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Effect of conditions of air-lift type reactor work on cadmium adsorption

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Abstract−We investigated cadmium sorption by activated sludge immobilized in 1.5% sodium alginate with 0.5% polyvinyl alcohol. Experiments were conducted in an air-lift type reactor at the constant concentration of biosorbent reaching 5 d.m./dm^3, at three flow rates: 0.1, 0.25 and 0.5 V/h, and at three concentrations of the inflowing cadmium solution: 10, 25 and 50 mg/dm^3. Analyses determined adsorption capacity of activated sludge immobilized in alginate as well as reactor's work time depending on flow rate and initial concentration of the solution. Results achieved were described with the use of Thomas model. The highest adsorption capacity of the sorbent (determined from the Thomas model), i.e., 200.2 mg/g d.m. was obtained at inflowing solution concentration of 50 mg/dm^3 and flow rate of 0.1 V/h, whereas the lowest one reached 53.69 mg/g d.m. at the respective values of 10 mg/dm^3 and 0.1 V/h. Analyses were also carried out to determine the degree of biosorbent adsorption capacity utilization at the assumed effectiveness of cadmium removal - at the breakthrough point ($C=0.05*C_0$) and at adsorption capacity depletion point ($C-0.9*C_0$). The study demonstrated that the effectiveness of adsorption capacity utilization was influenced by both the concentration and flow rate of the inflowing solution. The highest degree of sorbent capacity utilization was noted at inflowing solution concentration of 50 mg/dm^3 and flow rate of 0.1 V/h, whereas the lowest one at the respective values of 10 mg/dm^3 and 0.1 V/h. The course of the process under dynamic conditions was evaluated using coefficients of tangent inclination - *a*, at point $C/C_0=½$. A distinct tendency was demonstrated in changes of tangent slope *a* as affected by the initial concentration of cadmium and flow rate of the solution. The highest values of *a* coefficient were achieved at the flow rate of 0.1 V/h and initial cadmium concentration of 50 mg/dm^3.

Keywords: Adsorption, Alginate, Air-lift, Cadmium, Activated Sludge

INTRODUCTION

Heavy metals are natural components of the lithosphere. Some of them, such as copper and zinc, constitute essential elements to the functioning of living organisms. In turn, others - like mercury, cadmium and lead - do not serve any functions in the body [1]. Natural presence of heavy metals in the environment usually has no negative effect on humans, animals and plants. But in excess, all heavy metals pose some risk. High concentrations of cadmium, mercury and lead are strongly toxic to animals and humans, and less toxic to plants, whereas copper, zinc and nickel have a negative effect also on plant growth [2-4].

Intensive civic, urban and industrial development has contributed to enhanced accumulation of heavy metals in the natural environment. Their continuously increasing concentrations may lead to contamination of waters and soil and, thus, to increased incidence of diseases amongst animals and plants [2,4]. Hazardous substances, including heavy metals, are toxic and non-biodegradable [5,6]. When they penetrate into the environment, they affect all elements of the food chain - beginning from bacteria and ending with humans [7].

Heavy metals penetrate to waters with sewage discharged to a receiver with surface run-off, with atmospheric precipitation or as a result of soil erosion. However, the greatest source of heavy metals in the natural environment is industrial wastewater which has recently become a serious threat to aquatic environment all over the world [8].

One of the heavy metals, the main source of which is industrial, is cadmium. It is a transition metal of the 12th group with atomic weight of 112.4 and density of 8.64 g/cm^3. In the environment, it isn't in the native state, but only in the form of mineral, i.e., grenokit (CdS), zinc ore and other metal ores such as lead. Cadmium can easily create a connection with sulfur, and in most environments is very mobile. Cadmium contamination mainly involves water environments, where it gets the atmospheric precipitation and water from rivers [9]. In Poland, the permissible level of cadmium in drinking water is 5 μg/dm^3 and usually this value is not exceeded [10]. When supplied every day to the human body such quantities of cadmium may, however, have a negative impact on health, because cadmium undergoes biomagnification [11,12]. This means that its quantity increases in the successive links of the food chain. In human tissues cadmium accumulates for the majority of the lifespan because its half-life is 20 years. It is a carcinogenic substance to humans. Symptoms of cadmium intoxication include ane-

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mia, potassium and magnesium deficiency, arterial hypertension, kidney damage, respiratory disorders and bone decalcification [9]. Intoxication with cadmium may be acute or chronic ("Itai - itai" disease) [13]. The above information indicates that it is necessary to search for technologies for cadmium removal from both water and wastewater.

