BIOMASS AMOUNT RESEARCH IN BIOSORPTION PROCESS
BIOMASAS DAUDZUMA PĒTĪŠANA BIOSORBCIJAS PROCESĀ

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Abstract. *Rising environmental standards for treated waste water necessitates to improve current waste water treatment methods or to look for the new ones. Often this task is rather difficult because new or modified methods have to be investigated thoroughly and the main parameters for process modeling and effectiveness estimation have to be set. Biomass concentration in biosorption process is important technological parameter though there is no accurate technique for its estimation. Thermal dissociation technique to determine biomass concentration was developed as an alternative to the standard volatile suspended solids (VSS) method. Biomass content is important for the technological calculations of the system, estimation of the oxidation potential and for the evaluation of biomass growth in accordance to decomposed pollutants, etc. Thermal dissociation technique is based on the difference in the sorbent and biomass burn out temperatures. The biomass content research results are given for sand, gravel and for activated carbon BAS-A.*

Keywords: *biosorption, biomass amount, technological control, thermal technique.*

Introduction

One of the main technological parameters for the biological waste water treatment process control is the biomass amount variation during process time span. Biomass concentration is important for the technological calculations of the system, estimation of the oxidation potential and for the evaluation of biomass growth in accordance to decomposed pollutants, etc. Media of different types used in complex biological waste water treatment processes films over with biomass and it becomes difficult to estimate biomass content and present it using identifiable units. The agglomerate media - biomass (active sludge) makes it impossible to use common method for the biomass estimation. The problem is that the biomass cannot be properly separated from the media. Also small particles of the media in the sample of active sludge would determine substantial analysis errors.

In the scientific literature usually methods for approximate biomass estimation can be found. The fluorescence of a fermentation culture was studied for its application as an estimator of biomass concentration [1]. But it is difficult to estimate biomass concentration in identifiable units, like g/l. Many factors have influence to exactitude of the analysis: temperature, pH, medium chemical composition and cell activity. Other authors [2] developed technique to determine biomass concentration as chemical oxygen demand (COD) as an alternative to the standard volatile suspended solid (VSS) method. But even using very small amounts of sorbent for COD analysis, COD values are very high. That is why this method can not be used for control of biosorption process. The modified micro-Kjeldahl and Lawry method [3] is designed for estimating amounts of organic nitrogen and proteins in the sample. These two components are the main components in the living cell, so it is possible to estimate biomass concentration from the results of this method. However, this technique has following limitations: (1) total organic nitrogen is measured, not only that in the cells; (2) the method requires careful standardization for any particular application; (3) the colour is not strictly proportional to the concentration. German scientists try to work out this problem. A very promising way appears to be the impedance spectroscopy which enables a fast determination of the biomass concentration even at high optical densities [4]. It utilizes the properties of the membranes of living cells which exhibit a high polarization and contribute a significant amount of capacitance to the impedance. The different polarization states of the cell yields a characteristic curve of permittivity from which

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the cell concentration can be derived. However this technology is in the initial stage yet and unique equipment is used. That is why another solution to solve this problem must be found.
The objective of our research was to develop and verify in practice accurate methodology for the determination of the biomass amount in the biosorption system, using fairly simple devices. The biomass amount in AC (active carbon), sand or gravel, and AS (active sludge) agglomerate - biologically activated system (BAS) - is the object of this research.
The research tasks are: 1) to determine thermal dissociation dynamics for active carbon A, sand and gravel in chosen temperature interval; 2) to determine thermal dissociation dynamics for active sludge in the same temperature interval; 3) to determine temperature points/intervals, when the mass of both components is unvarying; 4) to verify methodology in practice.

Materials and methods

The equipment needed for the experiment is muffle furnace, analytical scale, ceramic melting pots, desiccator. AC sample is dried for 1 hour at temperature 105 °C until the stable mass. Then AC is heated at: 200, 300, 400, 500, 600, 700, 800 and 900 °C temperatures. As too big mass changes were observed in temperature intervals 300-400 and 400-500 °C, these intervals were divided into smaller intervals and the temperature sequence for experiments was chosen: 200, 300, 350, 400, 430, 460, 500, 600, 700, 800 and 900 °C.
At each temperature AC is heated till stable weight is reached. Preparation and analysis of AS, sand and gravel is analogous to AC.

