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FITTING OF TEMPERATURE DURING SNOW-MELT IN ACTIVATED TANK IN WASTEWATER SLUDGE PLANTS

Eliška HORNIAKOVÁ[1], Tomáš BAKALÁR[2], Milan BÚGEL[2]

[1]Technical University of Košice, Faculty of Mining, Ecology, Process Control & Geotechnologies, Košice, SLOVAKIA
[2]Technical University of Košice, Faculty of Mining, Ecology, Process Control & Geotechnologies, Institute of Montaneous Science and Environmental Protection, SLOVAKIA

Abstract
The research deals with processes occurring in the activation tank when removing nitrogen from the organic substances in wastewater by using bacterii. Weather and the influent cold wastewater refrigerate the suspension in the activation tank. For a correct growth, the reproduction and metabolism of microorganisms, temperatures above 10 °C are necessary but the ideal temperature is from 20 to 30 °C. Intensive cold reduces or even stops the activity of bacterii while heating of the aeration tank prevents undercooling during critical term.
Fitting of temperature of slurry in activation tank may predict on set of heating of suspension in the tank in a critical time.
Key words:
aeration tank, bacterium, nitrification, denitrification, temperature

1. INTRODUCTION

During snow-melt road salts flow from roads to the sludge, to underground water and receiving water. Snow, cold wind and the influent cold water cool the suspension in the biological stage of the wastewater treatment plant. This stage of the wastewater treatment is used to remove dissolved and colloidal organic matter in the wastewater. The process involves two distinct operations usually performed in two separate basins: activation and settling (Figure. 1) (Droste, 1997; Chudoba et al., 1991; Tucek et al, 1988).

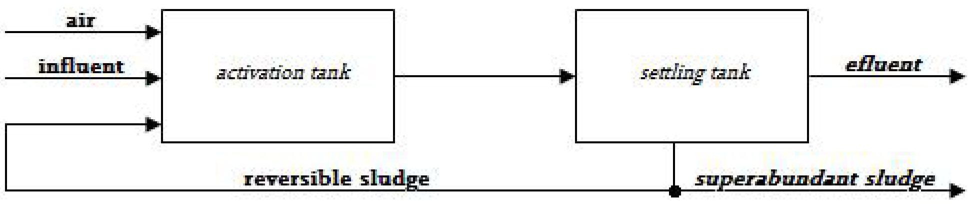

Figure. 1. Biological stage of wastewater treatment

Biological stage of wastewater treatment plant
In the activation tank there are organisms which metabolisms are nitrification and denitrification processes. They incorporate aerobic-anoxic sequences that favour growth and metabolism of organism that support for nitrogen removal.

Denitrification occurs when certain heterotrophic microorganisms in the environment devoid of oxygen use nitrate as an electron acceptor to oxidize organic matter. Nitrate is reduced to nitrogen gas. The water is in an anoxic state.

The autotrophic nitrifiers have a longer growth rate than heterotrophic bacteria responsible for the removal of carbonaceous biological oxygen demand. Nitrifier growth rates are strongly dependent on the temperature and other environmental variables. The nitrifiers are more fastidious in their environmental requirements than other organisms in the activated sludge process. The minimum sludge age used to ensure nitrification at average condition is 7 days. Rates for nitrification and denitrification at 5 °C were about one fifth and one fourth respectively. Removal of nitrogen is observed at 15 °C (Bak, 1989, Jes la Cour Jansen, 1987). The minimum dissolved oxygen concentration is 0.5 mg l^{-1}, although dissolved oxygen concentrations below 2.5 mg.l^{-1} may limit the rate of nitrification. Sufficient buffering capacity should be present to maintain pH in the range of 6.5 to 8. Than the optimum pH range for denitrification is 6 to 8 (Droste, 1997, Chudoba et al., 1991, Tucek et al, 1988).

Chemical composition of the suspension in the activation tank is changing following metabolisms of organisms and chemical composition of influent wastewater. This chemical composition of wastewater is changing during the day, according to the day schedule of townspeople releasing wastewater to the wastewater treatment plant, according to the season and according to immediate atmospheric conditions. In sewage there is a lot of fat from households and eatery and many detergents. When snow-melt flows into the sewage, road salt which is used for winter road maintenance also flows into the sewage. In Slovak Republic mixture of inert mass with NaCl is used for winter road maintenance salting (Zekeová et al., 1976, Buday, 2002, Pietriková et al, 2005).