Contemporary methods applied for the removal of heavy metals (including cadmium), namely, chemical precipitation, dialysis, electrolysis, ionic exchange, filtration and adsorption, have turned out to be too expensive and not always effective because concentrations of heavy metals in wastewaters are usually low [11,12,14]. Therefore, cost-efficient, easily-available and effective methods of metals removal are searched for. Biological techniques seem to be an alternative in this case [15].

The use of adsorbents of natural origin allows significant reduction of costs compared to artificial ion-exchange substances. Many types of microorganisms have been identified that effectively bind metals. Most often applied biosorbents include biomass of marine algae, adsorbents based on cellulose and bacterial strains, biomass of microorganisms being a by-product in the pharmaceutical industry, and activated sludge from the biological process of wastewater treatment [16-18].

This manuscript presents results of investigations on the removal of cadmium from an aqueous solution by activated sludge immobilized in sodium alginate (1.5%) and polyvinyl alcohol (0.5%). The research was conducted under dynamic conditions in the air-lift type circulatory reactor. Its aim was to determine the effect of conditions of work of the air-lift reactor on the adsorption of heavy metals and concentration of cadmium in the solution inflowing to the reactor as well as the effect of cadmium solution flow intensity on the effectiveness of metal removal with adsorption method on immobilized activated sludge.

In this study on cadmium removal from aqueous solutions, a new biosorbent was proposed which is a combination of a waste product, namely activated sludge from a wastewater treatment plant, and sodium alginate used to immobilize the sludge. Furthermore, polyvinyl alcohol was added to sodium alginate, which ensures the improvement of the mechanical properties of the biosorbent by increasing its mechanical resistance and sedimentation properties compared to the activated sludge alone.

Experimental data obtained in the study were described with the use of Thomas model. So far, this model has usually been applied in the case of column reactors. The determined values of R^2 coefficients demonstrated that this model well describes experimental results and enables their interpretation.

MATERIAL AND METHODS

1. Preparation of Biosorbent

The experiment was conducted with the use of excess activated sludge after methane fermentation that originated from a municipal wastewater treatment plant in Olsztyn. The sludge was dehydrated with acetone, centrifuged (4,500 rpm/10 min), and left on a water bath at 50 °C for 48 h. The sludge was disintegrated in a porcelain mortar and sieved through a screen with mesh size of 0.01 mm.

2. Immobilization of Activated Sludge

Polyvinyl alcohol (PVA 0.5 g) was dissolved in deionized water at 150 °C. Also, 1.5 g of sodium alginate was dissolved in 50 cm^3 of water and both solutions were mixed. Activated sludge (2 g) diluted in water was added to thus prepared mixture, and the whole mixture was filled up with deionized water to the weight of 100 g.

A 0.1 M solution of calcium chloride was prepared and mixed with saturated bromic acid prepared by dissolving 150 g of bromic acid in 1 dm^3 of deionized water. Homogeneous sol was instilled with a syringe to the prepared solution to form gel beads.

Biosorbent in the form of beads was left for 24 h in a 0.1 M solution of $CaCl_2$ with saturated boric acid for fixation. Afterwards, the beads were washed several times with deionized water.

3. Preparation of Metal Solution

Adsorption analysis was conducted using hydrated nitrate salt of cadmium. A stock solution of cadmium with the concentration of 20 g/dm^3 was prepared with the use of $Cd(NO_3)_2 \cdot 4H_2O$ salt. To obtain such a concentration of the solution, 54.8825 g of $Cd(NO_3)_2 \cdot 4H_2O$ was dissolved in 1 dm^3 of deionized water with pH 6. The pH value of cadmium solution ensuring the most effective adsorption process was determined based on preliminary study conducted under static conditions.

