MODELING AND OPTIMIZATION OF THE SEWAGE FILTRATION ON POROSIL USING EXPERIMENTS DESIGN PROCEDURES. I. A MICROBIOLOGIC STUDY

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Abstract:
This paper presents a study regarding the purification degree of waste water using porosil like filler material. The experiments were realized using a factorial 3^3 Experiment design, intending, in the same time, to realize the mathematical simulation and optimization of germs retention by filtered surfaces. The mesophilic germs content of sewage samples are influenced by filtered media characteristics and by physico/chemical properties of sewage. The results obtained are donned in tabular and graphical forms.

Keywords: sewage, mesophilic germs, optimization, experiment design, polynomial models, water filtration.

1. INTRODUCTION

Water filtration is a method of water transition through a porous medium on which are retained some water constituents mainly by physical phenomena [1]. There can be retained from water impurities from different sizes, from harsh pollutants to very fine pollutants and even some microorganisms [2,3].

The retention of the impurities on the filtrate surface depends on the particles physico-chemical characteristics, on the filtration medium properties, on the filtration velocity and on the physico-chemical characteristics of the water [1,2,3,].

At international level the problem of the utilization of very efficient filtration materials and with lower costs is of a largest interest. Presently, the most utilized filtrate materials for impurities retaining from sewage are the synthetic ion exchangers but these present the disadvantage of higher costs.

The present paper proposes an alternative to the classic water filtration materials, respectively the utilization of a natural material: the porosil. This is obtained from diatomitic rock or diatome soils that contain fossilized unicellular algae [4]. Actually, porosil is successfully used in food industry at wine and beer filtration [4].

In the studied literature there were no references about studies regarding the sewage microorganisms retaining on filtrate materials of porosil type. This paper originality consists in the optimization study of the microorganism retaining process using a design procedure of type 3^3.

Mathematical modelling through factorial design procedure takes into account not only the individual (simple) effect of each parameter but also the interaction and/or their possible synergy effects. Such a convenient procedure requires minimal number of experiments, through a suitable choose of the parameter ranges and can be easily generalized [5].

2. EXPERIMENTAL PART

In this paper was studied the microorganisms retention degree on different diameters of porosil particles. According to the design procedures (3^3 – three variables and three variation levels of the parameters) there were realized 27 experiments [7]. The process variables were: the granulosity of the filtrate material, the filtrate layer thickness and the sewage temperature. The variable values for the three choose levels (minimum, medium and maximum) are donned in table 1.

Table 1. Variables variation field

Nr. crt.	Parameters (X_i)	Minimum value $\left(X_i^{\min}\right)$	Maximum value $\left(X_i^{\max}\right)$	ΔX_i	X_i^{med}
1	Grading, in mm (X_1)	0,01	0,1	0,045	0,055
2	Filtrate layer thickness, in mm (X_2)	5	25	10	15
3	Sewage temperature, in ^{0}C (X_3)	5	40	17,5	22,5

2.1. Materials and methods

The materials used in this study are: porosil with different grading (0,1 mm, 0,01 mm and 0,05 mm), sewage sampling in may 2006 from the Epuration Station of Bacău City. The culture medium utilized for mesophilic germs observation is the nutritive gelosa medium seeded by the "incorporation method" [6]. A priori there were performed decimal dilutions. Other materials utilized in this study are: Buchner filter, calibrated pipette, double disk, Erlenmeyer beaker.

For streamline of the sewage filtration there was utilized the vacuum filtration. Before and after the filtration there was calculate the total number of germ for the contaminated water samples using the method previously described.

3. RESULTS AND DISCUSSION

The response function is represented by the number of colonies (germs) from sewage/mL sample (table 2). These were determined according to the methods existent in the literature [6,8]. Previously there was determined the microbial charge of the unfiltered sewage, respectively 7600 germs/mL sewage.

Table 2. Experiment programming and the relevant values of the response function

Sample	No germs/ mL sample	x_1 (adimensional value)	x_2 (adimensional value)	x_3 (adimensional value)
1	*2*	*3*	*4*	*5*
1	134	-1	-1	-1
2	120	-1	-1	0
3	97	-1	-1	+1
4	93	-1	0	-1