Microorganisms are adapted to the conditions of the variation of chemical composition during the day but they are not adapted to floods and the season of snow-melt. Consequently undercolling and poisoning of nitrifying microorganisms cause death in the activation tank due to cell lysii (Zekeová et al., 1976, Storm et al, 1976, Boltzanskaja, 2004, Kargi et al. 1998, Kargi et al. 2007). This is a seasonal effect which is periodically occurring in the winter.

Heating

The heating of the nitrifying part of the activation tank is a possibility to prevent this effect. It would be suitable to heat the activation and regeneration tanks with inside recycle of the sludge. In wastewater treatment plant the air temperature, which influences the temperature of suspension in the activation tank is measured. Several times a day the temperature of the influent wastewater is measured in a different locality.

Fitting of the temperature of slurry in the activation tank it is possible to predicate a set of heating of the suspension in the tank during the critical time. The number of hours of predication results from efficiency of equipment used to heat and from the heating method.

Selection and data processing

The data were measured in the activation tank using the oxygen sounder TriOxmatic 700, which is used for continual measurement of biological oxygen demand (BOD) and it has a sensor for continual measurement of the temperature in the suspension in the tank.

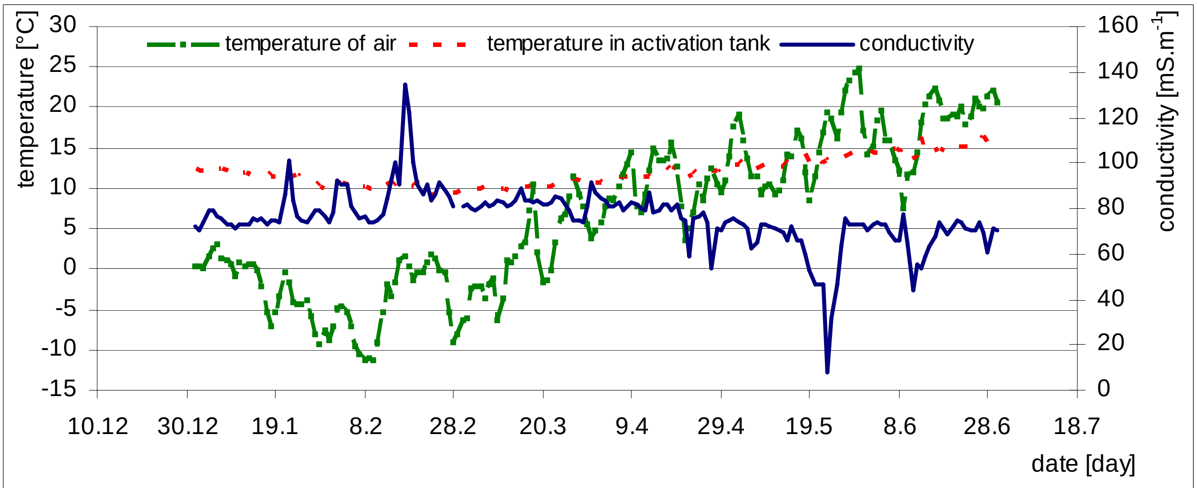

Figure. 2. Measured values of the temperature, the conductivity in the activation tank and the temperature of the air during the first half of 2005.

Period of measurement was a third of a second. Measured data were filtered in order that the interval of measurement was one per hour. Thus period of the measurements was the data processed from 2004 to 2007. The records of temperature in 2005 were made ones a day (Figure 2). This interval is used for fitting of temperature and it is followed by predication of deficient (insufficiency).

2. POLYNOMIAL OF 10th ORDER

Non-linear polynomial model of regression of 10th order used for fitting is presented in eq. (1) (Vítek, 1985, Hrubina, 2005, Rektorys et al, 1963).

$$y_i = a_0 + a_1.x_i + a_2.x_i^2 + a_3.x_i^3 + a_4.x_i^4 + a_5.x_i^5 + a_6.x_i^6 + a_7.x_i^7 + a_8.x_i^8 + a_9.x_i^9 + a_{10}.x_i^{10} \quad (1)$$

where x_i - time [h], y_i - measured temperature [°C], $i \in \langle 1; n \rangle$, where n is number of hours in critical time computed from midnight first day to midnight next day.

