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STUDY ON PRE-CLEANING OF POST PRODUCTION WASTEWATER CONTAINING ORGANIC GLUE BY THE PROCESS OF COAGULATION WITH THE USE OF CALCIUM HYDROXIDE

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Abstract: Presented are the results of laboratory research into one node of a technological setup involving the pre-treatment of wastewaters whose dominant components are adhesive or hardener residues. The work concerned coagulation with calcium hydroxide $Ca(OH)_2$, as well as gravitational sedimentation. The influence of doses of coagulant, sedimentation time and the initial concentration of pollutants on the effectiveness of the process was assessed. The use of calcium hydroxide coagulation allowed for a c. 85% removal in the concentration of digestion-resistant organic substances expressed in terms of COD (at an initial concentration of 45850 mg O_2/dm^3), as well as 80% removal in the concentration of organic carbon where the initial value was 18200 mg C/dm^3. The process conditions considered optimal were a dose of $Ca(OH)_2$ equal to 0.6 g/dm^3, as well as sedimentation time t_S of 2 hours. The values for pollution indicators in the post-coagulation wastewaters are closely dependent on the initial concentrations in wastewaters, albeit with this relationship (decline) being linear. It is proposed that, following coagulation and gravitational sedimentation, wastewaters should be further treated in consecutive nodes, i.e. by way of gravitational filtration and sorption. The results obtained provided for the defining (using the central point method) of analytical/empirical equations by which to describe the influence of the independent parameters on the values of resulting parameters. In order to verify these equations, several additional experiments were carried out with randomly-selected values for the different variables X1, X2 and X3, albeit with these lying within the range studied previously. They were furthermore chosen in such a way that they would not be associated with the central point of the approximation, but rather with the space around that point, and hence that within which the obtained equations were deemed applicable.

INTRODUCTION

The timber and furniture industry produces liquid and solid waste [9]. The various machinery and apparatus used to apply glue during furniture manufacturing [28] require periodic cleaning and washing. During these processes, waste is created and then collected in different kinds of containers and settling tanks where precipitation of solid forms takes place. Water from sedimentation is drained into a system of drainage tubes and the leftover residue is collected and taken to a dumping ground [15–19].

One popular type of glue used for conjoining large and over sized pieces of wood has a chemical base of polyvinyl acetate (PVAC). Because of its ease of application and excellent adhering properties, the use of this type of glue is constantly increasing [27]. Polymers [20–22, 31] and water diluent resins [12, 13] that are resoluble in water are the binding agents used in the production of glue, varnish and paint. These binding agents are less harmful for the environment [2–8]. The environmental advantages of polymeric water diluent binding agents, open doors to the market for a greater variety of water based glues, varnishes and paints. The advantages of polymeric materials include limited emission of organic dissolvents, less harmful impact on people [30] dealing with the materials and a decreased fire hazard.

This paper presents the results of laboratory study of one node of the technological system of pre-cleaning postproduction wastewater containing organic glue. The study focuses on the process of coagulation and gravitational sedimentation using calcium hydroxide $Ca(OH)_2$.

PROPOSAL OF A TECHNOLOGICAL SYSTEM FOR PRE-CLEANING WASTEWATER CONTAINING ORGANIC GLUE

The wastewater that is the subject of this study is water used to rinse gluing installations in furniture manufacturing at DREWEXiM Company in Koszalin, Poland. These installations are primarily rollers, which are used in the process of gluing doors, windows and other wooden elements. The glues used are polymeric glues based on polyvinyl acetate. DREWEXiM Company has provided all chemical characteristics of the glues examined in this study. All definitions, qualifications and attributes of the glues examined in this study were furnished to DREWEXiM Company by the glue manufacturer and are as follows [11]:

JOWACOLL 120.20 – glue used to conjoin wooden elements that are exposed to weather conditions, such as doors and windows as well as furniture designed for high humidity areas. It is universal glue used for soft and hard wood as well as for hardboard and other wooden materials manufactured with a gluing press. It is based on polyvinyl acetate (PVAC) and it undergoes reticulation [11]. Chemical characteristics:

- polyvinyl acetate and copolymer vinyl in the amount of up to 50% of its weight,
- water up to 50%,
- isopropanol up 0.5%,
- binding and preserving components up to 0.2%.

Hardener Jowat 195.30 – hardener with built-in binding elements that increase water resistance. It is based on chloride aluminum and is added to Jowacoll 102.20 glue in the amount of 5%. In a concentrated form it can corrode steel; therefore all parts touching the glue must be made of either precious metals or neutral synthetic materials (Teflon, polypropylene, polyamide). Contact with base metals is not recommended (zinc, brass, copper, aluminum) [11]. Chemical characteristics:

- chloride aluminum up to 20–25%,
- chloride nitrate up to 10–20%,
- water up to 60%.

All information included in the safety card in accordance with 91/155/EWG, 2001/58/WG is based on results and practical experiments [11].

