ON THE MODELING OF PURIFICATION PROCESS OF SPENT WATERS FROM COMPLEX ORGANIC COMPOUNDS

V.V. Oshchapovsky[1], Z.M. Yaremko[2], G.V. Skomorovich[2],
V.A. Marchenko[2], V.V. Shylo[2], Ye.R. Kurilas[2]

[1]Lviv State Institute of Fire Safety
P.O.Box 10676, Lvov, 79000, UKRAINE
E-mail: asu@franko.lviv.ua and oshchapovsky@yahoo.com

[2]Lviv National University
1, Universitetska Str., Lvov, 79000, UKRAINE
E-mail: asu@franko.lviv.ua

Abstract
The purification method of spent washing waters from organic compounds was developed. Electrolysis was used as the most effective method in the purification process of aquatic solutions. In L-L system, the influence of technological factors was studied: electrolysis voltage, interelectrode distance. To optimize the purification process, the method of passive mathematical modeling was used. Mathematical model of purification degree $Y_p = f(X_{NaCl}, X_l, X_t)$ was created. Here Y_p and X_i are standardized values of purification degree, quantity of NaCl addition, interelectrode distance, electrolysis duration. Control of purification was conducted by decrease of COD magnitudes. Program of purification description including the interaction effects was developed. The program has many levels. It permits to describe the process both in linear form and in the form of complicated polynomials. Program allows to select coefficients in the regression equations, describing water purification degree depending on the technological factors. Non-dimensionality of standardized values of factors permits to evaluate their "weights". Created program was used while studying the spent water purification of polygraphic processes during processing of photoplates from admixtures. With the increase of length and complication of polynomial, the accuracy of approximation increased from 10 to 5%. This allowed to determine the optimal regime of purification.

Introduction

Modeling of multi-parameters systems represents the complicated mathematical task, especially when there is a great number of casual, difficultly controlling factors and therefore the direct description of process with help of physico-chemical and other laws is impossible. Particular complexity represents the description (modeling) of systems, when analyzed factors (parameters of system) are of different nature and, of course, have the various physical dimensionality. In that case it is necessary to use empirical and semi-empirical mathematical statistical models with arbitrary coefficients.

Methods and Results

The photoplates, which are used in printing production include a great number of harmful and toxic components: polyester resins, styrenes, derivatives of methacrylic acid and other unsaturated organic compounds (alcohols, acids, esters, etc.). The destruction and removal of those components as well as the purification of spent waters in principle are possible, however, they require a long search of optimal conditions. In order to purify the polygraphic washing waters the electrolysis method was used. The purification degree of spent solutions was checked according to the decrease of COD-parameter by known methods (1,2). The search of optimal conditions for purifying process required a great number of complex experiments. (Some results of the experiments are shown in table 1.)

Table 1.

Time, min	$Mass_{NaCl}$, g	Interelectrode distance, cm	COD
0.5	10	3	3341
1	7.5	3	2227
2	9	6	4347

In order to describe and provide further optimization of the purification of spent washing waters used in processing of photoplates the mathematical model (program) which permits to complicate and modernize the form of approximizing polynomial was created.

To optimize the purification process, the method of passive mathematical modeling was used. Mathematical model of purification degree $Y_p = f(X_{NaCl}, X_l, X_t)$ was created. Here Y_p and X_i are standardized values of purification degree, quantity of NaCl addition, interelectrode distance, electrolysis duration. Program of purification description includes the interaction effects. The program has many levels. It permits to describe the process both in linear form and in the form of complicated polynomials. Program allows to select coefficients in the regression equations, describing water purification degree depending on technological factors. Non-dimensionality of standardized values of factors permits to evaluate their "weights".

