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Research paper

Assessment of factors influencing the process electrohydraulic water treatment

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Abstract

The article is devoted to modeling the assessment of factors affecting the process of electrohydraulic water treatment. A screening two-level experiment according to the plan of Plackett-Berman is planned and carried out. A matrix of the Plackett-Berman plan is being developed with factors in coded units and an objective function in physical units. Significant factors that affect the process of obtaining fertilizers during electro-hydraulic treatment of solutions are identified. An error variance estimate is given. The method of random balance is used to separate non-essential variables and dominant factors that may in one way or another influence the process under study. A mathematical model is being developed, which includes 15 linear effects and 105 paired interactions. The plan matrix is determined and the random balance experiment results are identified; scatterplots are built, on the basis of the results of which significant factors are identified, whose influence on the process is eliminated. Each of the contributions is estimated based on the determination of the coefficients of the respective samples; checks the significance of the coefficients and estimates of each of the contributions by the t-test. The most significant factors are the magnitude of the applied voltage; storage capacitors; number of pulses.

Keywords: *Breakdown Voltage; Influence Factors; Placket-Berman Plan; Pulsed Discharges; Sifting Experiment.*

1. Introduction

The undoubted advantage of the electrohydraulic (EH) technology is that the regulation of the discharge parameters allows to control these processes and selectively influence their passage. An analytical review of the collected theoretical information on the topic under consideration and experiments carried out taking into account the theoretical foundations of the generation and propagation of electromagnetic waves in the high-voltage range in media shows that the process of electrohydraulic treatment of solutions in combination with a large number of factors, but only a small part of them has a significant effect on result [1], [4], [7], [8]. Therefore, it is important to identify the most significant factors affecting the yield of digestible forms of fertilizers during EG processing. Along with this, have the opportunity to vary the modes of operation of the installation. The parameters of exposure and operating modes of the facility are proposed to be considered as factors, the size and level of which mainly determine and change the output results of experiments. Modeling of factors influencing the process of EH-processing is carried out in two ways. The first method is based on the plan of Plackett-Berman and is intended to sifting non-essential factors. The second method is based on applying the random balance method to isolate the most significant factors influencing the process of EH-exposure in aqueous solutions with ionic conductivity [2].

2. A sifting experiment based on the plackett-berman plan

In this regard, a two-tier experiment was planned. The first level includes the choice of an impressive number of variable factors of the main most significant initial factors on the basis of which this process takes place. To solve the above, a separate experiment is conducted, called sifting. At the second level, the degree of influence on the object of study of the most important factors is determined. This is achieved by constructing a mathematical model due to the solution of the problem of planning a two-level experimental formulation based on the use of the Plackett-Berman plan [2].

The planning of a two-level experiment is based on the operation of choosing the number of experiments and the requirements for conducting them. Determined by their number, sufficient to resolve the question posed. Then the required degree of accuracy is determined. The main properties and characteristics of the object of research vary according to special functional dependencies. Next, a mathematical model characterized by specific statistical properties is developed. It displays, compiles and structures the results of the experiment.

At the initial stage of planning an experiment, the authors need to solve the following tasks:

- identify the factors that influence in varying degrees on the system
- analyze the factors
- systematize them according to the form and method of management, denoting their levels
- develop a matrix of sifting experiment.

Authors construct the mathematical model according to the principle - from simple to complex. The object of study is represented in the form of an n-pole or a black box system, where n - is the number of input parameters or, in our case, factors.

Input and output parameters that determine the state of the object of study, classify into groups with individual features:

1) The group $X = (x_1, ..., x_k)$ - the initial independent factors that influence the behavior of the system. These parameters

appear to be controlled, with the help of which the given technological mode is realized.

2) The group Z = (z_1, ..., z_m) corresponds to factors that influence the behavior of the system and do not allow their purposeful change, including the initial information of the previous links in the technological chain.
3) The group Q = (q_1, ..., q_n) consists of uncontrollable factors that influence changes in a given system. They show perturbations that can be measured quantitatively which is difficult or impossible (not given in the tasks).
4) The group Y = (y_1, ..., y_p) - output variables, target values with certain optimization parameters. This group can be correlated system response to the effects or dependencies between input and output factors.

Theoretical analysis along with a priori information showed that during EH-treatment of solutions, the following 12 factors can affect the yield of nitrate nitrogen in water [3-5].