4. Air-lift Reactor

A reactor with circular cross-section made of Plexiglas, 5 cm in diameter, with the volume of 0.77 dm^3 and height of 0.45 m was used in the study. Inside reactor there was a 35 cm long partition mounted centrally, 4 cm below water table. A snorkel in the bottom part of the reactor allowed cadmium solution inflow, whereas a snorkel mounted in the upper part of the reactor was used to discharge the solution from the reactor. Biosorbent circulation was enforced by introduction of air to reactor's interior. The air-lift reactor was coupled with a sampler, namely a disc with 36 receivers that was rotating with various frequency depending on flow intensity. The disc was coupled with a motor that enabled its rotation and with

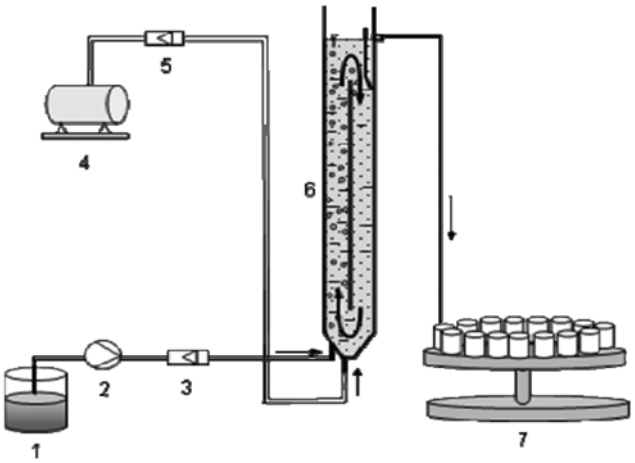

Fig. 1. Experimental arrangement for operating the biosorption air-lift reactor.

1. Stock container with metal solution
2. Peristaltic pump
3. Flowmeter
4. Air
5. Rotameter
6. Reactor with biosorbent
7. Automatic sample collection

a photocell that was indicating the site of disc arrest (Fig. 1) [19].

5. Analysis of Cadmium Adsorption in Air-lift Reactor

Experiments were conducted at a constant concentration of biosorbent and at three flow intensities of the inflowing solution. Before the study, the reactor was filled with deionized water and then 80 g of biosorbent was introduced to the reactor. To enforce biosorbent flow, air was supplied to air-lift reactor. Cadmium solution was dosed in the bottom part of the reactor with a peristaltic pump with the flow rates of 1.7 dm^3/h, 4.25 dm^3/h, and 8.5 dm^3/h. These rates corresponded to the following flow intensities: 0.1 V/h, 0.25 V/h and 0.5 V/h (where V-reactor volume). Analyses were conducted for three initial concentrations of metal: 10 mg/dm^3, 25 mg/dm^3 and 50 mg/dm^3.

6. Analytical Methods

Cadmium concentration in the solution at the outlet from the circulatory reactor was determined with the atomic adsorption method at the wavelength of 228.8 nm. In brief, 10 cm^3 of the solution was collected for analyses. The samples were acidified with nitric acid and the concentration of metal left in the solution was determined according to a standard curve with a SpectraAA apparatus by Varian Company.

7. Computational Methods

The quantity of cadmium adsorbed under continuous flow conditions was calculated with two methods: the first with Eq. (1) and the second with Thomas model [20-23].

$$Q = \frac{\Sigma_{t=1}^{n}((C_k - C_t)\cdot q \cdot t)}{V \cdot m} \quad (1)$$

Q : quantity of adsorbed metal [mg/g d.m.]
C_k : mean concentration of metal at reactor outlet in the control sample [mg/dm^3]
C_t : mean concentration of metal in effluent from the reactor in time t [mg/dm^3]
q : intensity of metal solution inflow to reactor [dm^3/h]
t : adsorption time [h]
V : reactor volume [dm^3]
m : concentration of adsorbent in reactor [g d.m./dm^3]

