MATHEMATICAL MODELLING OF THE WASTEWATER SLUDGE BEHAVIOUR AT THE TREATMENT WITH MICROWAVES

— research paper —

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Abstract: In this paper, sludge resulted from the wastewater treatment unit of Sibiu, Romania was investigated. Sludge was irradiated with 2450-MHz microwaves and the concentration of the organic volatile fraction was measured, as indicator of the sludge quality. Two series of experiments were realised: the first series of experiments was realised with microwaves at constant intensity (700 W) for different times (1, 2 and 3 minutes) and the second series of experiments at different intensities (140 W, 420 W and 700 W) for 1 minute. The results were used to build a mathematical model which describes the sludge behaviour as function of microwaves intensity and action time. The variation of the concentration of the volatile fraction of sludge treated with microwaves (C_V) as function of the volatile fraction of the untreated sludge (C_0) is $C_V = \frac{C_0}{I^{0,02}} \cdot e^{(0,066-0,0138 \cdot t)}$ where I is the microwaves intensity and t is the duration of treatment.

Keywords: wastewater, sludge, model, microwaves

INTRODUCTION

The ecological demands require all domestic and industrial wastewater to be treated prior to discharge to the environment (Turovskiy and Mathai, 2006). Depending on the wastewater generator, the contaminants can be removed using a variety of techniques at the municipal level. In the primary and secondary treatments, contaminants are removed in sedimentation basins or

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in filtration processes. The removed material is referred to as sludge and is dewatered and hauled to a sanitary landfill for disposal. Sludge accumulated in a septic tank is pumped out and transported to the local treatment plant for additional processing and dewatering (Dow and Hafsi, 1998).
The wastewater sludge disposal is regulated by regulations regarding, for example, the minimum solids content, maximum sludge concentrations for select inorganic and organic compounds that are detrimental to the environment and public or prohibition of the disposal of sludge contaminated with hazardous materials
Two types of sludge are obtained:

- Primary sludge, consisting on settleable organic and inorganic matter, which is readily degradable;
- Waste activated sludge (WAS), consisting on microbial biomass, extracellular polysaccharide substances and inorganic materials, that is dificult to degrade due to the stability of the loc structure and microbial cell walls (Eskicioglu et al., 2005).

These two sludge types are typically mixed together and stabilised via anaerobic digestion. As a large portion of the organic material is bound within the loc structure and cell walls in WAS, greater solids stabilisation and concomitant methane production may be obtained by pretreating WAS prior to digestion (Kim, 2003).
Pretreatment processes which aim to disrupt the WAS structure and bacterial cell walls in order to increase the organic material available for digestion include chemical, electron beam, mechanical, ozonation, thermal , ultrasound , steam explosion and other solutions (Kennedy et al., 2007). One of the actually tested solutions uses microwaves, for example, in inactivation of faecal coliforms and *Salmonella* spp. (Pino-Jelcic et al., 2006) or dewaterability of sewage sludge (Wojciechowska, 2005).

This paper investigates the action of microwaves on WAS resulted from the wastewater treatment unit of Selimbar, Sibiu in Romania. The major aim is to obtain a model which describes the relation between the parameters of the microwaves treatment (intensity of microwaves and duration of treatment) and the physical-chemical characteristics of WAS (especially the concentration of the organic volatile fraction). Such a model helps to understand the processes in the activated sludge at these treatment and could be used to predict the variation of WAS with the microwaves treatment.

MATERIALS AND METHODS

WAS was obtained from the wastewater treatment unit of Selimbar, which discharge the domestic and industrial wastewater from Sibiu. The activated sludge used was 22 days old.

Two series of treatments with microwaves were realised:

- the first series of experiments was realised with microwaves at constant intensity (700 W) for three different times: 1, 2 and 3 minutes;
- the second series of experiments was conducted at different intensities of microwaves: 140 W, 420 W and 700 W for 1 minute.

The quality of activated sludge used was appreciated by measuring the concentration of the organic volatile fraction C, measured thermogravimetrically in the sludge treated with microwaves (C_V) and in the untreated sludge (blind sample, noted C_0). Tables 1 and 2 presents the values C obtained experimentally. The model was build using the Matlab language.