Sifting experiment will perform according to plan of Plackett-Berman. The choice of this method is due to the following considerations:

the selection of significant factors can be made at the lowest possible expenses (the minimum number of experiments);

the orthogonality of these plans allows you to reduce the resource processing results.

To use the plan of Plackett-Berman to highlight significant variables, add three fictitious factors to the above. Fictitious factors are located under a random index number of 8, 13, 15. In this case, it will be necessary to conduct N = 16 experiments for 15 factors. The selected factors vary on two levels: the lower level corresponds to the smaller value of the Hmin factor (-1), the upper one - to the greater Hmax (+1). Choose so that they are on the boundaries of the planning area.

As a result, obtain the values of the variation levels, which have been in table 1.

Table 1: Factors Affecting the System

No. p/p	Classification of factors and objective function	Decipherment of factors and objective function	Levels of variation	
			-1	+1
1	X1	The magnitude of the applied voltage, kV	10	70
2	X2	The duration of the experiment, s	60	600
3	X3	Capacity of storage capacitors, uF	0,025	0,2
4	X4	Volume of test chamber, l	1	5
5	X5	Pulse frequency, Hz	1	50
6	X6	Pulse energy, J	1,25	490
7	X7	Electrode area, mm^2	1	2500
8	X8	Fictitious factor	-	-
9	X9	Number of pulses, pcs.	10	300
10	X10	The inductance of the discharge circuit, mH	50	200
11	X11	Water source (lake, sea)	lake	sea
12	X12	Electrode material (copper, titanium)	copper	titanium
13	X13	Fictitious factor	-	-
14	X14	Electrode shape, (needle, circle)	needle	circle
15	X15	Fictitious factor	-	-
16	Z1	Solution temperature, °C	0	50
17	Z2	Ambient temperature, °C	-20	+20
18	Y	Nitrogen yield, mg / l	10	1500

Due to certain design features of the installation, it is not possible to vary the temperature of the solution and the environment at this stage of the experiments. In this regard, the factors Z1 and Z2 in the first approximation are neglected. Based on the data in table 1, the authors compose a matrix of the Plackett-Berman plan with factors in coded units and with objective function in physical units in accordance with table 2.

Table 2: The Matrix of the Plackett-Berman Plan

No. p/p	Factor levels															Response
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	Y
1	+	+	+	+	-	+	-	+	+	-	-	+	-	-	-	1500
2	+	+	+	-	+	-	+	+	-	-	+	-	-	-	+	390
3	+	+	-	+	-	+	+	-	-	+	-	-	-	+	+	110
4	+	-	+	-	+	+	-	-	+	-	-	-	+	+	+	1500
5	-	+	-	+	+	-	-	+	-	-	-	+	+	+	+	25
6	+	-	+	+	-	-	+	-	-	-	+	+	+	+	-	97
7	-	+	+	-	-	+	-	-	-	+	+	+	+	-	+	51
8	+	+	-	-	+	-	-	-	+	+	+	+	-	+	-	540
9	+	-	-	+	-	-	-	+	+	+	+	-	+	-	+	540
10	-	-	+	-	-	-	+	+	+	+	-	+	-	+	+	413
11	-	+	-	-	-	+	+	+	+	-	+	-	+	+	-	319
12	+	-	-	-	+	+	+	+	-	+	-	+	+	-	-	108
13	-	-	-	+	+	+	+	-	+	-	+	+	-	-	+	365
14	-	-	+	+	+	+	-	+	-	+	+	-	-	+	-	51
15	-	+	+	+	+	-	+	-	+	+	-	-	+	-	-	413
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10

Processing of experimental results.

1) The calculation of the effects of individual factors.

The estimate of the effect of B_i is equal to the difference between the sums of the values of the objective function for factor x_i at levels +1 and -1 divided by N/2:

$$B_i = \frac{\sum_{j=1}^{N} y^j x_i^j}{N/2}. \qquad (1)$$

In accordance with (1) are:

B_{i1} = 392,25; B_{i2} = 33; B_{i3} = 299,75; B_{i4} = -28,75; B_{i5} = 44; B_{i6} = 197; B_{i7} = -250,25; B_{i8} = 32,5; B_{i9} = 593,5; B_{i10} = -247,5; B_{i11} = -215,75;

B_{i12} = -29,25; B_{i13} = -40,75; B_{i14} = -40,25; B_{i15} = 44,5.