Adsorption capacity was also determined by using the Thomas model, which is one of the models often applied for adsorption dynamics description. This model is similar to the Langmuir isotherm and second-order reversible kinetic reaction (2). It has the following form:

$$\frac{C_e}{C_0} = \frac{1}{1 + e^{K_{th}(q_0 \cdot m - C_0 \cdot V)/Q}} \quad (2)$$

In turn, the linear form of equation for the Thomas model is as follows (3):

$$\ln\left(\frac{C_0}{C_e} - 1\right) = \frac{K_{th} \cdot q_0 \cdot m}{Q} - \frac{K_{th} \cdot C_0}{Q} \cdot V \quad (3)$$

K_{th} : constant in Thomas model
C_0 : initial concentration of metal [mg/dm^3]
C_e : metal concentration after adsorption [mg/dm^3]
q_0 : quantity of adsorbed metal [mg/g d.m.]
m : adsorbent weight in reactor [g]
Q : intensity of metal solution inflowing to reactor [dm^3/h]
V : effluent volume after time [cm^3/min]

RESULTS

The adsorption process may be conducted under static or dynamic conditions in a single- or multi-stage batch system. The effectiveness of adsorption under flow conditions is influenced by many factors, including process conditions (e.g., pH value), flow intensity, adsorbate concentration in the influent as well as properties and structure of adsorbent. Flow intensity is one of the factors that determine the effectiveness of adsorption process. The flow rate of a solution needs to be appropriately adjusted. In addition, contact time of metal and biosorbent ought to be long enough to allow metal ions binding at active sites of the biosorbent.

In this study, analyses were conducted at three flow rates of the inflowing solution: 0.1 V/h, 0.25 V/h and 0.5 V/h (where V denotes reactor's volume) and at three initial concentrations of metal: 10 mg/dm^3, 25 mg/dm^3 and 50 mg/dm^3. Results achieved in these analyses allowed determining the effect of metal concentration and solution flow rate on the effectiveness of cadmium removal from the solution.

1. FTIR Analysis

Fig. 2 presents FTIR spectra for sodium alginate, polyvinyl alcohol (PVA) and activated sludge that were constituents of the biosorbent. A wide band from 3,660 to 3,004 cm^{-1} may be observed in sodium alginate spectrum, which indicates vibration of -OH groups. The peak at 1,602 cm^{-1} is typical of sodium alginate and indicative of stretching vibrations of C=O. Asymmetric adsorption band at 1,403 cm^{-1} appeared in response to vibrations of COO- groups and suggested the presence of carboxyl groups in a molecule of sodium alginate. The peak at 1,296 cm^{-1} is induced by vibration of C-O, whereas the vibration band at 1,035 cm^{-1} shows the presence of -COC groups [24]. The spectrum of polyvinyl alcohol also possesses a wide band at 3,600-3,100 cm^{-1} which indicates the presence of -OH groups. Another peak at 2,900-2,940 cm^{-1} may be linked to a vibration band of -CH group of alkyl groups. The peak at 1,713 cm^{-1} appeared as a result of stretching vibrations of C=O of the acetate

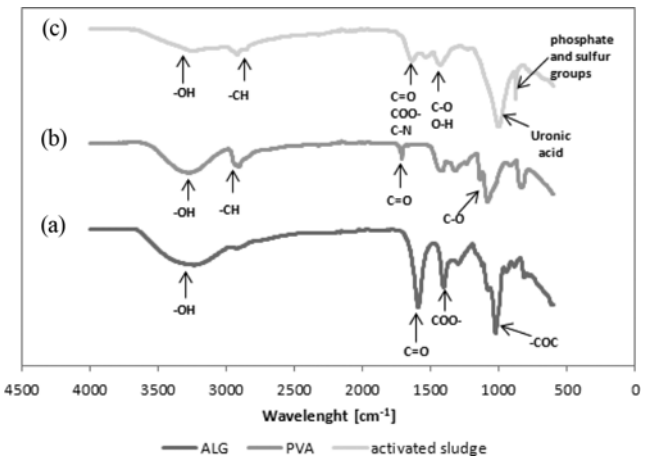

Fig. 2. FTIR spectrum of: (a) sodium alginate, (b) polyvinyl alcohol, and (c) activated sludge.