Based on many years of research, a method of pre-cleaning post production wastewater containing organic glue [24, 25] has been suggested and is presented in Figure 1. In the first stage of pre-cleaning the raw wastewater is subjected to a coagulation process

(Stage I, Fig. 1). The coagulation process is conducted using calcium hydroxide $Ca(OH)_2$. After the process of coagulation and gravitational sedimentation, wastewater is subjected to the technological stage, which is gravitational filtration (Stage II, Fig. 1). Filtrate from the gravitational process next undergoes the sorption process (Stage III, Fig. 1). Eluate, which results from the sorption process, can be returned to production or carried away in the sewage system.

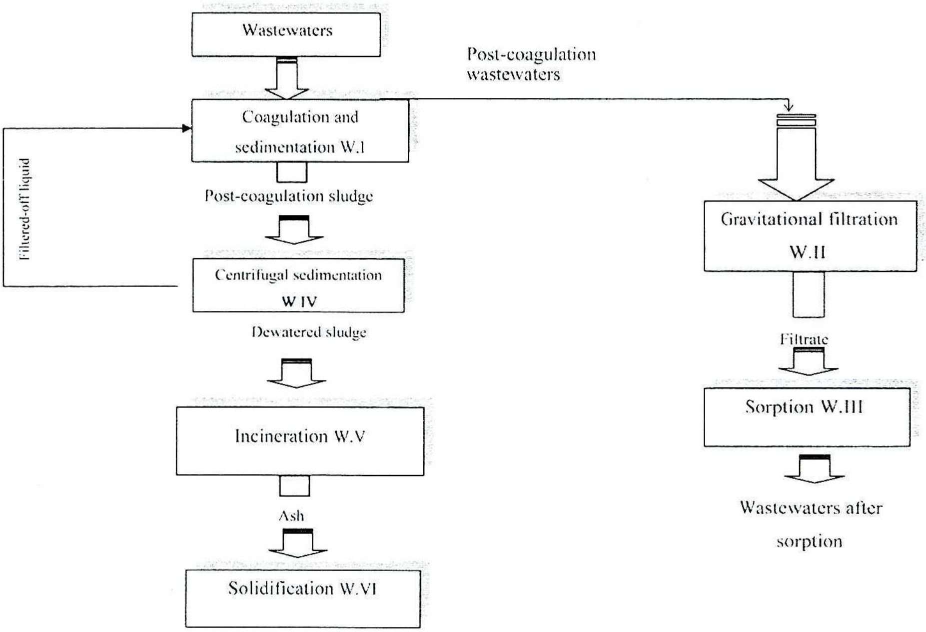


Fig. 1. Diagram presenting the treatment sequence for wastewaters from the DREWEXiM Company

METHODOLOGY

Independent variable parameters in the process of coagulation and gravitational sedimentation were set. These parameters were as follows:

X1 – reagent dose – D [g/dm^3],
X2 – sedimentation time – t_S [h],
X3 – value of the indicator of contamination of wastewater subjected to the process – X_N [mg/dm^3],

The result parameters in the process of coagulation and gravitational sedimentation assumed:

Y1 – total suspension – T_S [mg/dm^3],
Y2 – chemical oxygen demand – COD [mg O_2/dm^3],
Y3 – ether extract – E_E [mg/dm^3],
Y4 – total organic carbon – TOC [mg C/dm^3].

In the first stage of study of the process of coagulation and gravitational sedimentation, an independent parameter assumed a constant time for gravitational sedimentation of 2 hours. This value was taken as a central point of approximation for this parameter. The independent parameter variable assumed a dose of the reagent (X1), which were 0.3; 0.6; 1.0 and 1.5 g/dm^3.

In the next stage of the study, an independent constant parameter assumed a dose of the reagent of 0.6 g/dm^3. This value was at the same time the central point of approximation for this parameter. The independent parameter variable assumed the time of gravitational sedimentation (X2) to be 1; 2; 4 and 6 hours.

In the last stage of the study, independent constant parameters assumed time of sedimentation $t_S = 2$ h and dose of the reagent $D = 0.6$ g/dm^3. The independent parameter variable assumed values of pollution indicators in the inflow wastewater (X3) X_N [mg/dm^3].

The study was conducted using wastewater taken on different days from DREWEXiM Company, and varied in the level of contamination.

Table 1 shows the characteristics of the raw wastewater used in five series of tests made during the study. The process of coagulation and gravitational sedimentation was conducted in such a way that after the reagents were introduced into the wastewater, the solution was mixed quickly for a minute and then slowly for 20 minutes at a speed of 30 min^{-1}.

