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WASTEWATER PURIFICATION FROM COLORANT BY FLOTATION AND BIO-COAGULATION

USUWANIE BARWNIKA ZE ŚCIEKÓW W PROCESACH FLOTACJI I BIOKOAGULACJI

Abstract: The aim of this work is to study the effect of wastewater treatment by flotation and biocoagulation from toxic compounds (colorants), depending on the concentration and parameters of activated sludge in the treated water as well as the duration of flotation and colorant concentration. During the researches, size of sludge layer during flotation process was observed, together with effect of purification changing in time. The samples of activated sludge from purification plant of linen factory wastewater were used in our experiment. Samples were taken at the outflow from secondary sedimentation tank. At the laboratory, the sludge was used to prepare the model solutions of process factor of various concentrations. The obtained results showed time varying effect of purification with different concentration of activated sludge and a constant concentration of colorant as well as with the different concentration of colorant and a constant concentration of activated sludge.

Keywords: wastewater treatment, activated sludge, colorant, flotation, biocoagulation, sorption

Literature reports show that removal of colorant from wastewater is also possible by biological methods [1-6]. Samples of activated sludge from purification plant of linen factory were used for the experiment presented in this paper. Nowadays, this purification plant is also used as a wastewater treatment plant (WWTP) for urban sanitary sewage. Samples of activated sludge were taken at the outflow of the secondary sedimentation tank. At the laboratory, sludge was used to prepare the model solutions of process factor of varied concentrations.

A toxic colorant used in the linen factory was applied as a treated pollutant in our experiment [3-5, 7]. Name of colorant is “a straight brown”, it is water-soluble and it has an active anion. The composition of used colorant includes the molecules of sulfonic acid which contain groups SO_3H. The chemical nature of azo dyes is organic matter, painting process is carried out in aqueous solution. These dyes are used in the textile industry for dyeing knitting yarn and products made of various fibers: natural, artificial and synthetic. Manufacturer of colorant is corporation “Factory of fine organic synthesis - Barwa”, Ivano-Frankivska oblast, Ukraine. This type of colorant is popular in factories in Ukraine, so it was used in our experiments [7, 8]. Using common industrial impurities and activated sludge, we checked a process of wastewater treatment by biological method in presence of toxic chemical compound [3, 6, 8-10]. As the world’s literature show [11-16] such way of municipal and industrial wastewater treatment is applied around the world. Also, there is the possibility of purification processes control by the bioindication methods [16-20].

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The concentration of activated sludge was calculated by the weight method. To determine the concentration of sample with the colorant solution, we used the proportion:

$$V_1 \cdot C_1 = V_2 \cdot C_2 \tag{1}$$

$$C_2 = \frac{(V_1 \cdot C_1)}{V_2} \tag{2}$$

where: V_1 - volume of activated sludge, C_1 - concentration of activated sludge in the water selected for the experiments, V_2 - volume of activated sludge with the colorant solution, C_2 - concentration of activated sludge in sample.

The group of experiments was conducted to study the removal process of colorant, dissolved in water, with activated sludge by the biological treatment methods - biocoagulation and sorption, with the pressure of saturation of colored solution - 2 at and the duration of saturation 4 min in laboratory conditions [6, 10].

The results of our research showed dependence of the flotation and biocoagulation process, namely the volume and height of the sludge, the degree of illumination, and the effect of treatment on the duration and concentration of the activated sludge [1, 2]. Characteristics of sample solutions used in experiments are presented in Table 1.