group. The adsorption band at 1,141-1,096 cm^{-1} was probably linked with the presence of C-O functional groups [25]. The spectroscopic FTIR analysis of activated sludge shows a wide adsorption band of the -OH group (3,600-3,200 cm^{-1}). The peak at 2,922-2,852 cm^{-1} may be linked with the -CH group. In turn, the band at 1,639 cm^{-1} confirms the presence of proteins in activated sludge and is likely induced by stretching vibrations of COO-, C=O and C-N. The peak at 1,443 cm^{-1} indicates vibrations of C-O and O-H groups of phenolic compounds. In addition, the spectrum of activated sludge shows a band at 1,004 cm^{-1} which confirms the presence of uronic acids and a peak at 827 cm^{-1} which indicates the presence of functional groups containing phosphorus and sulfur [26,27].

2. Adsorption Capacity of Adsorbent

The reported study was conducted under dynamic conditions in a continuous flow system, in an air-lift type reactor. Concentration of adsorbate in the inflowing solution and flow intensities varied, whereas adsorbent quantity was constant. Cadmium concentrations in the influent reached 10 mg/dm^3, 25 mg/dm^3 and 50 mg/dm^3, flow intensities reached 0.1 V/h, 0.25 V/h and 0.5 V/h, whereas biosorbent quantity was 5 g d.m./dm^3.

For each series, adsorption capacity of biosorbent (formula 2) and total working time of the reactor were determined depending on flow intensity and cadmium concentration in the solution, assuming that cadmium concentration in the effluent will equal that in the influent ($C=C_0$) (Table 1).

The analysis of results presented in Table 2 enables determining the effect of flow intensity and concentration of the inflowing solution on time when $C=C_0$. The longest adsorption process (368 h) was observed at flow intensity of 0.1 V/h and concentration of 10 mg/dm^3, whereas the shortest process (124 h) was observed at 0.5 V/h and 50 mg/dm^3, respectively. These results proved that the working time of reactor shortens along with increasing flow intensity. A similar dependency was observed by Filipkowska and Waraksa [19], who were examining adsorption of dyes onto chitosan under dynamic conditions. In their study, the longest time of reactor work (2,000 min) was achieved in the series with the lowest flow intensity reaching 0.1 V/h.

Adsorption capacities of adsorbent were also determined in each experimental series according to the Thomas model (formula 3, 4) (Table 2).

According to literature data, the Thomas model is mainly applied to determine adsorption capacity of adsorbent in column reactors [20,21,28]. However, when comparing sorption capacities presented in Tables 2 and 3 and fit of Thomas model to experimental data (Fig. 3), it may be concluded that this model may also be used in continuous reactors. Adsorption capacities determined according to formula 2 and Thomas model differ maximally by 10%, whereas the coefficients of fit R^2 range from 0.969 to 0.995.

The highest adsorption capacity reaching 191.7 mg/g d.m. (acc. to Thomas model - 200.2 mg/g d.m.) was achieved at the highest examined flow intensity (0.5 V/h) and the highest concentration of the inflowing solution (50 mg/dm^3). In contrast, the lowest adsorption capacity reaching 50.6 mg/g d.m. (acc. to Thomson model - 53.9 mg/g d.m.) was recorded at flow intensity of 0.1 V/h and influ-

Table 1. Adsorption capacity and reactor work time depending on flow intensity and initial concentration of influent

Flow intensity / Concentration of Cd	0.1 V/h		0.25 V/h		0.5 V/h	
	Q [mg/g d.m.]	t [h]	Q [mg/g d.m.]	t [h]	Q [mg/g d.m.]	t [h]
10 mg/dm^3	50.6	368	67.4	272	121.8	184
25 mg/dm^3	69.6	324	114.9	256	122	162
50 mg/dm^3	57.6	153	153	132	191.7	124