Table 1. Values for pollution compositions in raw wastewaters sampled randomly at the DREWEXiM Plant

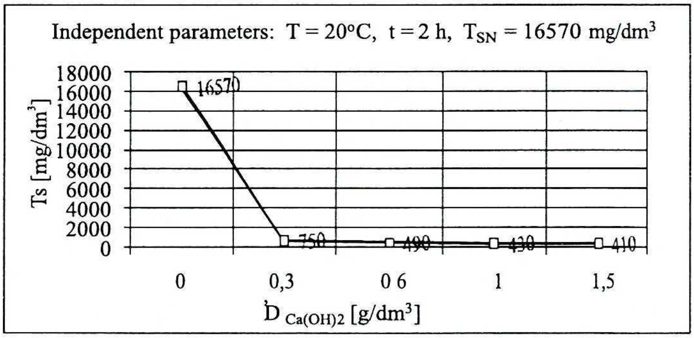
Parameters	Unit	Values for pollution indicators				
		Sampling date				
		9/5/2006	30/5/2006	13/6/2006	27/6/2006	18/7/2006
Reaction	pH	4.18	4.25	4.02	4.00	4.40
BOD	mg O_2/dm^3	0.9	0.7	0.4	0.7	0.3
COD	mg O_2/dm^3	45850	32500	28000	31200	56380
Total suspended matter	mg/dm^3	16570	13980	21670	14600	20580
Ether extract	mg/dm^3	120	185	98	78	112
Total organic carbon	mg C/dm^3	18200	20700	15390	16820	11300
Dissolved substances	mg/dm^3	6310	4280	7420	5850	6950

Based on the results of the study, the analytical-empirical equation describing the influence of specific independent parameters on the value of result indicators was established using the method of central point. The mathematical description of the method used to clean wastewater containing organic glue as depicted in Figure 1 appears in [11]. Analytical-empirical equations were applied to randomly selected experiments in order to verify the results achieved during this study. Randomly selected values of particular variables for X1, X2, X3 stayed within the tested range of changes. Measures were taken to insure that these values were not linked to the value of the central point of approximation, but stayed within the range of which it is assumed the equations could be tested.

DESCRIPTION AND ANALYSIS OF RESEARCH RESULTS

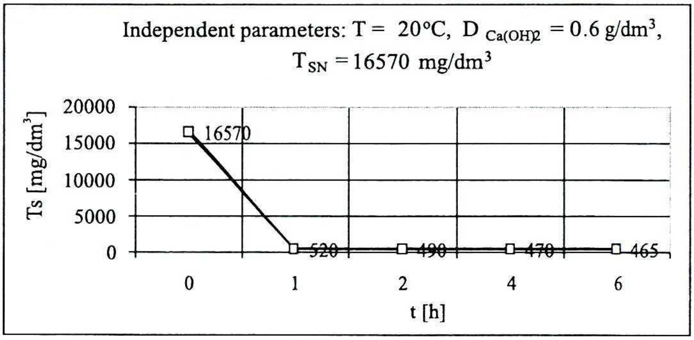
Total suspension

Results of the study showing the influence of three variables – the time of gravitational sedimentation, the level of wastewater contamination, and a dose of Ca $(OH)_2$ introduced into the process – on the contents of general suspension in the wastewater after coagulation are presented in Figures 2–4.



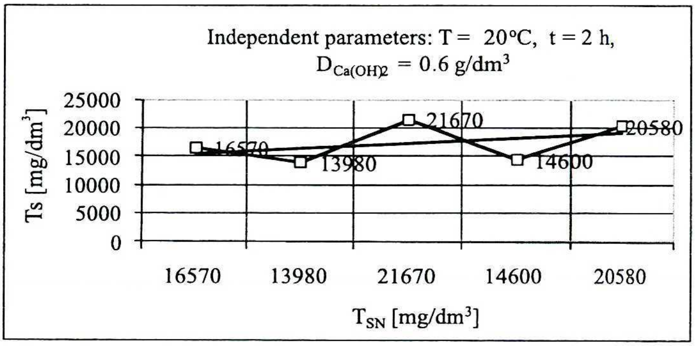
Independent parameters: T = 20°C, t = 2 h, T_{SN} = 16570 mg/dm^3

Fig. 2. Influence of $Ca(OH)_2$ dose on the concentration of total suspension T_s in wastewater after coagulation



Independent parameters: T = 20°C, $D_{Ca(OH)2}$ = 0.6 g/dm^3, T_{SN} = 16570 mg/dm^3

Fig. 3. Influence of the time of gravitational sedimentation t_s on the concentration of total suspension T_s in wastewater after coagulation



Independent parameters: T = 20°C, t = 2 h, $D_{Ca(OH)2}$ = 0.6 g/dm^3

Fig. 4. Influence of the concentration of total suspension in inflow wastewater T_{SN} on the concentration of total suspension in wastewater after coagulation T_s

The equation, after approximation, in the first, second and third stages is as follows:

$$T_S(D, t_S, T_{SN}) = \exp(9.69 - 13\cdot D) + \exp(9.69 - 5.88\cdot t_S) + 0.04\cdot T_{SN} - 246 \tag{1}$$

where:
T_S – result parameter – total suspension [mg/dm^3],
D – $Ca(OH)_2$ dose [g/dm^3],
t_S – sedimentation time [h],
T_{SN} – total suspension in inflow wastewater [mg/dm^3].

