Preliminary Research on Removal of Organic Substances Contained in Wastewater from Plastic Lenses Production

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Abstract More than 80 percent of all eyeglasses worn today have plastic lenses. Plastic lenses made of polycarbonate discs are created through the process of machining which requires the use of a coolant. During the production process, the rotating disc and blade are poured with a mixture of water and synthetic coolant to remove the resulting chips and cool the blade and discs. The ensuing wastewater contains chips, water and coolant. The chips are separated by filtration and the water and coolant are returned to the machine tool. Due to the low particle weight some of the plastic dust flotates easily and creates foam. If there is too much foamed dust, a skimmer is added. In order to avoid machine damage and product quality deterioration, the mixture in circulation is changed every 24 hours. This mixture is wastewater with a high COD value of 11 200 - 20800 mg/L, a turbidity of 260-870 NTU, and a colour of about 200 mg/L. For their treatment, a coagulation process using mainly aluminum coagulants and advanced oxidation processes (AOPs) used of Fenton reagents were applied.

Keywords: organic substances, wastewater treatment, advanced oxidation process, Fenton reagent

1. Introduction

The most popular forms of plastic processing are the methods using the phenomenon of their flow at elevated temperatures (e.g. injection moulding, casting) (Wilczyński, 2000). However, there are products made of plastic, whose main production process is machining, which requires the use of coolant. An example of such products are plastic eyeglass lenses. The production wastewater containing chips, dust, water, coolant and skimmer is directed to a sewer. If such wastewater contains fine suspended solids or colloids, it can clog the sewer it is discharged through. Synthetic coolants and oil-in-water emulsion coolants, mostly semi-synthetic, less commonly mineral, are used for machining plastics. Used emulsions and coolants should not be discharged into the sewerage system, among others due to the difficulties they may cause in municipal sewage treatment plants. They are characterised by a high content of chain hydrocarbon compounds, due to which the COD value may be as high as several hundred thousand mg O_2/L, which may lead to a significant change in the load of organic pollutants in biological reactor of the treatment plant. Further problems may arise in the sludge management. Oils contained in emulsions interfere with methane digestion of sludge . Besides, carcinogenic substances are present in some coolants . The oil phase emitted in the sewage pipes can lead to clogging . For these reasons, used coolants (especially emulsion coolants) should be treated before discharge into the sewage system, or they should be collected and taken back by specialised companies. The treatment of such wastewater can be carried out by chemical way (e.g. coagulation or advanced oxidation processes). Fenton may be considered as a one of the most effective advanced treatment processes in the removal of hazardous organic pollutants from wastewater. (Xu et al., 2020)

2. Materials and Methods

Wastewater from the production of plastic eyeglass lenses was tested. The wastewater was sampled from the synthetic coolant circuit, just before it was replaced. The raw wastewater was characterized by a pH value of 8.33-

8.84, turbidity of 260-870 NTU, color of about 200 mg/l, and COD of 11 200 - 20 800 mg/l. The analysis of wastewater parameters were made according to standards methods. The experiment was divided into two main stages that would cover the following analytical tasks:

1) coagulation process using coagulants: PAX18, PAX XL 19-H, Tanflock SG, (stages I-III);

2) advanced oxidation process using Fenton reaction, (stages IV-VI).

Coagulant doses of 0.2; 0.4; 0.6 and 0.8 ml/l were used in the process. The destabilization time was 1 minute, flocculation time was 15- 30 minutes and sedimentation time was 30 minutes.

Due to the limited effectiveness of coagulation in reducing organic compounds, it was decided to test the susceptibility of wastewater to treatment by advanced oxidation processes using Fenton's reagent. In series IV, reagent doses were used so that the weight ratio of Fe^{+2}/H_2O_2 was 0.125, with a reaction time of 15 min. In series V and VI, the reagent doses were changed, the reaction time was increased to 1 and 2 h (Cetinkaya et al., 2018), and the alkalinisation of the samples was changed.

3. Results and Discussion

3.1. Coagulation process

The results obtained in series I-III for the coagulation process are shown in Tables 1-3.