Table 2. Adsorption capacity acc. to Thomas model and goodness of fit coefficients depending on flow intensity and initial concentration of influent

Flow intensity / Concentration of Cd	0.1 V/h		0.25 V/h		0.5 V/h	
	Q [mg/g d.m.]	R^2	Q [mg/g d.m.]	R^2	Q [mg/g d.m.]	R^2
10 mg/dm^3	53.9	0.982	71.8	0.984	136.6	0.995
25 mg/dm^3	76.7	0.969	127.6	0.988	126.7	0.984
50 mg/dm^3	63.3	0.995	160.2	0.982	200.2	0.934

Table 3. Degree (%) of adsorption capacity utilization at the assumed effectiveness of cadmium removal depending on flow intensity and initial concentration of influent

Flow intensity / Concentration of Cd	Adsorbent consumption %					
	0.1 V/h		0.25 V/h		0.5 V/h	
	$C=0.05*C_0$	$C=0.9*C_0$	$C=0.05*C_0$	$C=0.9*C_0$	$C=0.05*C_0$	$C=0.9*C_0$
10 mg/dm^3	1.0	97.4	9.7	98.2	1.2	97.1
25 mg/dm^3	6.9	97.2	8.03	97.3	2.2	94.8
50 mg/dm^3	39.7	98.9	32.3	98.1	13.4	97.4

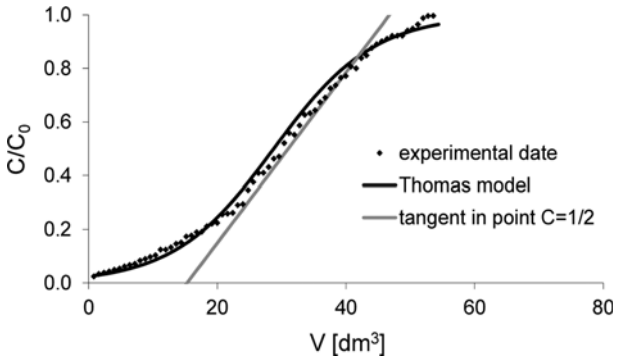

Fig. 3. Changes in cadmium concentration in effluent from reactor at the initial concentration of C=10 mg and flow rate of p=0.25 V/h.

ent concentration of 10 mg/dm^3. These results enabled concluding that both the solution flow intensity and the concentration of inflowing solution were the factors that decreased the effectiveness of heavy metals removal with the adsorption method on the tested biosorbent. The fact that adsorption effectiveness is influenced by the contact time of metal with biosorbent was also confirmed by other researchers. For instance, Deng et al. determined the effect of time on the effectiveness of lead and cadmium adsorption by *Cladophora fascicularis* algae [29]. The highest removal effectiveness of both metals was noted within the first 30 minutes. Also Shin et al., who investigated sorption effectiveness of a mixture of heavy metals. Cr^{3+}, Ni, Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+} on, e.g., shells of oysters, confirmed that reaction equilibrium time was shorter than 60 min [30]. This is linked with a dependency that the longer the contact time of metal ions with immobilized activated sludge, the lower the number of available active sites of biosorbent. Literature data confirm also that the effectiveness of cadmium adsorption increases along with influent concentration. It was proved by Pino et al. [31] who were investigating cadmium adsorption from coconut shell powder. They reported that coconut shell powder was more effective in cadmium ions removal when they occurred in high concentrations - reaching even 1,000 mg/*l*. At such an initial concentration, the adsorption capacity of adsorbent reached 286 mg/*l*. Similar conclusions were formulated by Das et al. [32] who were examining the capability of black tea for chromium adsorption. In their study, the adsorption capacity was also increasing along with an increasing initial concentration of chromium, and its highest value was achieved at the initial chromium concentration above 150 mg/*l*.