The analysis of the results suggests that when the first independent variable is changed (X1), (i.e. the dose of coagulant $Ca(OH)_2$) in the range of 0.00 g/dm^3 to 1.5 g/dm^3, the value of T_S decreased from m 16570 mg/dm^3 to 410 mg/dm^3. This constitutes a reduction of the analyzed variable parameter of 97.5%.

This procedure can be explained in the following way: the best conditions for precipitation of $CaCO_3$ are with a pH in the range of 9.3–9.5. Further dosage of carbonate leads to the rise of pH; and when pH reaches 11.0–11.5, hydroxide of magnesium is precipitated from the cleaned medium. An increased level of contamination elimination is also observed. Precipitated $Mg(OH)_2$ is a good sorbent and because of its positive electrical charge, organic anions are successfully bound [1, 14]. In addition to colloidal and suspended contaminants being removed during coagulation in the alkaline environment, good results are also achieved in removing dissolved organic substances as well as some heavy metals.

Based on the graph in Figure 2, it can be concluded that using higher doses of coagulant does not significantly change the amount of suspended contaminants removed from the wastewater. Figure 2 indicates that the optimal amount of coagulant equals about 0.6 mg/dm^3. This value makes it the central point of approximation.

When changing the second independent variable (X2) (i.e. the time of sedimentation) in the range of 0 to 6 hours the value of T_S decreases from 16570 mg/dm^3 to 465 mg/dm^3. The analysis of the results allows for the conclusion that as the time of gravitational sedimentation increases, the value of T_S indicator in the wastewater after coagulation decreases. The shape of the curve suggests that increasing the time of gravitational sedimentation will decrease the amount of the indicator T_S in the wastewater after coagulation. In this case, as the graph shows, the optimal time of sedimentation is $t_S = 1$ h. Extending the time of sedimentation over 1 hour does not significantly decrease the remaining amount of suspension in the wastewater after coagulation.

Figure 4 presents the results of the conducted on the influence of change of the last independent variable (X3) (that is, the value of T_S in inflow wastewater), on the value of wastewater after coagulation with the constant dose of $Ca(OH)_2 = 0.6$ g/dm^3 and constant time of sedimentation $t_S = 2$ hours. Analysis of the parameters shows line dependency between the T_{SN} content in wastewater before coagulation and gravitational sedimentation and the T_S content in wastewater after coagulation.

Chemical demand for oxygen

Results of the study conducted on the influence of three variables – $Ca(OH)_2$ dose, sedimentation time and the level of contamination of inflow wastewater – on the value of COD in wastewater after coagulation are presented in Figures 5–7.

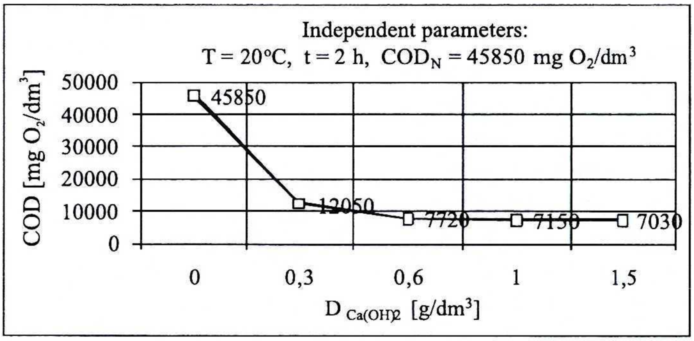


Fig. 5. Influence of $Ca(OH)_2$ dose on the value of COD in wastewater after coagulation

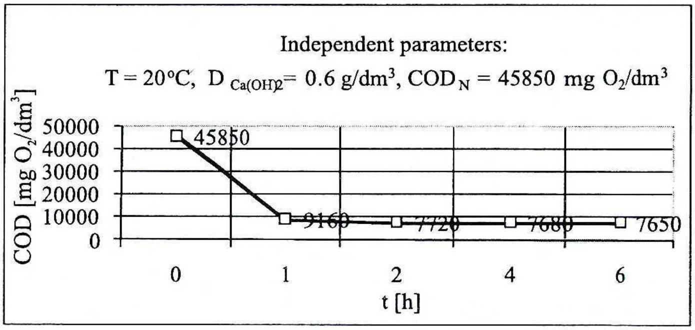


Fig. 6. Influence of sedimentation time t_S on the COD value in wastewater after coagulation

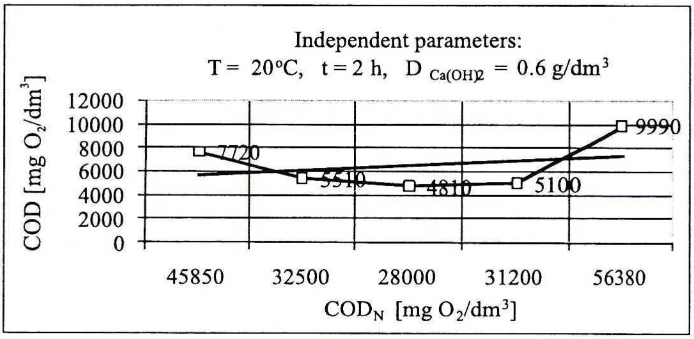


Fig. 7. Influence of COD value in inflow COD_N on COD value in wastewater after coagulation