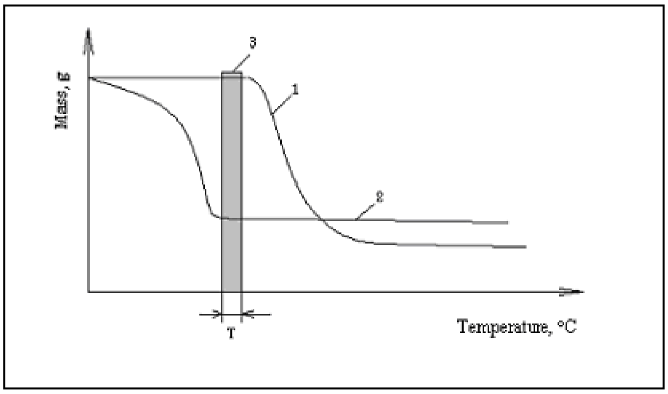

Fig. 1. **Theoretical thermograms: 1) thermogram of AC; 2) thermogram of AS; 3) the temperature range acceptable for agglomerate heating.**

Theoretical thermograms of activated carbon and active sludge are represented in fig. 1. The character of the thermograms of AC and AS was defined hypothetically, after preparative heating analysis. Their character was predicted before the experiment, i.e. it was premised that the curves would have three regions. These regions would represent temperature intervals when dissociation of both components does not take place, when dissociation takes place for both components and when both components are completely dissociated. The following model can be used to describe the dependency of dissociation and temperature:

$$P(t) = \frac{A}{1 + e^{B \times (C - t)}} \quad (1)$$

Here *A* and *B* are the constants, *t* - temperature.

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Results and discussion

The characters of plotted experimental data were analogous with the character of theoretical curves, fig. 2.

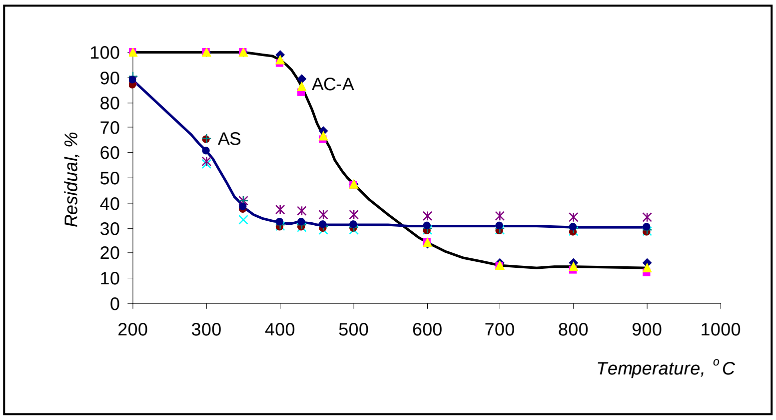

Fig. 2. **Experimental thermograms of AC-A and AS**

Mathematical dependencies for each component are:

For AC-A: $$P(t)=\frac{100}{1+e^{-1.5\times(5.1-t)}};\qquad (2)$$

For AS: $$P(t)=\frac{100}{1+e^{-1.7\times(3.2-t)}};\qquad (3)$$

The equation for the first region of curve of AC is:

$$y_1=3\cdot10^{-7}t^2-0.0002t+100,\ R_1^{\,2}=0.98\qquad (4)$$

Where y_1 – residual of activated carbon, %, in temperature range 105-400 °C; t – temperature, °C.

The equation for the third region of curve of AS is:

$$y_2=2\cdot10^{-6}t^2-0.0045t+31.93,\ R_2^{\,2}=0.96\qquad (5)$$

Where y_2 – residual of active sludge, %, in temperature range 350-900 °C; t – temperature, °C.