Table 1

Characteristics of model solutions

Number of sample	**Amount of water with activated sludge V_1 [cm^3]**	**Amount of water [cm^3]**	**Amount of solution with the colorant V_2 [cm^3]**	**The concentration of activated sludge in the sample C [g dm^{-3}]**
1	500	-	500	0.22
2	250	250	500	0.16
3	125	375	500	0.12
4	62.5	437.5	500	0.08

The laboratory installation and experiment

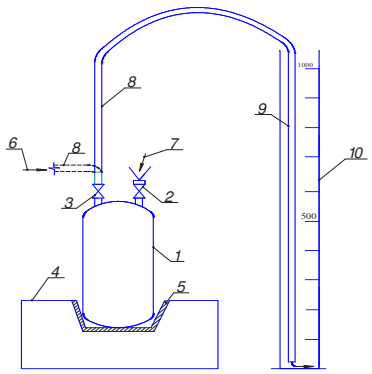

Fig. 1. Scheme of laboratory installation: 1 - pressure tank, 2 - flush valve, 3 - valve for pressure regulation and air compressor, 4 - vibrator, 5 - rubber gasket, 6 - inlet from air compressor, 7 - supply of water to dilute, 8 - rubber tube, 9 - glass tube, 10 - scaled cylinder

The laboratory installation applied to our experiment consists of the following elements: stainless steel, capacity of 1 dm^3, pressure tank (1) equipped with a flush valve for tank filling and releasing water-mixture into a measuring cylinder (2); pressure regulation valve of saturated water-air and air from the compressor (3); vibrator for the better saturation of water-air mixture (4); glass graduated cylinder (10) of 1 dm^3 capacity, with a pipe (9) for a mixture of water-intake and sampling to cylinder (Fig. 1).

Experiment No. 1, p = 2 atm

Pressure tank capacity of 1 dm^3 was filled with 500 cm^3 of the tested colorant solution. Then, all the valves were closed and the tank was supplied with air from the compressor, the saturation pressure was set to 2 at. Further, pressure tank was installed on mini table vibrator for better mixing and dissolution of air in the water, applied duration of vibrating - 4 min. Then the water-air mixture was served through the tube into 1 dm^3 cylinder volume, which was already containing 500 cm^3 of the tested activated sludge and where the process of flotation and biocoagulation occurred. After a time interval which is given in Table 2 the height of slurry [cm], and the volume of slurry [cm^3] were measured. Experiment lasted 60 minutes.

To determine the flotation rate V [cm min^{-1}] from each subtracts of sludge, its height was measured and compared with the difference in the duration of flotation time.

To determine the effect of color solution changes, after a certain period selected for this initial trial and after 20, 30 and 60 min (end of test duration), the volume of test solution was taken. After filtering the selected volumes through a filter paper, the effect of illumination on the colorimeter was determined. Photoelectric colorimeter CFC-2, manufactured by Co Ltd "Hemical procurement" (Himsnabzhenie), Kharkov, Ukraine was used. Application of photo-colorimeter allowed possibility to change a length of light wave and color of light filter. Light of wavelength equal to λ = 440 nm, green filter and 10 mm wide cuvette were used in our experiment.

Cleaning effect of solution was determined by the formula:

$$\eta = \frac{s_1 - s_2}{s_1} \cdot 100 \tag{3}$$

where: η - cleaning effect, s_1 - initial color of the solution, s_2 - final color of the solution.

Table 2

Results of experiment No. 1

The concentration of activated sludge [g dm^{-3}]	**0.16**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	28.0	18.5	17.5	16.0	15.5	14.0	13.0
Volume of slurry [cm^3]	780	505	480	430	415	395	360
Lifting speed [cm min^{-1}]	1.9	0.2	0.3	0.05	0.1	0.06	-
Effect of purification [%]	-	-	-	82.0	82.0	-	82.0
Concentration of colorant [g dm^{-3}]	-	-	-	0.11	0.11	-	0.1

The results of experiment No. 1, at the concentration of activated sludge equal to 0.16 g dm^{-3} in volume of 250 cm^3, the colorant saturation pressure 2 at and the duration of saturation of 4 min are presented in Table 2.

Experiment No. 2, p = 2 atm

Saturation of water and water-air mixture in the cylinder was similar as in case of experiment No. 1, but concentration of activated sludge was equal to 0.12 g dm^{-3}. In addition, the same time interval was considered during the measurement of the height and volume of the sludge. The results are presented in Table 3.