Mathematical processing of the experimental data of the purification process of spent washing waters purification gives a possibility to obtain the statistical models of square and cubic type with the standardized parameters of undimensional form:

$$Y_{deg.pur.} = \Sigma a_i X_i + \Sigma a_{ij} X_i X_j + a_{ijq} X_i X_j X_q + \Sigma a_{ii} X_i^2 \qquad \text{(square type)}$$

$$Y_{deg.pur.} = \Sigma a_i X_i + \Sigma a_{ij} X_i X_j + a_{ijq} X_i X_j X_q + \Sigma a_{ii} X_i^2 + \Sigma a_{iii} X_i^3 \qquad \text{(cubic type)}$$

On the basis of standardized magnitudes of studied factors (X_1 – duration of electrolysis, X_2 – mass of added NaCl, X_3 – interelectrode distance), the concrete empirical mathematical model of purifying process was created. Concretely, the equations in form of COD = $f(t, m_{NaCl}, d_{ie})$ were obtained. Accuracy of cubic model constituted 9.7 %. With its help the role and “weight” of each parameters of electrolysys process of purification were evaluated: the quantity of NaCl addition, interelectrode distance and process duration. It is established that the model of cubic type in standardized units has a form of:

$$COD_{stand} = -3.18 \cdot m_{NaCl} - 4.23 \cdot m_{NaCl} D_{ie} + 8.43 \cdot (m_{NaCl})^2 - 2.91 \cdot (m_{NaCl})^3$$

Analysis of the model showed that the greatest influence on the purification of washing waters has the quantity of added sodium chloride NaCl as well as joint (synergical) effect of interaction $[m_{NaCl}]\times[d_{ie}]$.

The purification degree of the spent solutions out of an organics was increased to ~9 % by further correction of process with help of obtained model. As a result of the conducted investigations on the laboratory plant (volume of work electrolytical batch is ~1 L) sufficiently high degree of purification of spent washing solutions out of organic pollutions was reached: 90-95%. There were less expenditures of electroenergy than during the use of the known methods of purification.

Developed model was also used to optimize the air purification in the working zones of the woodworking departments of certain Lvov enterprises. The dust-catcher-cyclone of jalousie type was employed for purification (3,4). The air purification level out of dust was quite high: from 80 to 92 %. However, in order to increase the dust-catching degree, it was necessary to determine the optimal quantity of angle α of jalousie turn concerning the gas flow movement direction. The obtained linear and quasi-linear (considering the joint effects) models did not permit to determine the optimal quantity of angle. They showed that the gas flow rate and dimensions D of dust particles have a weak influence on the air purification degree. Further complication of the model to the square and cubic forms (after elimination of the terms of little significance) gave the following form: square model (in standardized form) of:

$$Y_{st} = 1{,}16 \cdot D + 5{,}81 \cdot \alpha - 0{,}91 \cdot D \cdot \alpha - 6{,}49 \cdot \alpha^2 \qquad (I)$$

in natural values of

$$Y_{nat}\,(\%) = -75{,}80 + 0{,}54 \cdot D + 8{,}63 \cdot \alpha - 4{,}82 \cdot 10^{-5}\, D \cdot \alpha - 0{,}11 \cdot \alpha^2 \qquad (II)$$

and cubic model (in standardized form) of

$$Y_{st} = 1{,}10 \cdot D + 36{,}73 \cdot \alpha - 0{,}91 \cdot D \cdot \alpha - 69{,}01 \cdot \alpha^2 + 31{,}68 \cdot \alpha^3 \qquad (III)$$

in natural values of

$$Y_{nat}\,(\%) = -715{,}09 + 0{,}51 \cdot D + 54{,}51 \cdot \alpha - 9{,}72 \cdot 10^{-3} \cdot D \cdot \alpha - $$

$$- 1{,}20 \cdot \alpha^2 + 8{,}55 \cdot 10^{-3} \cdot \alpha^3 \qquad (IV)$$

Good approximation was obtained when using the square polynomial (with the accuracy 1.7 %) and cubic polynomial (with the accuracy 1.5 %).