The values of a_i are equal to half of the respective effect estimates. Table 3 shows the levels of factors and the effects of B_i (or the coefficients a_i), which are determined in accordance with expression 1.

2) Check the significancy of the parameters.

To identify significant factors, t-criterion is used and the condition is checked:

$$|a_i| \geq t_{cr} \cdot S_i, \qquad (2)$$

where t_{cr} – critical value of the t-distribution for the significance level α and φ degrees of freedom; S_i^2 –estimate of the dispersion of the coefficient a_i.

The variance of observation errors is estimated using special experiments, introducing into the plan fictitious factors from x_{l+1} to x_{N-1} in accordance with the expression:

$$S_i^2 = \frac{4k(a_{l+1}^2 + a_{l+2}^2 + \ldots + a_{N-1}^2)}{4k-l-1}. \qquad (3)$$

Regarding the structuring of fictitious factors and in accordance with (3), for calculating the variance of observation errors, the expression is obtained:

$$S_l^2 = \frac{4k(a_8^2+a_{13}^2+a_{15}^2)}{4k-l-1}, \qquad (4)$$

Where

k = 4, l = 12.

In accordance with (4) determine

$S_l^2 = 16 \cdot 391{,}421875.$

The variance of the estimates of the coefficient a_i is determined from the expression:

$$S_i^2 = \frac{S_l^2}{4 \cdot k}. \qquad (5)$$

Thus, in accordance with (5) receive

$S_i \approx 19{,}78.$

Taking into account α = 0,05 and φ = 3 from the table of t-distribution (distribution according to the Student's t-test) find $t_{кр}$ = 3,18.
The significancy of the indexes is checked in accordance with (2) and is shown in table 3

$|a_i| \geq 3{,}18 \cdot 19{,}78 \approx 62{,}9.$

Table 3: The Selection of Significant Factors

Classification of factors	Decipherment of factors	Levels of variation		a_i	Significancy
		-1	+1		
X1	The magnitude of the applied voltage, kV	10	70	196,125	yes
X2	The duration of the experiment, s	60	600	-123,75	yes
X3	Capacity of storage capacitors, uF	0,025	0,2	149,875	yes
X4	Volume of test chamber, l	1	5	98,500	yes
X5	Pulse frequency, Hz	1	50	22,000	not
X6	Pulse energy, J	1,25	490	-14,375	not
X7	Electrode area, mm^2	1	2500	-125,125	yes
X8	Fictitious factor	-	-	16,250	-
X9	Number of pulses, pcs.	10	300	296,750	yes
X10	The inductance of the discharge circuit, mH	50	200	16,500	not
X11	Water source (lake, sea)	lake	sea	-107,875	yes
X12	Electrode material (copper, titanium)	copper	titanium	-14,625	not
X13	Fictitious factor	-	-	20,375	-
X14	Electrode shape, (needle, circle)	needle	circle	-20,125	not
X15	Fictitious factor	-	-	22,250	-

As a result of the significance test, the edge factors, that is, significant and insignificant factors that have a certain impact on the target output function in accordance with the initial indicators, were identified. In order to determine the estimates of the influence of each of the essential factors and for their more descriptive analysis, their distribution is compiled according to the degree of influence on the target value in accordance with the diagram in fig. 1.

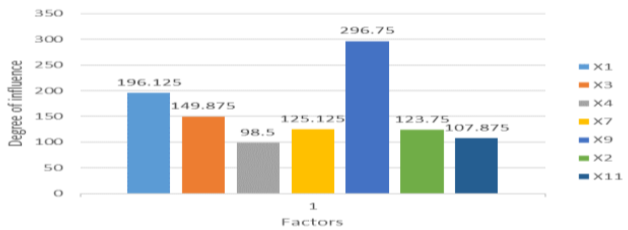

Fig. 1: Distribution of Factors According to the Degree of Their Influence on the Target Value.

As a result of the sifting experiment based on the Plackett-Berman plan, it was revealed that the significant factors affecting the yield of nitrate forms of nitrogen are:

- X1 the magnitude of the applied voltage;
- X3 capacity of storage capacitors;
- X6 pulse energy;
- X7 electrode area;
- X9 number of pulses;
- X10 the inductance of the discharge circuit;
- X11 water source.