5	101	-1	0	0
1	*2*	*3*	*4*	*5*
6	145	-1	0	+1
7	94	-1	+1	-1
8	85	-1	+1	0
9	86	-1	+1	+1
10	980	0	-1	-1
11	989	0	-1	0
12	1115	0	-1	+1
13	718	0	0	-1
14	852	0	0	0
15	902	0	0	+1
16	631	0	+1	-1
17	692	0	+1	0
18	615	0	+1	+1
19	1970	+1	-1	-1
20	2100	+1	-1	0
21	2870	+1	-1	+1
22	1786	+1	0	-1
23	1957	+1	0	0
24	2340	+1	0	+1
25	1560	+1	+1	-1
26	1670	+1	+1	0
27	1700	+1	+1	+1

3.1. Drawing up of the mathematical modeling

The response function of the 3^3 design procedure has the following form:

$$Y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_{12} x_1 x_2 + a_{13} x_1 x_3 + a_{23} x_2 x_3 + a_{123} x_1 x_2 x_3 + a_{11} x_1^2 + \\ + a_{22} x_2^2 + a_{33} x_3^2 \qquad \textbf{(1)}$$

According to the literature data's [5,7,9], in order to modelling and to simulate the microorganisms retaining on the filtrate material, several stages will be run through (table 3).

Table 3. Calculus of the polynomial coefficients

Coefficient	Calculus formula	Results
1	2	3
Arithmetic average of the measured values (27 experiments)	$Y_0 = \dfrac{\sum_{k=1}^{27} Y_k}{27}$	Y_0 = 978,22
Interaction coefficients	$a_{ij} = \dfrac{\sum_{k=1}^{27} (x_i x_j)_k \cdot Y_k}{\sum_{k=1}^{27} (x_i x_j)_k^2}, \quad i, j = 1,2,3$	a_{12} = -160,33 a_{13} = 132,25 a_{23} = -73,5 a_{123} = -98,62

	$a_{123}=\dfrac{\sum_{k=1}^{27}(x_1x_2x_3)_k\cdot Y_k}{\sum_{k=1}^{27}(x_1x_2x_3)_k^2}$	
1	*2*	*3*
Coefficients for quadratic terms	$a_{ii}=\dfrac{\sum_{k=1}^{27}(x_i^2-2/3)_k\cdot Y_k}{\sum_{k=1}^{27}(x_i^2-2/3)_k^2},\quad i=1,2,3$	a_{11} = 216,66 a_{22} = -16,66 a_{33} = 39,66
Coefficient a_0	$a_0=y_0-\dfrac{2}{3}(a_{11}+a_{22}+a_{33})$	a_0 = 818,44

Replacing the coefficients from the relation (1) with the values from table 3, it can be obtained the mathematic model that describes the response function of the optimization criteria:

$$Y=818{,}44+944{,}33x_1-180{,}11x_2+106{,}33x_3-160{,}33x_1x_2+132{,}25x_1x_3-73{,}5x_2x_3-$$
$$-98{,}62x_1x_2x_3-+216{,}66x_1^2-16{,}66x_2^2+39{,}66x_3^2 \qquad \textbf{(2)}$$

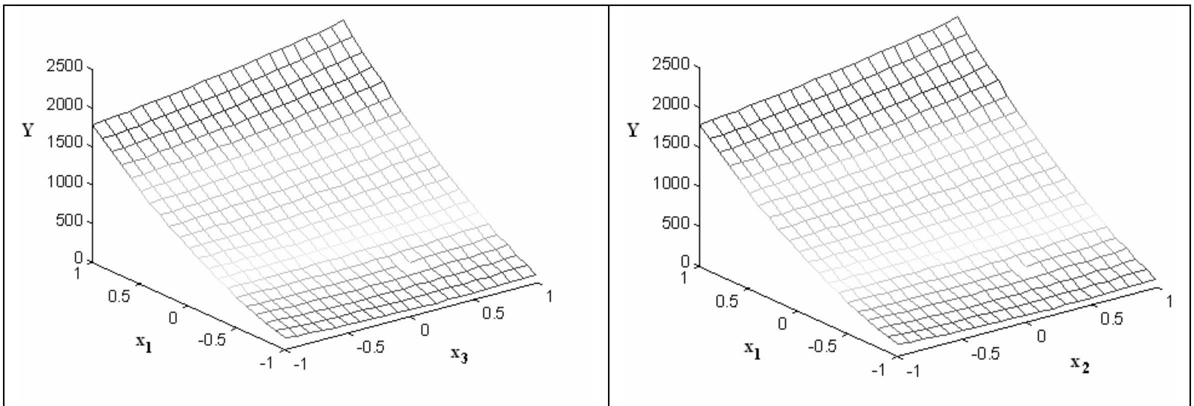
3.2. Optimization of the germs retain process

After the derivates method applying [5,7,10] are obtained the following adimensional values: x_1= -0,83, x_2= 0,98, x_3= -0,32. These are the optimal values of the three variables in adimensional coordinates. For the obtaining of the real values of the parameters is utilized the relation (3), the terms significations being the same with those presented in table 1.