Approximation equation after first, second and third stage is as follows:

$$COD(D, t_S, COD_N) = \exp(10.57 - 6.84 \cdot D) + \exp(10.55 - 3.24 \cdot t_S) + (0.18 \cdot COD_N) - 1188 \quad (2)$$

where:

COD – result parameter – chemical demand for oxygen [mg O_2/dm^3],
D – $Ca(OH)_2$ dose [g/dm^3],
t_S – sedimentation time [h],
COD_N – COD in wastewater before the process of coagulation [mg O_2/dm^3].

The analysis of the results indicates that when the first independent variable (X1) (i.e. the dose of coagulant $Ca(OH)_2$) is changed within the range of 0.00 g/dm^3 to 1.5 g/dm^3, the COD value decreases from 45850 mg O_2/dm^3 to 7030 mg O_2/dm^3. This constitutes a reduction of the COD value of 85%. Results of the study, as shown by the curve, indicate that when the level of $Ca(OH)_2$ increases, the level of removed COD also increases. Furthermore, the results indicate that the optimal dosage of coagulant equals 0.6 g/dm^3, which is also the central point of approximation. Removing suspension by sedimentation and removing dissolved organic substances by adsorption and co-precipitation decreased the indicator of contamination. Additionally, difficult to dissolve compounds were precipitated in the process of adding carbonate from the cleaned medium creating floccules. These floccules assumed the role of sorbents and co-precipitating factors, which combine with contaminants to create agglomerates. The compounds which create the floccules are: $CaCO_3$ and $Mg(OH)_2$ [1, 14]

When the second independent variable is changed (X2) (i.e. the time of sedimentation) within a range of 0 to 6 hours, the COD decreases from 45850 mg O_2/dm^3 to 7650 mg O_2/dm^3. The analysis of the results indicates that when the time of gravitational sedimentation increases the value of the COD indicator decreases. The results also show that most COD is removed within the first hour of sedimentation. This indicates that extending the time of sedimentation does not significantly influence the value change of the COD indicator.

Results of the study on the influence of the last independent variable (X3) (i.e. the COD_N value in inflow wastewater on the COD value of the wastewater after coagulation bearing constant dose of $Ca(OH)_2$ = 0.6 g/dm^3 and constant sedimentation time t_S = 2 hours are presented in Figure 7. The analysis of the results indicates that as the value of the COD_N indicator in inflow wastewater decreases, the value of the COD indicator in the wastewater after the coagulation likewise decreases. Figure 7 also shows that the measuring points group on a nearly straight line. This suggests that, within the tested area of variability of COD, the removal efficiency of this indicator is almost constant.

Ether extract

The results of the study on the influence of a change of three variables – $Ca(OH)_2$ dose, time of sedimentation and wastewater contamination before the coagulation – on the value of ether extract in wastewater after coagulation is presented in Figures 8–10.

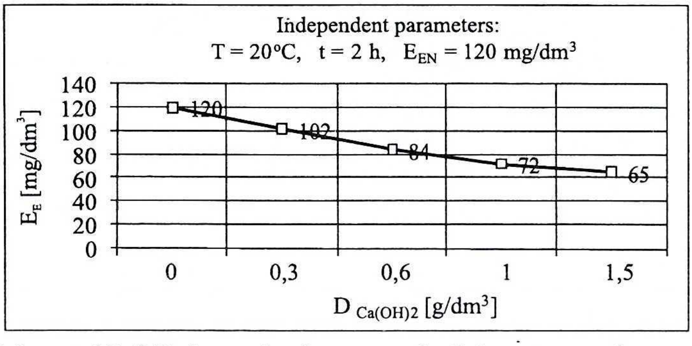


Fig. 8. Influence of $Ca(OH)_2$ dose on the ether extract value E_E in wastewater after coagulation

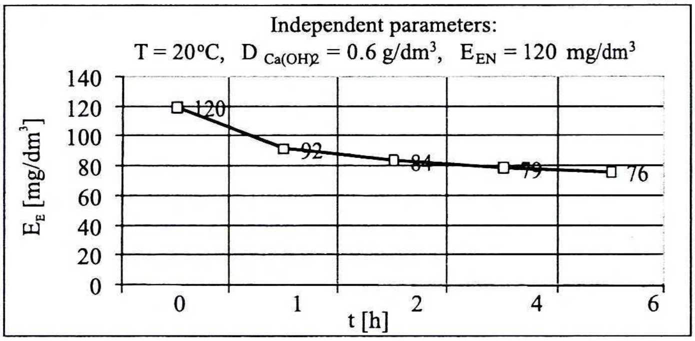


Fig. 9. Influence of sedimentation time t_S on ether extract value in wastewater after coagulation