Of the above, the most significant factors are:

- X1 the magnitude of the applied voltage;
- X3 capacity of storage capacitors;
- X9 number of pulses.

3) Simulation of significant factors by random balance method

In addition to the sifting experiment according to the Plackett-Berman plan, the distribution of significant factors was performed using the random balance method [2].
Estimation of the number of the above factors, their number - 15, allows the authors to perform the procedure for selecting the planning of the experiment and its processing. In this context, it is advisable to use supersaturated plans. This makes sense in order to structure the number of experiments within the limits of which statistical processing will be carried out with minimal funds and costs. It is proposed to apply the method of random balance. The developer of this method is Saterzuite.
According to this method, significant factors are singled out from a large set of variables. They also take into account their paired interactions. It is assumed that from the entire flow of factors only their insignificant or significant part, what will be established as a result of the experiment, will probably have a significant impact on the output dependent magnitude. Impact parameters and operating modes of the installation with a minor impact can be considered the so-called “noise”.
The mathematical model includes 15 linear effects and 105 paired interactions. The planning edge areas of the experiment were developed for 15 process-influencing factors, where x1 – is the level of applied voltage; x2 – the duration of the experiment; x3 – inductance; x4 – material test chamber; x5 – the area of the electrodes; x6 – is the number of pulses; x7 – is the volume of the test chamber; x8 – electrode material; x9 – is the pulse frequency; x10 – the shape of the electrodes; x11 – is the pulse energy; x12 – capacity of storage capacitors; x13 – type of aqueous solution; x14

– is the temperature of the aqueous solution; x15 – ambient temperature [6, 9, 10]. Factors vary according to two levels. The lower level is the minimum value of the factor (x_{min}). The upper level corresponds to the maximum value of the factor (x_{max}). When selecting them, it is necessary to take into account the condition of respecting the greatest possible difference between them, which reflects their location at the boundaries of the planning area. Rationing factors is determined by the following expression:

$$x_i = \frac{x_i^* - x_{i0}^*}{L_i}, \tag{6}$$

where x_i^* – is the natural form of the factor; x_{i0}^* – is the natural form of the zero factor; Li – is the variation interval.

$$L_i = \frac{x_{i\text{макс}}^* - x_{i\text{мин}}^*}{2}. \tag{7}$$

In accordance with table 4, the boundaries of the planning area are defined.

Table 4: Regional Planning Areas of the Experiment for the 15 Influence Factors Studied

Factors		x_1^*	x_2^*	x_3^*	x_4^*	x_5^*	x_6^*	x_7^*	x_8^*	x_9^*	x_{10}^*	x_{11}^*	x_{12}^*	x_{13}^*	x_{14}^*	x_{15}^*
Levels	+1	70	600	20	Ti	2500	300	5	Cu	50	C	490	0,2	L	50	20
	-1	10	60	5	Fe	1	100	1	Ti	1	N	1,25	0,025	S	0	0

To construct the plan of the experiment, the mixing of randomly formed samples, that is, the set of test cases obtained on the basis of fractional plans, is used. The resulting factors are structured into the following groups.

1) x1, x2, x3, x4.
2) x5, x6, x7, x8.
3) x9, x10, x11, x12.
4) x13, x14, x15.

An experiment plan of type 2^4 is chosen. Through a random sampling of numerical values from the matrix of the plan 2^4, rows are marked by a random method. This is done individually for each of the composed groups of factors. For 16 experiments, 16 lines are selected. For this sample, the following sequence of lines are obtained:

- group 1: 10,6, 3,16, 4,15, 14,1, 5,9, 7,13, 2,8, 12,11;
- group 2: 13,3, 7,16, 2,9, 2,16, 6,12, 13,7, 9,12, 3,6;
- group a 3: 5,10, 15,16, 3,4, 15,4, 6,9, 9,3, 16,5, 6,10;
- group 4: 7,15, 11,8, 16,3, 5,13, 4,12, 6,2, 2,1, 14,9.

The developed matrix of the plan along with the results of the experiment are presented in accordance with table 5.