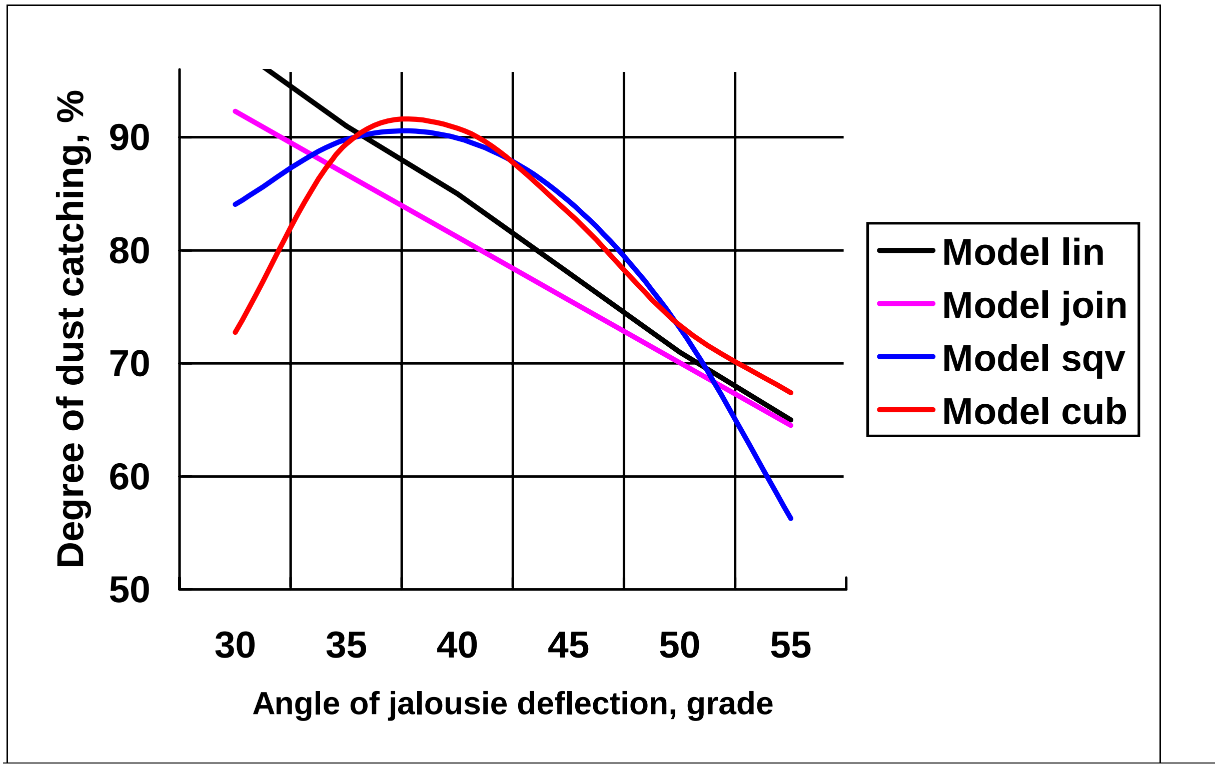

Fig. 1 – Determination of optimal angle of jalousie plates slope of dust-catcher.

Additional mathematical analysis of obtained expressions (I) – (IV) permitted to make more precise the optimal quantity of jalousie slope angle α concerning the gas flow, which was found equal 37-38° (fig.1). It allowed to increase the air purification degree to 96 %.

Conclusion

Thus, the developed mathematical model (program) of purifying procedure description can be successfully applied to different technological processes of large profile, the searching and selection of optimal regimes, for the creation of the regression equations of the interconnection description of the complicated many-factor systems, as well as for various scientific aims.

Reference

1 Ye.Ye. LURYE, Unified Methods of Waters Analysis, «Chemistry», Moscow, UnSSR, (1974). – In Russian.
2 A.P. SHITSKOVA, Methods of harmful substances determination in water of reservoirs, «Medicine», Moscow (1981). – In Russian.
3 V.A. BATLUK, Yu.Ye. SHELYUKH, Ukr. Patent No 53864 A, Kiev, Ukraine (2003). – In Ukrainian.
4 V.A. BATLUK, Scientific foundation of creation of the effective dust-catching equipment, Thesis of doct., Lvov (2001). – In Ukrainian.