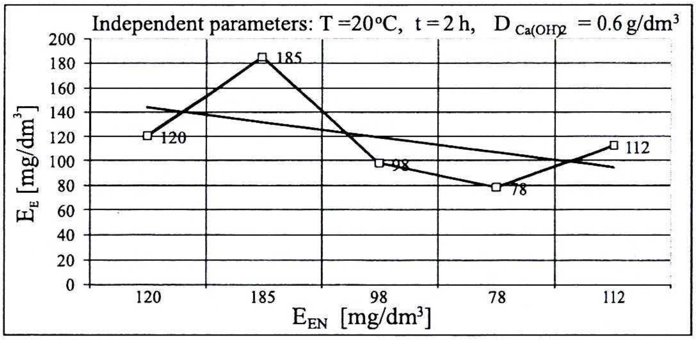


Fig. 10. Influence of ether extract value in inflow E_{EN} on ether extract E_E value in wastewater after coagulation

Approximation equation after first, second and third stage is as follows:

$$E_E(D, t_S, E_{EN}) = \exp(4.20 - 1.27 \cdot D) + \exp(3.75\ t_S) + 0.97 \cdot E_{EN} - 69 \qquad (3)$$

where:
E_E – result parameter – ether extract [mg/dm³],
D – $Ca(OH)_2$ dose [g/dm³],
t_S – sedimentation time [h],
E_{EN} – ether extract in wastewater inflow [mg/dm³].

The analysis of the results indicate that when changing the first independent variable (X1) (i.e. the dose of coagulant $Ca(OH)_2$ in the range from 0.00 g/dm³ to 1.5 g/dm³ and the constant sedimentation time t = 2 hours), the value of E_E decreases from 120 mg/dm³ to 65 mg/dm³. This constitutes a decrease in value of about 46%. One explanation for this decrease could be that the $Ca(OH)_2$ in the process of gravitational sedimentation adsorbs substances extracted by kerosene ether.

When the second independent variable is changed (X2) (i.e. the time of sedimentation in the range of 0 to 6 hours), the value of E_E decreases from 120 mg/dm³ to 76 mg/dm³ after 6 hours of sedimentation. These results indicate that when the gravitational sedimentation time increases, the value of the E_E indicator of the wastewater after coagulation decreases. The analysis of the exponential curve suggests that extending the sedimentation time beyond 4 hours does not influence the efficiency of the removal of the substances extracted by kerosene ether.

Results of the study on the influence of the change of the last independent variable (X3) (i.e. the value of E_E in the inflow wastewater) on the value of E_E in wastewater after coagulation with the constant dose of $Ca(OH)_2$ = 0.6 g/dm³ and constant sedimentation time of t_S = 2 hours are presented in Figure 10. The analysis of these results indicates line dependency between the amount of E_{EN} in the inflow wastewater and the amount of E_E in the wastewater after coagulation. This indicates that, within the studied area, efficient removal of the contaminants extracted by kerosene ether with variable amounts of contaminants in inflow wastewater is constant.

Total organic carbon

Results of the study on the influence of change of three variables – $Ca(OH)_2$ dose, the sedimentation time and the contamination level of inflow wastewater – on the value of total organic carbon in wastewater after coagulation is presented in Figures 11–13.

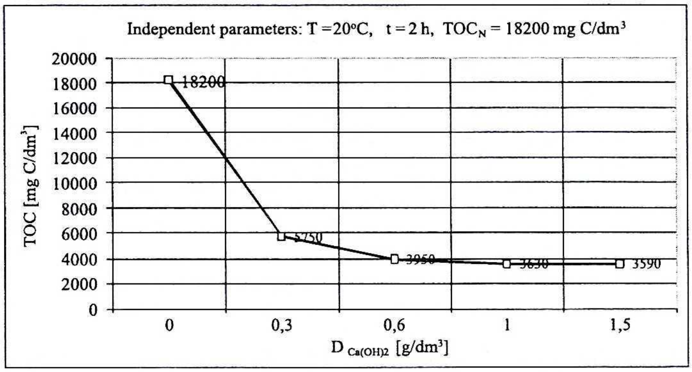


Fig. 11. Influence of $Ca(OH)_2$ dose on total organic carbon TOC in wastewater after coagulation

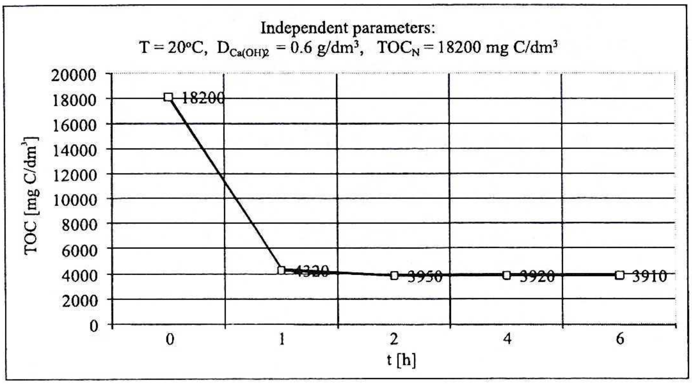


Fig. 12. Influence of sedimentation time t_s on the total organic carbon value TOC in wastewater after coagulation

