, which confirmed the possibility of using the equation without quadratic terms.

Verification of the linearity of the adopted model makes it possible to discard pairing interactions. To solve this problem, a planning matrix of a three-factor experiment was constructed with discarded numbers of pair interactions, supplemented by $\hat{y}_m$, calculated by the newly taken equation (table 3) [3].

Table 3: Planning matrix for a three-factor experiment with rejected members of paired interactions

№	x_1	x_2	x_3	$\bar{y}_m$	$\hat{y}_m = b_0 + b_1x_1 + b_2x_2 + b_3x_3$	$\hat{y}_m$	$\bar{y}_m - \hat{y}_m$	$(\bar{y}_m - \hat{y}_m)^2$
1	–	–	–	47,8	$\hat{y}_1 = b_0 - b_1 - b_2 - b_3$	9,1	38,7	1497,7
2	+	–	–	139,7	$\hat{y}_2 = b_0 + b_1 - b_2 - b_3$	161,1	-21,4	458,0
3	–	+	–	90,5	$\hat{y}_3 = b_0 - b_1 + b_2 - b_3$	105,9	-15,4	237,2
4	+	+	–	255,8	$\hat{y}_4 = b_0 + b_1 + b_2 - b_3$	257,9	-2,1	4,4
5	–	–	+	68,0	$\hat{y}_5 = b_0 - b_1 - b_2 + b_3$	62,7	5,3	28,1
6	+	–	+	191,8	$\hat{y}_6 = b_0 + b_1 - b_2 + b_3$	214,7	-22,9	524,4
7	–	+	+	130,7	$\hat{y}_7 = b_0 - b_1 + b_2 + b_3$	159,5	-28,8	829,4
8	+	+	+	358,0	$\hat{y}_8 = b_0 + b_1 + b_2 + b_3$	311,5	46,5	2162,3

The adequacy of the model under consideration was tested by the Fisher criterion and gave a positive result.

Thus, the final regression equation for the assessment of illumination at the workplace can be represented as follows:

$$\hat{y} = 160{,}3 + 76{,}0x_1 + 48{,}4x_2 + 26{,}8x_3 .$$

CONCLUSION

Studies have shown that the level of illumination at the workplace can be described by a linear model, with the prevailing influence of such factors as the power of the lighting device and the supply voltage. The degree of interaction of factors with each other can be ignored.

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