3. Degree of Adsorption Capacity Use

The potential use of adsorbent in a technical scale is determined

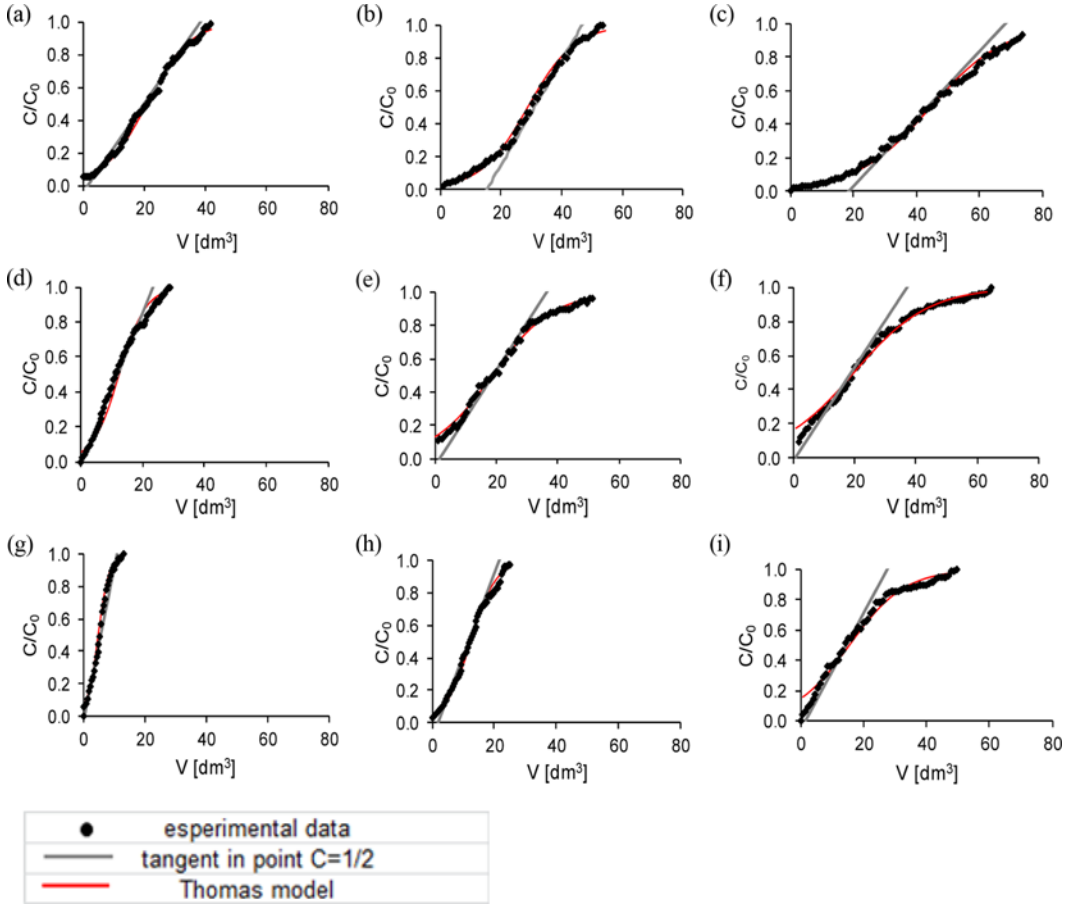

Fig. 4. Changes in cadmium concentration in effluent from reactor depending on the volume of the inflowing cadmium solution (a) C=10 mg p=0.1 V/h, (b) C=10 mg p=0.25 V/h, (c) C=10 mg p=0.5 V/h, (d) C=25 mg p=0.1 V/h, (e) C=25 mg p=0.25 V/h, (f) C=25 mg p=0.5 V/h, (g) C=50 mg p=0.1 V/h, (h) C=50 mg p=0.25 V/h, (i) C=50 mg p=0.5 V/h.

by the use of its maximum capacity at specified effectiveness of adsorbate removal. Results obtained in the study allowed calculating the degree of adsorption capacity utilization at two points of the breakthrough curve - at breakthrough point ($C=0.05*C_0$) and at the point of adsorption capacity depletion ($C=0.9*C_0$) (Tabele 3). The breakthrough point was determined as metal concentration in the effluent reaching ≥5% of metal concentration in the solution inflowing to the reactor ($C=0.05*C_0$). The point of biosorbent adsorption capacity depletion was determined as metal concentration in the effluent reaching ≥90% of metal concentration in the influent ($C=0.9*C_0$).