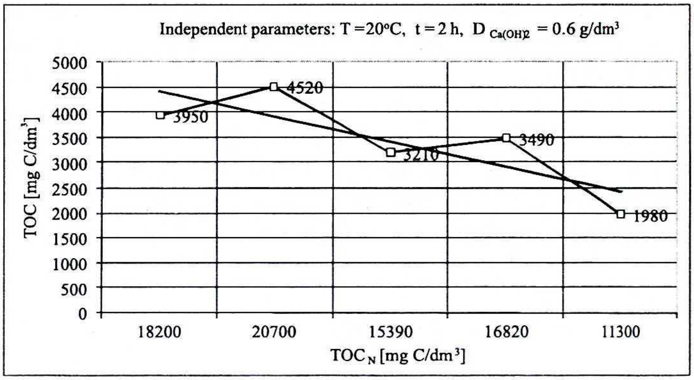


Fig. 13. Influence of total organic carbon value TOC_N in inflow wastewater on total organic carbon TOC value in wastewater after coagulation

Approximation equation after first, second and third stage is as follows:

$$TOC(D, t_S, TOC_N) = \exp(9.59 - 6.38 \cdot D) + \exp(9.57 - 3.58 \cdot t_S) + 0.27 \cdot TOC_N - 1369 \quad (4)$$

where:
TOC – result parameter – total organic carbon [mg C/dm^3],
D – $Ca(OH)_2$ dose [g/dm^3],
t_S – sedimentation time [h],
TOC_N – total organic carbon in inflow wastewater [mg C/dm^3].

The analysis of the results indicate that when changing the first independent variable (X1) (i.e. the dose of coagulant $Ca(OH)_2$ in the range from 0.00 g/dm^3 to 1.5 g/dm^3), the value of TOC indicator decreases from 18200 mg C/dm^3 to 3590 mg C/dm^3. This constitutes a decrease of the studied parameter variable of about 80%.

The study results, as shown by the curve (Fig. 11), indicate that the level of TOC removal increases together with the incremental increase of $Ca(OH)_2$ dose up to a point. The optimal level of coagulant equals 0.6 g/dm^3. This value is, at the same time, the central point of approximation. Removing suspension by sedimentation and removing dissolved organic substances by adsorption and co-precipitation decreased the indicator of contamination as well as the chemical oxygen demand [1, 14]. As the graph indicates, using the higher doses of coagulant does not significantly influence change of the indicator value.

When the second independent variable is changed (X2) (i.e. the time of sedimentation in the range of 0 to 6 hours), the value of TOC indicator decreases from 18200 mg C/dm^3 to 3915 mg C/dm^3. The study analysis allows us to state that when the sedimentation time increases, the value of the TOC indicator in wastewater after coagulation decreases. The curve in the graph indicates that when the gravitational sedimentation time is increased this will decrease the amount of TOC indicator in wastewater after coagulation to some level. In this case, as the graph shows, the optimal time of sedimentation is $t_S = 1$ h. This indicates that extending the time of sedimentation over 1 h does not significantly influence the value change of TOC in wastewater after coagulation.

The study indicates line dependency between the value of TOC_N indicator in the inflow wastewater and the value of TOC in the wastewater after coagulation in the tested area of indicator change. This means that when the value of TOC indicator of inflow wastewater increases the indicator defined for the wastewater after coagulation will also increase by constant value.

The analysis of these results indicates line dependency between the value of TOC_N indicator in the inflow wastewater and the value of TOC in the wastewater after coagulation within the tested area of indicator change. This suggests that, within the tested area of indicator change, when the value of TOC indicator of inflow wastewater increases, the indicator defined for the wastewater after coagulation will also increase by a constant value.

VERIFICATION OF OBTAINED EQUATIONS

To verify the accuracy of equations derived from this study, additional research was conducted using randomly selected values for the variable independent parameters X1, X2, X3 which stayed within tested range of changes. Measures were taken to insure that these values were not linked to the central point of approximation, but stayed within the range of which it is assumed the equations could be tested.

Table 2 compares results obtained during laboratory testing with the values calculated from analytical-empirical models when $Ca(OH)_2$ is used in the process of coagulation. The differences between values obtained during the laboratory testing and those based on analytical-empirical models are insignificant and vary within a few percent.

The accuracy of the equations [23, 29] was verified with t-student tests. For n - 1 = 6 degrees of freedom and a significance level $\alpha = 0.05$ t-tables give a limit value t_α as follows: $t_{0.05} = 2.447$. In all cases, the respective values of testing function t with the limit value $t_{0.05}$ are smaller than the limit value. It can therefore be concluded with 95% accuracy that the models derived from the process of coagulation and gravitational sedimentation are correct and that the results obtained using analytical-empirical equations are consistent with the results obtained in the laboratory conditions.