Table 1: The values C_V and C_0 obtained in the first set of experiments realised with microwaves at constant intensity (700 W) for three different times: 1, 2 and 3 minutes

WAS sample	C_0, *mg/l*	C_V, *mg/l*		
		1 min	2 min	3 min
1	11725	11332	10860	10635
2	11248	10514	10132	9608
3	10367	10204	9871	9583

Table 2: The values C_V and C_0 obtained in the second series of experiments with different intensities of microwaves: 140 W, 420 W and 700 W for 1 minute

WAS sample	C_0, *mg/l*	C_V, *mg/l*		
		140 W	420 W	700 W
4	63.7	63.7	62.4	62.6
5	63.2	62.6	62.3	60.6
6	63.6	63.5	62.5	62.6
7	67.3	66.9	66.1	65.7

RESULTS AND DISCUSSIONS

In order to describe the influence of the treatment with microwaves on WAS, based on the practical results presented in Table 1, the obtaining of a function with the form:

$$C_V = C_0 \cdot k \cdot e^{-a \cdot t} \qquad (1)$$

was investigated. In this function, *k* and *a* are coefficients.

For the model obtaining, the variation of the logarithmic difference between C_0 and C_V was represented graphically. The obtained values and the functions which describe the behaviour of the three analysed samples are presented in Figure 1.

As Figure 1 shows, the evolution of the logarithmic between the concentration of the volatile fraction in the sample treated with microwaves, C_V, and the concentration of the volatile fraction in the blind sample, C_0, has a linear form. So, the form proposed in equation 1 is adequate to describe the behaviour of the volatile fraction from sludge.

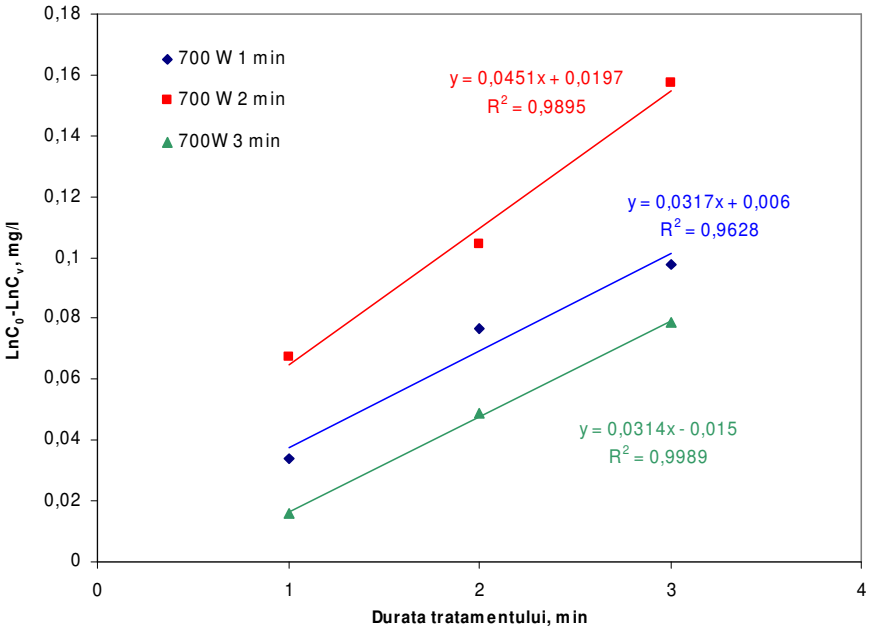

Figure 1. Variation of the logaritmic difference between C_0 C_V as function of the treatment time.

Figure 2 presents the curves and the functions which describe the behaviour of the four WAS samples analysed as function of the mcirowaves intensity.