The highest degree of adsorbent capacity utilization was determined at influent concentration of 50 mg/dm^3 and flow rate of 0.1 V/h, whereas the lowest one - at influent concentration of 10 mg/dm^3 and flow intensity of 0.1 V/h. It may, thus, be observed that the effectiveness of use of adsorption capacity is influenced by both the concentration of inflowing solution and solution flow intensity. This was also confirmed by Barron-Zabrana et al. [32], who were examining adsorption capacity of dyes onto chitosan. They achieved the highest degree of adsorption capacity use (at around 40%) for dye concentration of 50 mg/*l* and flow intensity 0.5 m/h [33]. Results obtained in our study enable concluding that the highest effectiveness of metals removal in the process of adsorption onto immobilized activated sludge was achieved at higher concentrations of the influent.

The course of the process under dynamic conditions was also evaluated with the use of tangent slope coefficients- *a*, the values of which are presented in Table 4. To calculate this coefficient for all experimental series also their tangents at point $C/C_0=1/2$ were calculated (Fig. 4).

A distinct tendency was observed for a change in *a* tangent slope depending on the initial concentration of cadmium and solution flow intensity. The highest values of *a* coefficient were achieved at the flow rate of 0.1 V/h and initial concentration of 50 mg/dm^3. The process of adsorption under continuous flow conditions was the most effective at high values of *a* coefficient. Based on results presented in Tables 3 and 4, it may be observed that the dependency between the value of *a* coefficient and effectiveness of cadmium adsorption is directly proportional. When the coefficient describing tangent slope at point $C/C_0=1/2$ was high, then the time of effective adsorption of cadmium was elongating, and after adsorbent saturation there occurred a rapid increase in cadmium concentration in the effluent. When the value of *a* coefficient was decreasing, the time of highly effective adsorption of cadmium was shortening and the adsorption capacity of biosorbent was not completely utilized (Table 4).

Table 4. Values of tangent coefficients *a* depending on flow intensity and initial concentration of influent

C_0 of Cd \ Flow intensity	0.1 V/h	0.25 V/h	0.5 V/h
10 mg/dm^3	0.037	0.038	0.022
25 mg/dm^3	0.047	0.037	0.032
50 mg/dm^3	0.094	0.050	0.039

CONCLUSIONS

Our study on the adsorption of heavy metals onto biosorbent with immobilized activated sludge enabled determining the best conditions for cadmium removal from aqueous solutions. Adsorption of cadmium was the most effective at the initial concentration of 50 mg/dm^3 and flow rates of 0.1 V/h and 0.25 V/h. Adsorption capacities and curves of reactor work were determined for three initial concentrations and three flow intensities of a solution under continuous flow conditions in the air-lift type reactor. Results achieved enabled formulating the following conclusions: Thomas model may be applied to determine adsorption capacity of adsorbent in continuous reactors. Wastes from wastewater treatment plants in the form of activated sludge may be used in the process of heavy metal adsorption. Immobilized activated sludge is characterized by high effectiveness of cadmium adsorption. The initial concentration of a solution and intensity of its flow have a significant effect on biosorbent capability to bind heavy metals and on reactor work time. Reactor work time shortens along with increasing values of influent concentration and flow intensity. The time of effective adsorption of cadmium elongates along with an increasing value of *a* coefficient, which describes the tangent slope at point $C/C_0=1/2$. A decreasing value of *a* coefficient is accompanied by decreasing utilization of the adsorption capacity of biosorbent. Results of the conducted study on cadmium adsorption from aqueous solutions onto activated sludge immobilized in alginate using the air-lift type reactor allow speculating that the applied biosorbent and the air-lift type reactor are suitable for metal removal. The determined adsorption capacity approximating 200 mg/g d.m. is higher compared to adsorption capacities of biosorbents described in literature. The use of the air-lift type reactor and Thomas equation as a mathematical model enables good interpretation of experimental results.

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