Table 3

Results of experiment No. 2

The concentration of activated sludge [g dm^{-3}]	**0.12**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	10.0	9.0	8.0	7.0	6.5	6.2	6.0
Volume of slurry [cm^3]	265	230	220	185	180	165	145
Lifting speed [cm min^{-1}]	0.2	0.2	0.2	0.05	0.02	0.01	-
Effect of purification [%]	-	-	-	70.8	79.1	-	79.1
Concentration of colorant [g dm^{-3}]	-	-	-	0.14	0.10	-	0.10

Experiment No. 3, p = 2 atm

Saturation of water and water-air mixture in the cylinder was similar as in experiments No. 1 and No. 2. Concentration of activated sludge was equal to 0.08 g dm^{-3}. The results of the experiment are presented in Table 4.

Table 4

Results of experiment No. 3

The concentration of activated sludge [g dm^{-3}]	**0.08**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	5.3	4.3	3.7	3.5	3.2	2.8	2.5
Volume of slurry [cm^3]	150	120	100	95	90	75	65
Lifting speed [cm min^{-1}]	0.2	0.12	0.04	0.03	0.02	0.02	-
Effect of purification [%]	-	-	-	70.8	70.8	-	77.1
Concentration of colorant [g dm^{-3}]	-	-	-	0.14	0.14	-	0.11

The next three experiments were conducted with different concentrations of colorant, but with the same initial concentration of activated sludge in all three samples (0.16 g dm^{-3}).

Experiment No. 4, p = 2 atm

Saturation of water and water-air mixture in the cylinder was similar as in the previous experiments. Concentration of colorant was equal to 0.22 g dm^{-3}. Results of the experiment are shown in Table 5.

Table 5

Results of experiment No. 4

The concentration of colorant [g dm^{-3}]	**0.22**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	24.0	20.0	17.9	15.0	14.7	14.5	13.0
Volume of slurry [cm^3]	600	530	470	410	400	390	360
Lifting speed [cm min^{-1}]	0.8	0.40	0.58	0.03	0.01	0.1	-
Effect of purification [%]	-	-	-	63.6	63.6	-	70.4
Concentration of AS [g dm^{-3}]	-	-	-	0.08	0.08	-	0.065

Experiment No. 5, p = 2 atm

Saturation of water and water-air mixture in the cylinder was similar as in the previous experiments. Concentration of colorant was equal to 0.33 g dm^{-3}. Results of the experiment are presented in Table 6.

Table 6

Results of experiment No. 5

The concentration of colorant [g dm^{-3}]	**0.33**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	13.6	11.5	11.2	10.5	9.0	8.5	7.5
Volume of slurry [cm^3]	360	320	300	280	250	220	210
Lifting speed [cm min^{-1}]	0.42	0.06	0.14	0.15	0.03	0.03	-
Effect of purification [%]	-	-	-	83.3	83.9	-	84.8
Concentration of AS [g dm^{-3}]	-	-	-	0.055	0.053	-	0.050

Experiment No. 6, p = 2 atm

Saturation of water and water-air mixture in the cylinder was similar as in case of the previous experiments. Concentration of colorant was equal to 0.44 g dm^{-3}. Results of the experiment are shown in Table 7.

Table 7

Results of experiment No. 6

The concentration of colorant [g dm^{-3}]	**0.44**						
Duration of flotation [min]	5	10	15	20	30	45	60
Height of slurry [cm]	22.0	17.5	16.0	15.0	13.5	12.5	11.5
Volume of slurry [cm^3]	580	470	430	400	360	330	310
Lifting speed [cm min^{-1}]	0.9	0.3	0.2	0.15	0.07	0.07	-
Effect of purification [%]	-	-	-	81.9	82.5	-	82.9
Concentration of AS [g dm^{-3}]	-	-	-	0.085	0.082	-	0.08

Based on the data obtained during the experiments, the graphical interpretation, presented at Figure 2 was prepared.