The interpolation of the polynomial was derivation equation about n unknown, which can be written in the form of a matrix (2).

$$y_i = \begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & \ddots & & & & \\ \vdots & & \ddots & & & \\ a_{i1} & & & a_{ij} & & \vdots \\ \vdots & & & & \ddots & \\ a_{n1} & & \cdots & & & a_{nn} \end{vmatrix} \cdot \begin{vmatrix} x_1 \\ x_2 \\ \vdots \\ x_i \\ \vdots \\ x_{n-1} \end{vmatrix} \quad (2)$$

The parameters of the matrix a_{ij} are the roots of the individual formulas, which were obtained by a numerical iterative method of partial period.

For each polynomial the index of correlation for non-linear regression for was computed according to eq. (3).

$$I_{xy} = \sqrt{\frac{\sum_{i=1}^{n} (y_i - Y_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}} \quad , \quad (3)$$

where y – measured temperature, $\bar{y}$ - arithmetic average, Y_i - computed data.

Index of correlation $\in \langle 0;1 \rangle$, when approaching to 1 then the selected regression model is better approximating the measured data.

The computed parameters of the matrix (1) are the roots of the equations of individual polynomial (Table. 1).

Table. 1. The parameters of computed equations of the polynomial of 10th order

Parameter	19-21 february 2004	23-25 february 2004	22-26 january 2006	22-25 october 2007
a_0	10.47062441	9.894592821	11.66202787	15.83935348
a_1	0.140071913	0.803649107	-0.14816729	0.095174612
a_2	-0.03261937	-0.2141807	0.035879554	-0.00705998
a_3	0.000782236	0.0252728	-0.00370312	-0.00177724
a_4	0.000213358	-0.00152378	0.000169334	0.000250504
a_5	-2.013e-05	4.72277e-05	-4.2863e-06	-1.3411e-05
a_6	8.02722e-07	-6.5432e-07	6.59751e-08	3.77947e-07
a_7	-1.7348e-08	-7.5021e-10	-6.3483e-10	-6.1105e-09
a_8	2.11424e-10	1.40343e-10	3.73696e-12	5.70156e-11
a_9	-1.3672e-12	-1.6236e-12	-1.2316e-14	-2.8577e-13
a_{10}	3.65174e-15	6.12646e-15	1.74094e-17	5.96204e-16
Index of correlation				
	0.977	0.983	0.990	0.968
FitStdError				
	0.045	0.176	0.093	0.102

In the following figures measured temperatures during the critical period in February 2004 from 19th to 21st (Figure. 3a) and from 23rd to 25th (Figure. 3b), in January 2006 from 22nd to 26th (Figure. 3c) and in October 2007 from 22nd to 25th (Figure. 3d) with polynomial approximation are presented.