In every temperature, weight loss of active carbon A and biomass (%) is derived from 5 replicates. The values obtained at every temperature are similar within all 5 replicates, with the difference of ± 5 %. According to results, it can be assumed, that heated carbon A weight, calculated at different temperatures, is reliable and constant. Results are analogous with active sludge. These presumptions result in the following formulae that enable to calculate organic part of biomass in the sample:

$$m_{org}=m_{105}^{AS}-\alpha\cdot m_{900}^{AS},\qquad (6)$$

Where m_{org} – organic part of biomass, g; m_{105}^{AS} - organic part of biomass in a sample after drying at 105 °C temperature, g; m_{900}^{AS} - residual of biomass (mineral part), after sample heating at 900 °C temperature, g; α - constant.

$$m_{105}^{AS}=m_{105}-D\times\frac{C\cdot m_{900}-m_{350}}{A-B\cdot C},\qquad (7)$$

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$$m_{900}^{AS} = \frac{m_{350}}{C} - \frac{B(C \cdot m_{900} - m_{350})}{C^2(A - B \cdot C)}, \qquad (8)$$

Where $m_{105}, m_{350}, m_{900}$ - sample weight after heating at temperatures 105, 350 and 900 °C, respectively, g; *A, B, C, D* – constants.

By means of eqn (4) and (5) under accepted presumptions constants *A*, *C* and α can be calculated:

$$m_{105}^{AC} / m_{350}^{AC} = \frac{3 \cdot 10^{-7} \cdot 105^2 - 0{,}0002 \cdot 105 + 100}{3 \cdot 10^{-7} \cdot 350^2 - 0{,}0002 \cdot 350 + 100} = 1{,}002 \approx 1 = const.\, A, \qquad (9)$$

$$m_{350}^{AS} / m_{900}^{AS} = \frac{2 \cdot 10^{-6} \cdot 350^2 - 0{,}0045 \cdot 350 + 31{,}93}{2 \cdot 10^{-6} \cdot 900^2 - 0{,}0045 \cdot 900 + 31{,}93} = 1{,}037 = const.C, \qquad (10)$$

$$\alpha = \frac{m_{600}^{AS}}{m_{900}^{AS}} = \frac{2 \cdot 10^{-6} \cdot 600^2 - 0{,}0045 \cdot 600 + 31{,}93}{2 \cdot 10^{-6} \cdot 900^2 - 0{,}0045 \cdot 900 + 31{,}93} = 1{,}015 = const., \qquad (11)$$

Constant *B* can be calculated using experimental data referring to presumptions mentioned above:

$$m_{105}^{AC} / m_{900}^{AC} = 6{,}580 = const.\, B, \qquad (12)$$

Equation for constant *D* is get deriving eqn (7):

$$D = \frac{A \cdot B}{C}, \qquad (13)$$

It must be stressed that the values of all constants are the same only for the same type of active carbon and active sludge.

The temperature range for thermal separation of AS and AC composite (BAS) can be apparently seen in the thermogram of active carbon and active sludge agglomerate, fig. 3. The first region of the curve (105-350°C) goes down because of dissociation of active sludge. The third region of the curve represents thermal dissociation of active carbon. The median horizontal region (350-400 °C) represents the range of temperature when the amounts of both components do not change, i.e. active sludge is dissociated already and thermal dissociation of active carbon has not begun yet.

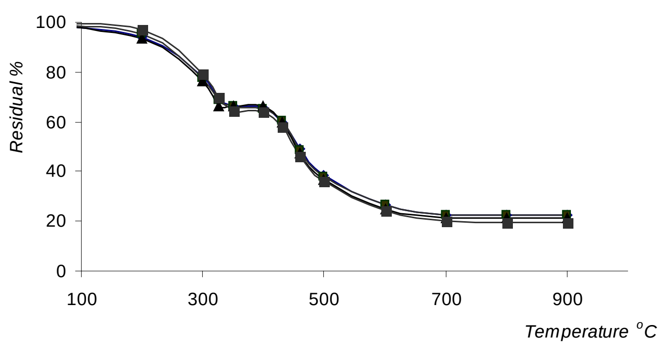

Fig. 3. **Thermogram of AC-A and AS agglomerate.**

It should be said, that all regions of all curves are arbitrary in conformity with experimental results.