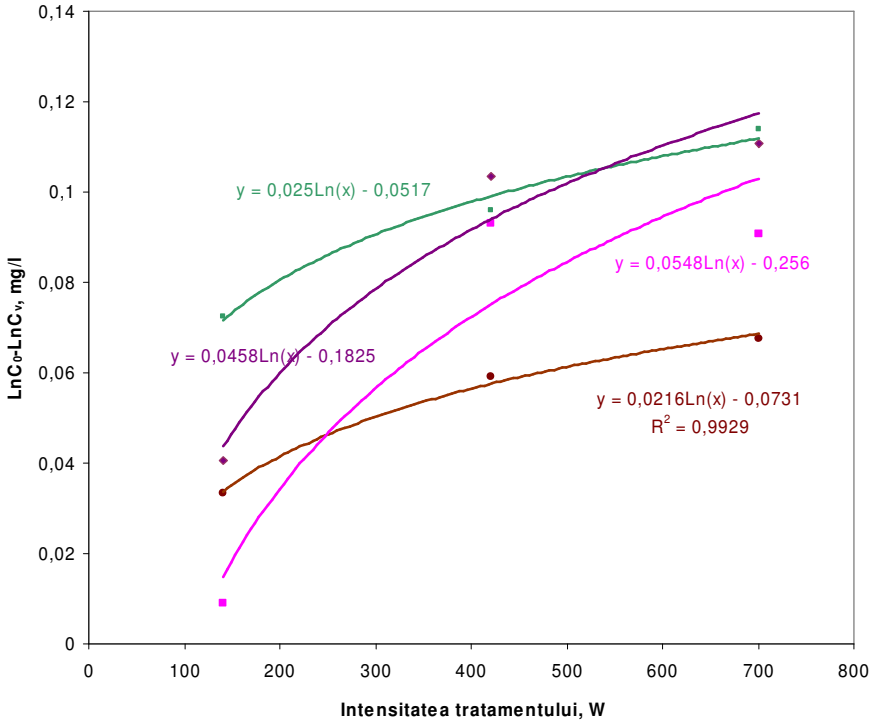

Figure 2. Variation of the logaritmic difference between C_0 C_V as function of treatment intensity

The function which describes mode adequate the behaviour of C_V depending on C_0 has the form:

$$C_V = C_0 \cdot k \cdot e^{(b-a \cdot t)} \qquad (2)$$

where:

- a and b are the model coefficients;
- $k = I^m$ represents a factor which takes into account the influence of the intensity of the treatment with microwaves I on the variation of Cv, and m is a coefficient
- t is the duration of the treatment with microwaves.

In this way, the model becomes:

$$C_V = \frac{C_0}{I^m} \cdot e^{(b-a \cdot t)} \qquad (3)$$

The values of the coefficients were determined by regression, using the methos of …. squares. The parameters are: m = 0,02; b = 0,066; a = 0,0138. The final model is :

$$C_V = \frac{C_0}{I^{0,02}} \cdot e^{(0,066-0,0138 \cdot t)} \qquad (4)$$

At the comparison of the model with the experimental values, the differnces presented in Tables 3 and 4 were obtained.

Table 3: Measurement of the model accuracy, by determining the error obtained with the model in comparison with the experimental data, at the treatment of activated sludge with microwaves with the intensity of 700 W for 1 minute, 2 minutes and 3 minutes

Exp	1 min	2 min	3 min
1	4.33	1.53	0.83
2	1.08	-1.25	-5.31
3	6.06	4.22	2.69

Table 4: Measurement of the model accuracy, by determining the error obtained with the model in comparison with the experimental data, at the treatment of activated sludge with microwaves for 1 minute with the intensities of 140 W, 420 W and 700 W

Exp	140 W	420 W	700 W
4	3.66	-2.52	-1.25
5	-2.66	-2.83	-3.61
6	0.57	-3.59	-3.30
7	1.30	0.89	1.08

The results obtained at the measurement of the model accuracy (Tables 3 and 4) shows that the model approximates accuratelly the sludge behaviour at the treatment with microwaves with different intensities for different times.

CONCLUSIONS

The influence of the microwave treatment on the organic volatile fraction of WAS was exeperimentaly investigated. A mathematical model that correlates satisfactory the parameters of the microwave treatment - intensity and time –

and of the WAS – initial organic volatile fraction - with the achived reduction in this fraction was proposed.
This model allows the prediction of the effects of microwave treatements and the optimal choice of paramters making possible the scale-up of the methode. Further investigation are needed to improve the accuracy of the model and to extend the prediction range.

Acknowledgments
This paper is part of the research grant CEEX 3822 contract no. 135/2005-2008 ″Tehnologii moderne neconvenţionale, conforme cu reglementările europene, de epurare a apelor uzate şi de tratare a nămolului rezidual în scopul reutilizării acestuia″ at the "Lucian Blaga" University of Sibiu, Romania, Faculty of Agricultural Sciences, Food Industry and Environmental Protection.

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