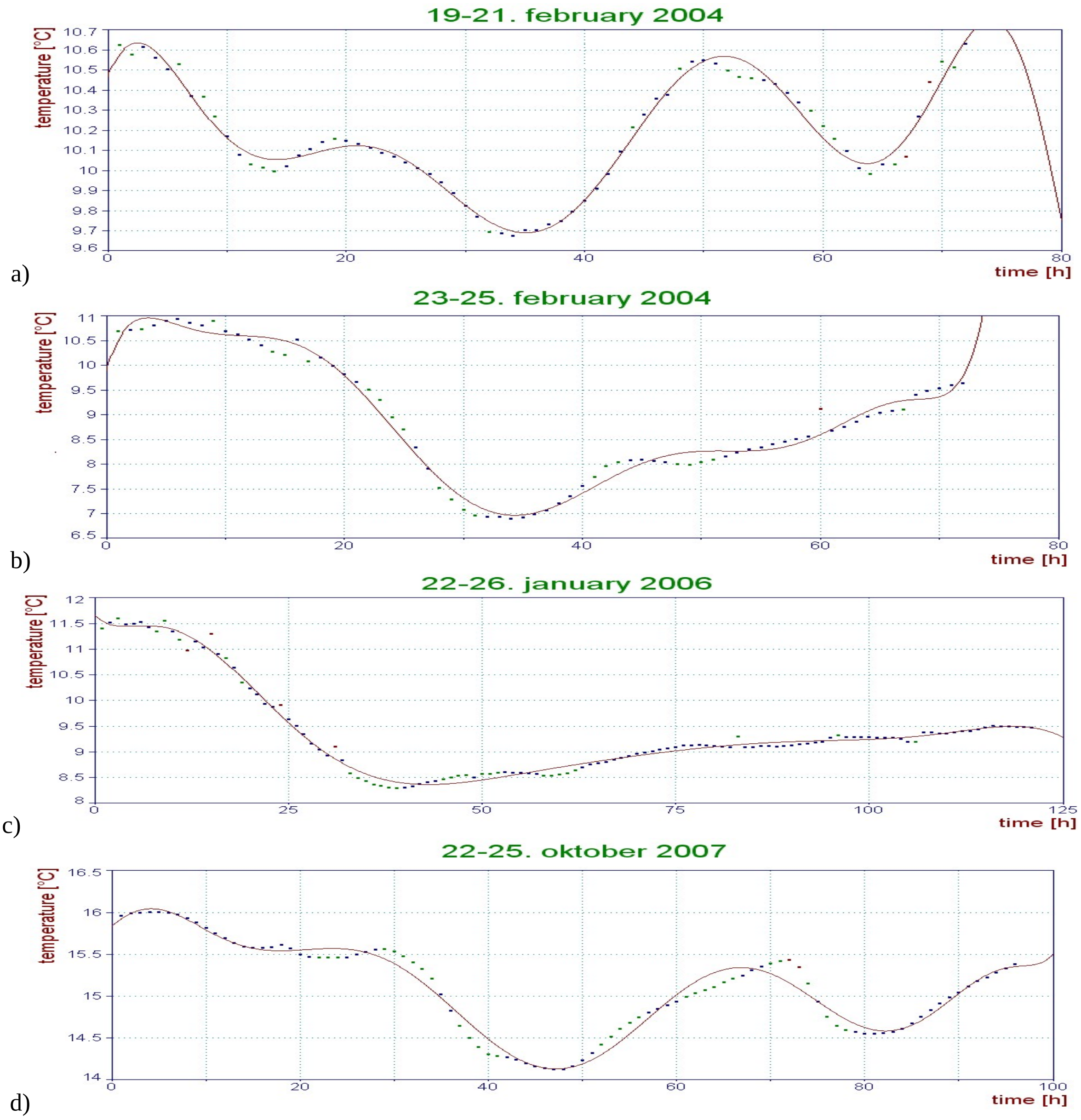

Figure. 3. Critical periods. The points represent the measured values and the curves represent the fitting of the polynomial.

Chebyshev polynomial of the 8th order

Formally, the Chebyshev function of degree n is defined by:

$$T_n(x) = \cos\left(n \arccos(x)\right) \qquad x \in \langle -1, 1 \rangle \tag{4}$$

A recursion formula exists:

$$T_{n+1}(x) = 2\,x\,T_n(x) - T_{n-1}(x) \tag{5}$$

The following expression describe the Chebyshev terms of 8th order

$$T_8(x) = 128x^8 - 256x^6 + 160x^4 - 32x^2 + 1 \tag{6}$$

and next is converted form of the Chebyshev model:

$$y = a + bT_1(x') + cT_2(x') + dT_3(x') + eT_4(x') + fT_5(x') + gT_6(x') + hT_7(x') + iT_8(x') \tag{7}$$

These equation is evaluated using the recurrence relation, which is quite efficient, although in general, you should expect a Chebyshev polynomial or rational evaluation to require about twice the time required for a standard polynomial or rational of the same coefficient count.

The computed parameters of the matrix (7) are the roots of the equations of individual Chebyshev polynomial (Table. 2).

Table. 2. The parameters of computed equations of the Chebyshev polynomial of the 8th order

Parameters	the 19-21. of february in 2004	the 23-25. of february in 2004	the 22-26. of januuary in 2006	the 22-25. of october in 2007
a	10.26800692	9.277484032	9.692077977	15.23849249
b	- 0.00446225	- 0.86636402	- 0.8544321	- 0.44001963
c	0.287505383	1.303872642	1.034914794	0.46738326
d	- 0.11037782	0.24356803	- 0.38128073	0.028872427
e	0.035145059	- 0.54888674	- 0.1401888	- 0.1006077
f	0.13873081	0.172533554	0.329489537	0.173344364
g	0.142618772	0.208197108	- 0.1719926	0.19460664
h	0.03196995	- 0.2402533	0.000725948	- 0.07717285
i	- 0.15056916	- 0.13839554	0.053791861	- 0.2775189
Index of correlation				
	0.9729628672	0.9692109544	0.9875734851	0.959931378

In the following figures measured temperatures during the critical period in February 2004 from 19th to 21st (Figure. 4a) and from 23rd to 25th (Figure. 4b), in January 2006 from 22nd to 26th (Figure. 4c) and in October 2007 from 22nd to 25th (Figure. 4d) with polynomial approximation are presented.