Table 1 Wastewater quality after coagulation process - **series I**

Parameter	Unit	Raw wastewater	PAX 18				PAX XL 19-H				Tanflock SG			
Dose	mL/L	-	0,2	0,4	0,6	0,8	0,2	0,4	0,6	0,8	0,2	0,4	0,6	0,8
pH	-	8,41	8,04	7,9	7,86	7,57	8,33	8,26	8,11	7,97	8,19	8,2	8,2	8,2
COD	mg O_2/L	13600	4320	4720	4640	4280	4240	4800	4640	4320	4800	4720	4880	4720
COD reduction	%	-	68,2	65,3	65,9	68,5	68,8	64,7	65,9	68,2	64,7	65,3	64,1	65,3
Turbidity	NTU	870	8	14	23	15	13	15	11	10	17,2	19,5	21,2	20
Colour	mg Pt/L	200	25	25	22	22	25	22	20	20	25	27	27	30
Sludge	mL/L	-	70	90	113	123	91	127	129	187	97	99	111	96

In series I, the flocculation time was 15 minutes. For each of the applied coagulants and successive doses, after the process similar values of COD in treated wastewater were obtained in the range of 4240-4880 mgO_2/L, and percentage reduction in the range of 64.1-68.5%. During this series, there was no influence of the dose or the type of coagulant on the efficiency of organic compound removal from wastewater. The undoubted advantage of conducting the process was to obtain treated wastewater with very low turbidity in the range of 8-20 NTU, which will not have the ability to precipitate suspended solids in the sewer.

In the second series, with the same doses of coagulant and extended flocculation time to 30 minutes, a lower reduction of organic compounds was obtained with a range of 29.1-34.5%. Achieving such a low reduction in COD values may be influenced by changing the coolant or surfactant used in the production process.

Table 2 Wastewater quality after coagulation process - **series II**

Parameter	Unit	Raw wastewater	PAX 18				PAX XL 19-H				Tanflock SG			
Dose	mL/L	-	0,2	0,4	0,6	0,8	0,2	0,4	0,6	0,8	0,2	0,4	0,6	0,8
pH	-	8,84	8,38	8,33	8,37	8,34	8,55	8,47	8,47	8,41	8,6	8,59	8,56	8,56
COD	mg O_2/L	13200	9040	8880	9120	8800	9040	8800	8800	8960	8640	8880	9200	9360
COD reduction	%	-	31,5	32,7	30,9	33,3	31,5	33,3	33,3	32,1	34,5	32,7	30,3	29,1
Turbidity	NTU	490	7,2	14,7	13,8	7,1	6,2	5,7	5,1	6,4	9,4	12,9	15,2	33,2
Colour	mg Pt/L	200	27	27	25	25	25	25	23	27	30	35	40	40
Sludge	mL/L	-	44	62	90	104	35	51	66	82	14	7	25	10

In series III, the efficiency of the coagulation process (at 30 minutes flocculation) was checked for the highest doses - 0.8 mL/L. Again, no differences in process efficiency were observed depending on the coagulant used. In the case of aluminum coagulants, the COD removal efficiency was about 55%, while for Tanfloc SG - 53%.

Table 3 Wastewater quality after coagulation process - **series III**

Parameter	Unit	**Raw wastewater**	**PAX 18**	**PAX XL 19-H**	**Tanflock SG**
Dose	mL/L	-	0,8	0,8	0,8
pH	-	8,43	8,13	8,25	8,37
COD	mg O_2/L	20800	9280	9200	9600
COD reduction	%	-	55,4	55,8	53,8
Turbidity	NTU	490	5,5	10,1	15,4
Colour	mg Pt/L	200	27	27	40
Sludge	mL/L	-	120	101	51

3.2. Advanced oxidation process using the Fenton reaction

The results obtained in series IV-VI are shown in Tables 4-6.