CONCLUSIONS

The use of calcium hydroxide coagulation allowed for a c. 85% removal in the concentration of digestion-resistant organic substances expressed in terms of COD (at an initial concentration of 45850 mg O_2/dm^3), as well as a 80% removal in the concentration of organic carbon where the initial value was 18200 mg C/dm^3. The process conditions considered optimal were a dose of $Ca(OH)_2$ equal to 0.6 g/dm^3, as well as a sedimentation time t_S of 2 hours. The values for pollution indicators in the post-coagulation wastewaters are closely dependent on the initial concentrations in wastewaters, albeit with this relationship (decline) being linear. It is proposed that, following coagulation and gravitational sedimentation, wastewaters should be further treated in consecutive nodes, i.e. by way of gravitational filtration and sorption.

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Table 2. Statistical analysis of the significance of resulting parameters obtained in laboratory experiments or calculated on the basis of analytical/empirical equations in the process of coagulation and gravitational sedimentation

Parameters	Units	Independent parameters			Equation	Laboratory	| d |	Mean $\bar{d}$	Sum of squares $\sum d^2$	Variance s	Standard deviation s^2	T test value t
		X_N	$D_{Ca(OH)2}$	t [h]								
COD	mg O_2/dm^3	37200	0.35	1.5	9471	9480	9	69	67568	70	4911	2.4067
		32500	0.45	1.5	6856	6910	54					
		28000	0.65	1.5	4699	4710	11					
		31200	0.85	1.5	4948	5120	172					
		42700	1.05	1.5	6971	7150	179					
		56380	1.15	1.5	9466	9470	4					
		45850	1.25	1.5	7527	7580	53					
T_S	mg/dm^3	10250	0.35	1.5	363	410	47	47	33031	50	2483	2.3245
		13980	0.45	1.5	394	480	86					
		15970	0.65	1.5	439	450	11					
		13900	0.85	1.5	348	360	12					
		9100	1.05	1.5	144	150	6					
		20580	1.15	1.5	632	650	18					
		21670	1.25	1.5	679	830	151					
TOC	mg C/dm^3	18200	0.35	1.5	5198	5230	32	80	92019	82	6677	2.4110
		20700	0.45	1.5	5138	5150	12					
		15390	0.65	1.5	3103	3310	207					
		16820	0.85	1.5	3324	3380	56					
		11300	1.05	1.5	1781	1820	39					
		14650	1.15	1.5	2681	2690	9					
		12680	1.25	1.5	2142	2350	208					

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BADANIA PODCZYSZCZANIA ŚCIEKÓW POPRODUKCYJNYCH ZAWIERAJĄCYCH KLEJE ORGANICZNE W PROCESIE KOAGULACJI Z ZASTOSOWANIEM WODOROTLENKU WAPNIA

W pracy przedstawiono wyniki badań laboratoryjnych jednego węzła układu technologicznego podczyszczania ścieków przemysłowych, których dominującym składnikiem były resztki kleju oraz utwardzacza. Badania dotyczyły koagulacji wodorotlenkiem wapnia $Ca(OH)_2$ i sedymentacji grawitacyjnej, Oceniono wpływ dawki koagulantu, czasu sedymentacji oraz stężenia początkowego zanieczyszczeń na efektywność procesu. Zastosowanie koagulacji wodorotlenkiem wapnia umożliwiło zmniejszenie o około 85% stężenia substancji organicznych trudno rozkładalnych wyrażonych jako ChZT (przy stężeniu początkowym 45850 mg O_2/dm^3) oraz o 80% stężenia węgla organicznego dla początkowej wartości 18200 mg C/dm^3. Jako optymalne warunki procesu przyjęto dawkę $Ca(OH)_2$ wynoszącą 0,6 g/dm^3 oraz czas sedymentacji t_s – 2 godziny. Wartości wskaźników zanieczyszczeń w wodzie nadosadowej po koagulacji zależały ściśle od stężenia początkowego w ściekach, przy czym zależność ta (spadek) była liniowa. Zaproponowano, aby ścieki po koagulacji i sedymentacji grawitacyjnej były doczyszczane w kolejnych węzłach tj. w procesie filtracji grawitacyjnej oraz sorpcji. Na podstawie uzyskanych wyników badań wyznaczono, stosując metodę punktu centralnego, równania analityczno-empiryczne opisujące wpływ poszczególnych parametrów niezależnych na wartości parametrów wynikowych. W celu weryfikacji otrzymanych równań matematycznych analityczno-empirycznych wykonano dodatkowo kilka losowych doświadczeń przy dowolnie wybranych wartościach poszczególnych zmiennych X1, X2, X3 mieszczących się w badanych poprzednio przedziałach zmian, celowo dobranych w taki sposób, aby nie kojarzyły się te wartości z punktem centralnym aproksymacji, lecz tylko z przestrzenią wokół tego punktu – a więc przestrzenią, w której przyjmuje się, iż otrzymane równania można stosować.