Table 5: The Plan and the Results of the Experiment According to the Method of Random Balance

No. p/p	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	y^1
1	+	-	-	+	-	-	+	+	-	-	+	-	-	+	+	811
2	+	-	+	-	-	+	-	-	+	-	-	+	-	+	+	144
3	-	+	-	-	-	+	+	-	-	+	+	+	-	+	-	193
4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1245
5	+	+	-	-	+	-	-	-	-	+	-	-	+	+	+	163
6	-	+	+	+	-	-	-	+	+	+	-	-	-	+	-	907
7	+	-	+	+	+	-	-	-	-	+	+	+	-	-	+	223
8	-	-	-	-	+	+	+	+	+	+	-	-	-	-	+	110
9	-	-	+	-	+	-	+	-	+	-	+	-	+	+	-	56
10	-	-	-	+	+	+	-	+	-	-	-	+	+	+	-	860
11	-	+	+	-	-	-	+	+	-	-	-	+	+	-	+	107
12	-	-	+	+	-	+	+	-	-	+	-	-	+	-	-	1489
13	+	-	-	-	-	-	-	+	+	+	+	+	+	-	-	180
14	+	+	+	-	+	+	-	+	-	-	+	-	-	-	-	220
15	+	+	-	+	-	+	-	-	+	-	+	-	+	-	+	983
16	-	+	-	+	+	-	+	-	+	-	-	+	-	-	-	1022

The next stage is the construction of a scatterplot. On the dependency graph, the values of the resulting function are plotted over each of the 15 factors considered in accordance with the scatter diagram in fig. 2. Both levels of varying factors +1 and -1 are noted and medians are found, that is, the mean lines of the factors studied. The criterion of the degree of influence of the corresponding factor is determined by the difference between the medians. The most significant impact has factor x4. This follows from the analysis of chart. The visual identification of dominant factors by the magnitude of the medians is allowed to be replaced by a method based on the determination of the number of "peculiar points".

"Peculiar points" are the definitions of the output function for the upper maximum level of the factor ($x_i = +1$), which are less than the smallest or greater than the largest value corresponding to another level ($x_i = -1$). The combination of such graphic points is allowed to characterize the importance of factors.

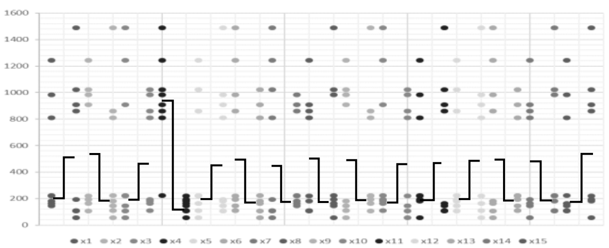

Fig. 2: The Scatter Diagram for 15 Factors.

The estimation of contributions is determined by the average value of the output function, for which the selected factor x_4 is located at a high level of +1. Then, the average value of the output function at a low level of -1 is subtracted from it. The coefficients of the experiment plan are determined similarly. Thus, the estimation of the factor x_4 is equal to $B_4^1 = 795{,}875$. The value B_4^1 allows you to get a parameter estimate $a_4^1 = B_4^1/2 = 397{,}9375 \approx 398$.

To find other significant factors, the influence of factor x_4 on the output function is eliminated. For this purpose, the value of $2 \cdot a_4^1 = 796$ is subtracted from all output functions for which x4 was at the level of +1 in accordance with table 6. Thus, the effect of the factor x_4 on these quantities is terminated. Following this action, a newly calculated vector of experimental results is formed. The scatter diagram is constructed, according to which factor x_4 already interrupts having an effect. Studies of the scatter diagram show that the factors x_2, x_{13}, x_{14} have the greatest influence.

Table 6: The Results of the Experiment According to the Method of Random Balance

Experiment number	y^2	y^3	y^4	y^5	y^6
1	15	15	25	279	238
2	144	144	167	310	158
3	193	72	105	216	105
4	449	146	179	562	410
5	163	-140	-140	131	90
6	111	-10	-10	-10	-10
7	-573	-573	-573	-190	-342
8	110	110	143	414	414
9	56	-126	-116	124	13
10	64	-118	-95	33	-78
11	107	-196	-186	-43	-154
12	693	511	544	544	544
13	180	-2	-2	109	-43
14	220	99	122	361	320
15	187	-116	-93	288	247
16	226	105	115	243	132

The next step is to assess the contributions of a_2, a_{13}, a_{14} for factors x_2, x_{13}, x_{14}. For each group of numerical values is the average value of the output function. Estimates of the contributions of factors are calculated by the differences between the sums of average values for high and low levels according to the following expression:

$$B_2^2 = \frac{y_3^m + y_4^m + y_5^m + y_6^m + y_{11}^m + y_{14}^m + y_{15}^m + y_{16}^m}{8} - \frac{y_1^m + y_2^m + y_7^m + y_8^m + y_9^m + y_{10}^m + y_{12}^m + y_{13}^m}{8} \quad (8)$$

where

$m = 2$.