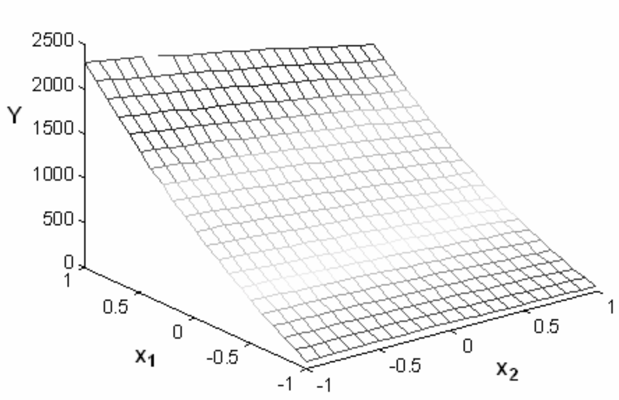
$$X_i=\Delta X_i\cdot x_i+X_i^{med} \qquad \textbf{(3)}$$

Hence, the real values of the parameters are: X_1= 0,017 mm, X_2= 24,8 mm, X_3= 16,9°C, respectively an optimum degree of microorganisms retaining on filtrate material is obtained in the case of utilization of particles with 0,017 mm size, a filtrate material thickness of 24,8 mm and at a temperature of sewage of 16,9°C.

The data's from table 1 can be performed with MathLab soft [7,10], the diagrams obtained also are illustrated in figure 1 (a,b,c).



(a) (b)



(c)

Fig. 1. Graphical representations of the response function if: (a) the grading, (b) the filtrate layer thickness, (c) sewage temperature, are maintained in the central variation domain.

The response curves from figure 1 represent the visualisation of the regression functions characteristics.

4. CONCLUSIONS

After the mathematic calculus it can be observed that the coefficients a_1, a_3, a_{13}, a_{11}, a_{33} have positive values, respectively influence positively the microorganisms retaining process. The coefficients a_2, a_{12}, a_{22}, a_{33} are negatives and do not favor the filtration process. Hence, the filtration process is favored mainly by the particle size and the sewage temperature point of view.

Indifferent of the experimental conditions, it can be observed that there is a decrease of the germs number, so, the filtrate material can be used properly for sewage filtration.

For the elimination of the insignificant experiments (reducing of the experiment number) was used the design procedure method that permit to simulate and to modeling the process of sewage filtration.

In this study was realized too, the optimization of the microorganism's retention process on porosil, the optimal condition being: particle size = 0,017 mm, filtrate layer thickness = 24,8 mm, sewage temperature = 16,9^{o}C.

The present paper represents an ostensible unconventional method between the most recent modeling and optimization methods and the most current work methods used in microbiology.

REFERENCES

[1]. Bratu Em.A., *Operații şi utilaje în industria chimică*, vol. I, Editura Tehnică, Bucureşti, 1960.
[2]. Măzăreanu C., *Microbiologie generală*, Editura Alma Mater, Bacău, 1999.
[3]. Blitz E., *Epurarea apelor uzate menajere şi orăşeneşti*, Editura Tehnică, Bucureşti, 1966.
[4]. Dabija A., *Tehnologii şi utilaje în industria alimentară fermentativă*, Editura Alma-Mater, Bacău, 2002.
[5]. Azzouz A., Rotar D., Zvolinschi A., Miron A. : *AMSE Symposium – 2002*, Girona (Spain), 2002, pp. 143-149.
[6]. Zarnea G. – *Tratat de microbiologie*, vol. 5, Ed. Academiei, 1990.
[7]. Azzouz, A. : *Concepte de modelare şi elemente de strategie în designul industrial*, Ed. Tehnică - Info, Chişinău, 2001.
[8]. Dunca S., Ailiesei O., Nimițan E., Ştefan M. – *Microbiologie aplicată*, Ed. Tehnopress, Iaşi, 2004.
[9]. Balaban C.: *Strategia experimentarii si analiza datelor experimentale. Aplicatii in chimie, inginerie chimica, tehnologie chimica,* Ed. Academiei Romane, Bucuresti, 1993.
[10]. Tovissi, L., Vodă, V.Gh. – *Metode statistice. Aplicații în producție*, Ed. Ştiințifică şi Enciclopedică, Bucureşti, 1982.