In case of systems with sand or gravel (for example sand filters) biomass amount estimation is considerably simpler. The results of sand and gravel thermal dissociation are shown in fig. 4.

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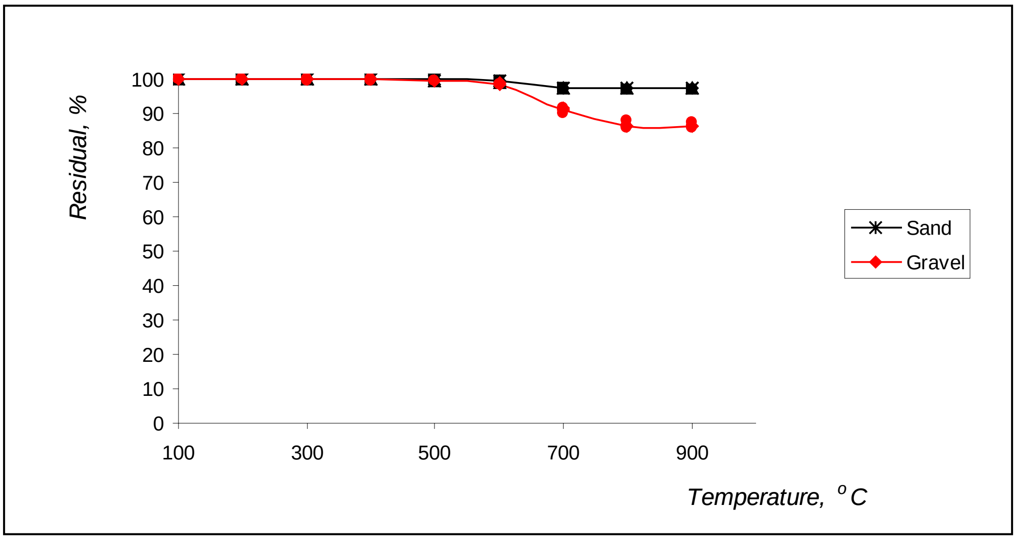

Fig. 4. **Thermogram of sand and gravel.**

It is evident that the mass of samples of sand and gravel remains almost the same in the temperature range 100 – 600 °C. The deviations from direct ratio of the burn out are inconsiderable, 0.70% and 1.40% for sand and gravel respectively. As this error does not exceed 5%, the thermal technique can be applied for the samples of sand and gravel without correction coefficients, i.e. after heating samples in 600 °C for two hours, the burnt out mass will represent organic part of the active sludge, which is responsible for the decomposition of organic pollutants.

Conclusions

1. It is experimentally proved that the heating process proceeds regularly. The relation between temperature and burnt out part of activated carbon at the temperature range 200-400 °C is strong and correlation coefficient is $R_1^2 = 0.98$. The relation between temperature and volatile organic part of active sludge at the temperature range 350 – 900 °C is strong and correlation coefficient is $R_2^2 = 0.96$.
2. The experimental research confirmed that organic volatile part of active sludge can be estimated after heating sample at the temperature of 350 °C. This value is used for calculating constants.
3. The ash content of the agglomerate active sludge - activated carbon is estimated at the temperature of 900 °C. This temperature is the final for heating samples.
4. Knowing weights of the samples after heating at the temperatures 105, 350 and 900 °C the organic part of biomass, the traditional (heated in 600°C) ash content of biomass and the mass of activated carbon in the sample can be estimated.
5. Organic volatile part of active sludge in the samples of sand and gravel can be estimated as mass difference after sample heating at the temperature of 600 °C. Correction coefficients are not calculated.

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