B_{13}^2 and B_{14}^2 are defined similarly. Estimates of the coefficients are calculated by the above expression. The values of the estimates of contributions and ratios thus more clearly allow us to characterize the degree of materiality of factors than the difference in medians. For the estimates of the coefficients a_2, a_{13}, a_{14}, the following numerical values were obtained:

$a_2^2 = 60{,}43$; $a_{13}^2 = 90{,}81$; $a_{14}^2 = 2{,}81$.

The numerical value of the coefficient estimate $a_{14}^2 = 2{,}81$ compared with the other two. Therefore, further calculation will be carried out in case of removal only from the influence of factors x_2 and x_{13}. This is achieved by subtracting from those output functions y^2, for which $x_2 = +1$ and $x_{13} = +1$, the values of B_2^2 and B_{13}^2 are correspondingly. Then a vector of results y^3 is obtained and a new scatter diagram is developed, which shows that factors x_6 and x_7 have the greatest influence. Calculation of parameter estimates is carried out according to the above method.
The result is the following:

$a_6^3 = -11{,}5$; $a_7^3 = -4{,}9$.

To isolate significant factors from the remaining ones, it is necessary to remove the vector of the y^3 results from the influence of factors x_6 and x_7. This is achieved by subtracting from the output function the values of B_6^3 and B_7^3 at x_6 and x_7, which assume a high level of values, respectively. The following scatterplot is constructed for the newly obtained vector y^4. Processing is carried out by visualization and calculation of medians. From which we can conclude the remaining factors that predominate or dominate. These are x_5, x_{11} and x_{15}. Next, new factors are calculated. They turn out to be equal:

$a_5^4 = -64{,}38$; $a_{11}^4 = -55{,}69$; $a_{15}^4 = -71{,}31$.

By the already well-founded law, the influence of the selected factors on the response of the function is excluded. As a result, the vector y5 is found. For this vector once again it is necessary to construct the fifth scatter diagram.
Visually are determined by the dominant factors x1 and x12. Further, the following coefficients are calculated:

$a_1^5 = 20{,}5$; $a_{12}^5 = 55{,}7$.

After eliminating the influence of factors x1 and x12 on the output function, the vector y6 is determined. The constructed scatter diagram of factors clearly demonstrates that the influence of the remaining factors is negligible and is defined approximately as one order of magnitude.
Ultimately, the following estimates are determined:

$a_1^5 = 20{,}5$; $a_2^2 = 60{,}43$; $a_4^1 = 398$; $a_5^4 = -64{,}38$; $a_6^3 = -11{,}5$; $a_7^3 = -4{,}9$; $a_{11}^4 = -55{,}69$; $a_{12}^5 = 55{,}7$; $a_{13}^2 = 90{,}81$; $a_{14}^2 = 2{,}81$; $a_{15}^4 = -71{,}31$.
The final stage is to test the significancy of the coefficients on the basis of the t-criterion. This condition is written in accordance with the expressions (2), (3), (4), (5).
This validation can only be performed if each cell of the table contains at least two values of the output function.
For example, we calculate the verification of the significance of the coefficient a_1:

$$S_1^2 = \frac{(310-197)^2 + (562-197)^2 + (-190-197)^2 + (109-197)^2}{3} = 101169,$$

$$S_2^2 = 58059,\ S_3^2 = 36088,\ S_4^2 = 19875,$$

$$S_F^2 = 1560,$$

$$S^2 = \frac{1}{16} \cdot 1560 \cdot \frac{4}{4} = 97{,}5,$$

$S = 9{,}9$, $\varphi = 12$.