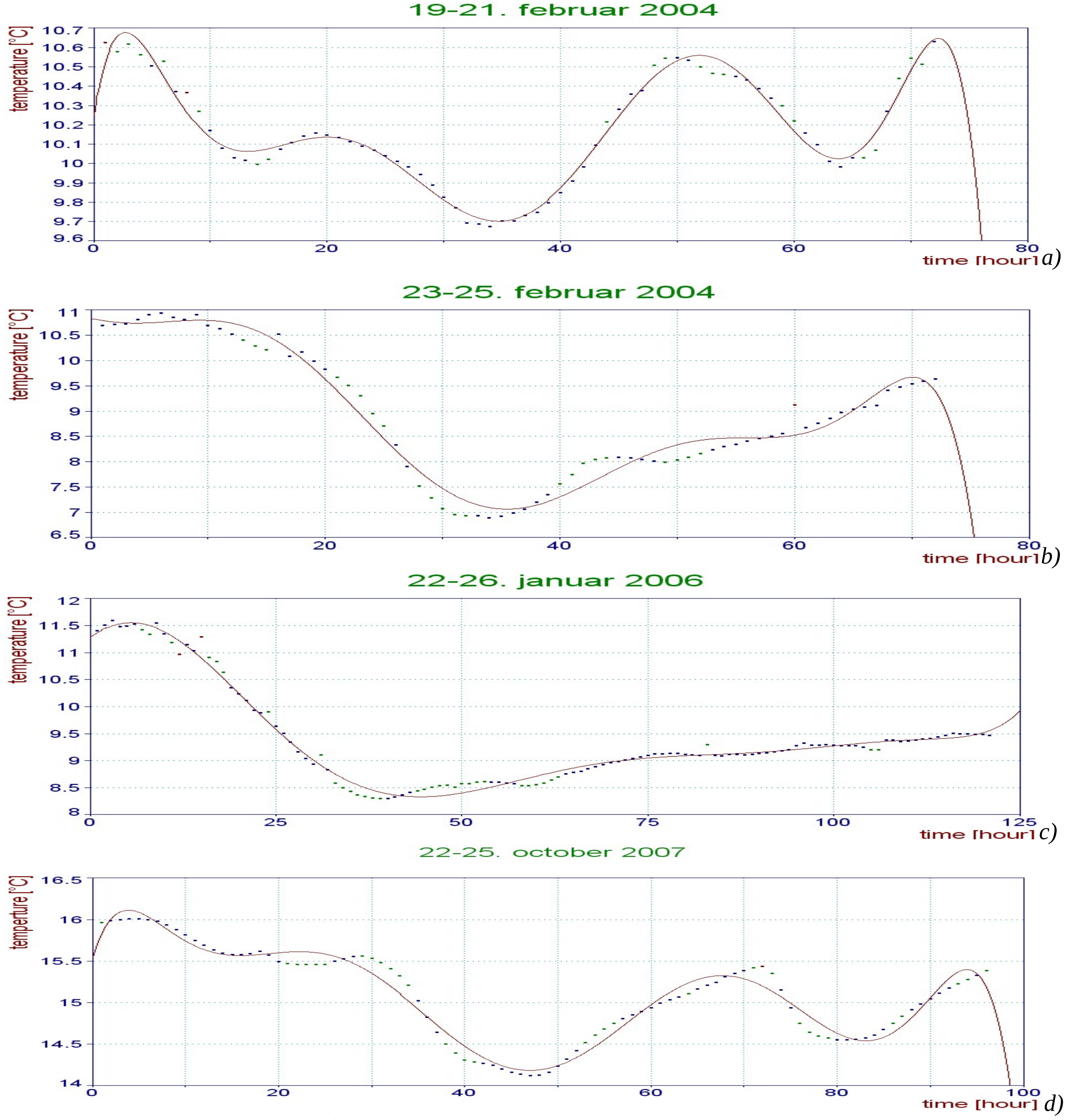

Figure. 4. Critical periods. The points represent the measured values and the curves represent the fitting of the Chebyshev polynomial

3. CONCLUSION

When the temperature in activated tank is about 10°C and below the heating of the suspension in nitrification section of the activation tank can be predicated. According to the results the classic polynomial of the 10th order and Chebyshev polynomial are suitable for fitting the winter temperature conditions in the activation tank during the period from 2004 to 2007 the index of correlation is 0.9. Polynomial of the 10th order is one of the possibilities to mathematical solve this problem.

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