Table 4. Wastewater quality after advanced oxidation processes using Fenton reagents - **series IV**

Parameter	Unit	**Raw wastewater**	**Fenton D_1**	**Fenton D_2**	**Fenton D_3**	**Fenton D_4**	**Fenton D_5**	**Fenton D_6**
Dose	mg H_2O_2/L	-	288	576	846	1100	1176	1768
	mg $FeSO_4$/L		100	200	300	300	400	600
pH	-	8,62	8,02	8,09	8,2	8,16	8,2	8,2
COD	mg O_2/L	13600	9280	9440	9120	8480	9120	8800
COD reduction	%	-	31,8	30,6	32,9	37,6	32,9	35,3
Turbidity	NTU	260	1,08	1,08	1,05	0,95	0,92	1,67
Colour	mg Pt/L	170	22	25	30	30	35	40

Series IV was treated as an exploratory series. During the experiment, the colour of the sample changed (milky white colour after lowering the pH to 3.0, dark blue after adding FeSO4, and red after adding H2O2). During a 15 minute reaction, a reduction in COD values in the range of 30.6-37.6% was obtained. In the next series, the reagent doses and Fe+2/H2O2 ratios were increased. The oxidation time was extended to 1 hour (series V) and 2 hours (series VI). Another factor whose influence was studied, was the method of alkalinisation. After oxidation, the samples sedimented for 30 minutes. The pH was then corrected to approximimately 8 in two ways: the samples containing sludge and the samples containing just decanted liquid.

Table 5 Wastewater quality after advanced oxidation processes using Fenton reagents (t_{r1} = 1h) - **series IV**

Parameter	Unit	**Raw waste water**	**Fenton D_1**		**Fenton D_2**		**Fenton D_3**	
			-	Decanted liquid	-	Decanted liquid	-	Decanted liquid
Dose	mg H_2O_2/L	**-**	3500		3000		2500	
	mg $FeSO_4$/L		1357		1357		1357	
pH	-	8,63	7,85	7,92	7,84	7,93	7,94	7,91
COD	mg O_2/L	11200	5920	6400	6240	7200	5760	6240
COD reduction	%	-	47,1	42,9	44,3	35,7	48,6	44,3
Turbidity	NTU	571	0,48	0,6	0,53	0,38	0,33	0,28
Colour	mg Pt/L	200	40	30	40	30	50	35
Sludge	mL/L	-	54	34	60	62	58	72

Table 6 Wastewater quality after advanced oxidation processes using Fenton reagents (t_{r2} = 2h) - **series V**

Parameter	Unit	Raw waste water	Fenton D_1		Fenton D_2		Fenton D_3	
			-	Decanted liquid	-	Decanted liquid	-	Decanted liquid
Dose	mg H_2O_2/L	-	3500		3000		3000	
	mg $FeSO_4$/L		500		500		600	
pH	-	8,63	8,07	7,93	8,00	7,88	7,93	7,90
COD	mg O_2/L	11200	6560	5600	5760	6000	6080	5520
COD reduction	%	-	41,4	50	48,6	46,4	45,7	50,7
Turbidity	NTU	571	0,57	0,43	0,48	0,47	0,36	0,33
Colour	mg Pt/L	200	40	40	40	40	40	35
Sludge	mL/L	-	110	76	70	74	96	55

Significantly increasing the doses of reactants as well as the reaction time resulted in the reduction of the COD values in the wastewater. In series V, the COD was reduced from 11200 mg O_2/L to values in the range 5520-7200 mg O_2/L (35.7-48.6%). The actual percentage reduction is much lower than that obtained by Sindhi (Sindhi et al., 2014) for wastewater from the textile and pharmaceutical industries. The results of the V series did not show any regularity indicating the influence of reagent dose and oxidation time on treatment efficiency. The influence of the reaction time on the COD reduction is evident in the samples which were alkalinised without sludge. In this case, the COD value is lower in all samples where the pollutants were oxidised for 2h.

4. Conclusions

Coagulation had a good effect of removing suspended solids and colloids from the wastewater, which are responsible for the overgrowth of the sewer. This is the main problem faced by the plant. Due to the simultaneous removal of the largest amount of suspended solids and the greatest reduction in COD values, the dose of 0.8 mL/L proved to be the most effective. The COD reduction of the effluent after the Fenton process was slightly lower. However, increasing the reaction time and the reagent dose resulted in better removal of organic compounds. Further studies are needed to select the appropriate process parameters for the deepened wastewater treatment.

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