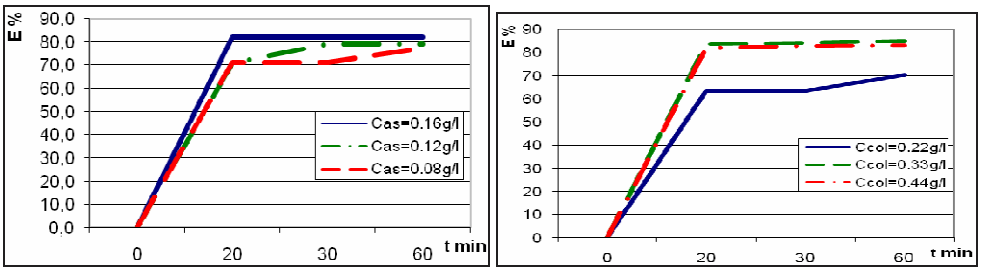

Fig. 2. Effect of purification with different concentrations of activated sludge and a constant amount of colorant (left), effect of purification with different concentrations of colorant and a constant amount of activated sludge (right)

Summary and conclusions

Based on our studies, it is possible to present the following conclusions:

- Process of purification, independent and dependent on activated sludge concentration, can be divided in two phases - exponential and plateau phase.
- The most efficient phase of exponential growth occurs during the first 20÷30 minutes from the start of experiment. During the next 30÷40 minutes, process becomes stable (plateau phase).
- Effectiveness of purification process depends on activated sludge concentration. Increase of activated sludge concentration results in enhanced process effectiveness, from 70 to 80%.
- Effectiveness of purification process revealed dependence of colorant concentration at constant concentration of activated sludge. The process can be also divided in two phases - exponential and plateau.
- Process of purification is most effective during the first 20 minutes (exponential phase). During the next 40 minutes, colorant extraction process occurs extremely slowly.
- Our observation showed that, the process reaches its highest effectiveness for activated sludge and colorant concentration equal to, respectively, 0.08 g dm^{-3} and 0.22÷0.33 g dm^{-3}. The increase of colorant concentration to 0.47 g dm^{-3}, decreased the process effectiveness by 20%. Thus, selection of the optimal concentrations of activated sludge and colorant allows reaching the maximal effectiveness of sorption.

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OCZYSZCZANIE ŚCIEKÓW Z BARWNIKA W PROCESACH FLOTACJI I BIOKOAGULACJI

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Abstrakt: Przedstawiono efekty usuwania barwnika ze ścieków za pomocą procesów biokoagulacji i flotacji. Przeanalizowano wpływ stężenia osadu czynnego wykorzystywanego jako czynnik procesowy oraz czasu biokoagulacji i flotacji na uzyskiwany efekt końcowy. Podczas eksperymentu badano grubość powstającej warstwy osadów oraz zmniejszanie się stężenia barwnika w oczyszczanej objętości ścieków. Do badań wykorzystano osad czynny pobrany z wylotu osadnika wtórnego oczyszczalni ścieków przemysłu włókienniczego. Wspomniany osad wykorzystano do sporządzenia roztworów z czynnikiem procesowym o różnych stężeniach. Uzyskane wyniki pierwszej serii badań pokazują zmieniające się w czasie stężenia barwnika dla różnych stężeń osadu czynnego przy jednakowym stężeniu zanieczyszczeń na początku eksperymentu. Wyniki drugiej serii przedstawiają wpływ oczyszczania w wybranych etapach eksperymentu przy stałym stężeniu czynnika procesowego i zmieniającym się stężeniu barwnika na początku eksperymentu.

Słowa kluczowe: oczyszczanie ścieków, osad czynny, barwniki, flotacja, biokoagulacja, sorpcja