When $\alpha = 0{,}05$, the critical value $t_{кр}$ is 2,18. In this connection, the a_1 estimate is insignificantly different from zero.
This completes the definition of linear effects. Next, the most basic of pairwise interactions is highlighted. Their total number is equal to the number of combinations of 15 to 2, that is, $C_{15}^2 = 15$. There is no need to build the scatter diagram for such a large number of paired interactions; moreover, this process will appear cumbersome and complex. A heuristic visual selection method will be used to find the most important pairwise interactions. The basis of this method is the following rule. The emergence of prominent points on high and low levels $x_i x_j = +1$ and $x_i x_j = -1$ is necessary. Then the pairwise interaction of the factors x_i and x_j can be ranked as significant. In the first case, x_i and x_j must be the same characters, and in the second - different. It follows from this that the pair interaction of such factors will be significant, in which the number of distinguished points will be large both at the same and at different levels. In fact, for these factors, the lower level of the scattering diagram should be similar to the mirror image of the upper one in accordance with fig. 3.

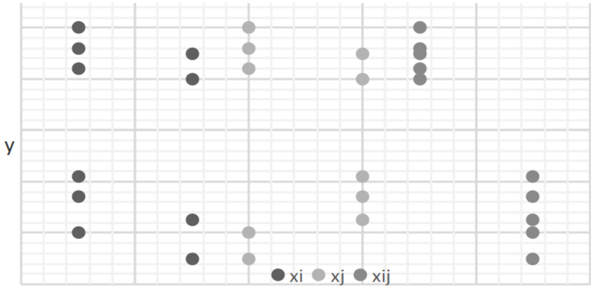

Fig. 3: The Scatter Diagram for Paired Interactions.

According to this statement, pairwise interactions are visually selected from the scatterplot, for which a new diagram is constructed. Corresponding tables are being developed for calculating the parameters. Due to the correlation between some rows, part of the cells in the tables remain unfilled. In this regard, the quantitative assessment of pair interactions is performed only on the basis of medians.
The following pairwise interactions are significant:
x_1x_{11}, x_3x_{10}, x_5x_{12}, x_6x_{13}, x_8x_{14}, $x_{11}x_{15}$.
This process of separating the materiality of couples can continue indefinitely. Therefore, at this stage a certain stopping criterion is required. It is possible to use the F - criterion.

$$F = \frac{S_m^2}{S^2} \quad (9)$$

where S_m^2 – is the estimate of the variance of the experimental results relative to their arithmetic average value at the r-step of the operation; S^2 – is the estimate of the variance of observation errors calculated on the basis of the results of several parallel observations. The change in the dispersions $S_m^2(r)$ depending on the step number r of the factor extraction procedure can be analyzed using the scatter plot. This dependence characterizes the change in the variances of the results of experiments. Following this diagram, it can be revealed that after five steps this dispersion is quite small. By repeating the experiments at one point of the plan, the estimate $s^2 = 32$ is found ($\varphi = 7$). Along with this, for $S_m^2(5) = 74,4$ ($\varphi_m = 12$) it turns out

$$F = \frac{74,4}{32} = 2,32 < 3,5 = F_{кр}, \alpha = 0,05.$$

All significant factors are highlighted. This indicates that the settlement operations for this procedure can be terminated.
The random balance method used in this topic due to the simplicity of processing and the possibility of varying factors at several levels revealed significant and insignificant factors influencing the process of electrohydraulic water treatment without recourse to technical tools and computer programs for processing experiments. In the end, inconsequential factors are reasonably defined: the duration of the experiment; test chamber material; the volume of the test chamber; pulse frequency.
Thus, the results of the constructed optimization models for identifying significant and insignificant factors on the basis of two methods coincide and are combined.

3. Conclusion

The evaluation of factors influencing the process of EH-processing was carried out in two ways: based on the use of the Plackett-Berman plan for screening out insignificant factors and using the random balance method to identify the most significant factors influencing the process. The results of the constructed optimization models for identifying significant and insignificant factors based on the two methods coincide and are combined. Non-significant factors are reasonably defined: the duration of the experiment; test chamber material; the volume of the test chamber; pulse frequency. Significant factors are: the magnitude of the applied voltage; storage capacitors; pulse energy; electrode area; number of pulses; inductance; water source. Of the above, the most significant factors are: the magnitude of the applied voltage; storage capacitors; number of pulses. The obtained results of the experiments performed allow optimizing the design parameters of the technical means for EH-processing and technological modes of operation.

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