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CHARACTERIZATION AND TREATABILITY STUDIES OF CIGARETTE INDUSTRY WASTEWATERS: A CASE STUDY

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ABSTRACT

In this study, the wastewater of one of the cigarette factories in Izmir was characterized and treatability studies were done. The characterization studies of the wastewater showed that the COD, and the pH changes drastically. The chemical treatability studies of the influent wastewater were done by using $Ca(OH)_2$, $FeCl_3$ and Fenton Reagent. The optimum dose of $FeCl_3$ was determined by jar tests. When using $Ca(OH)_2$, the best flocculation, settling behaviour, and the highest COD removal occurred around pH 11. The optimum doses of Fenton Reagent ($FeSO_4$ and H_2O_2) were determined. The supernatants of the previously chemically treated wastewaters were used for biological treatment. According to total COD removal efficiencies and the amount of sludge production during chemical treatment, $FeCl_3$ was found to be the most economical and effective coagulant. Chemical treatment units were designed for a batch and a continuous system. The batch system has more advantages than a continuous system in this case. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Batch system; chemical treatment; cigarette industry; Fenton Reagent; treatability.

INTRODUCTION

Cigarette consumption is high, and increasing in Turkey. In addition to national production industries, foreign investment in this field is increasing, and as a result, there are two foreign cigarette production factories in the city of Izmir.

The purpose of this work is to study the characteristics of the wastewater originating in one of the factories, and to investigate the treatment alternatives. The literature on this subject and on the treatment of this kind of wastewater is almost nil; probably because cigarette production industries operate in a very secretive fashion.

In the existing cigarette factory, three or four different kinds of cigarettes are produced. The wastewater of the cigarette factory is the combination of domestic and process wastewater. The existing wastewater treatment plant consists of an equalization tank, a compact biological unit, and a stabilization pond. For cigarette manufacture, tobacco is first conditioned, ordered or brought into case by adding moisture.

Flavourings are added to the blend by soaking, spraying, or dipping. By the application of spraying, the waste flavourings appear in the form of vapour. The flavourings are allowed to dissolve in water and pumped to the wastewater treatment plant. Flavouring agents consist of glycogenic substances and alcoholic substances. A schematic view of cigarette production is given in Figure 1.

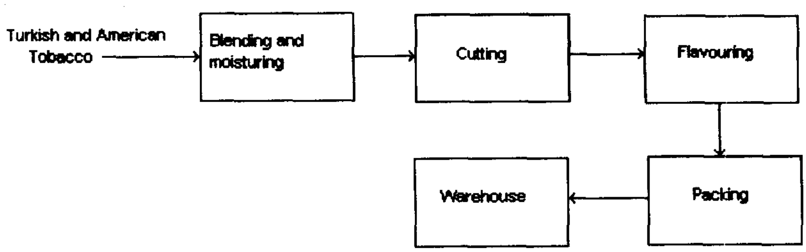

Figure 1. A scheme of cigarette production.

Domestic wastewater originating from restaurants, washing machines, dishwashers, toilets and showers is mixed with process wastewater before reaching the existing wastewater treatment plant. The effluent from the wastewater treatment plant did not comply with the previously set effluent standards.

In the scope of this work, past and present operational problems encountered in the treatment plant have been considered. Previous data collected in relation to wastewater characteristics and treatment plant efficiency were studied and re-evaluated. Numerous composite wastewater samples taken from the inlet pipe of the treatment plant were analysed to determine the fluctuations in wastewater characteristics. Treatability studies were carried out on a variety of samples; chemical treatment alternatives were investigated individually and in conjunction with biological treatment. The chemical treatment units for the wastewater and the appropriate belt filter system for dewatering the chemical sludges were designed.

METHODS

The characteristics of the wastewater were variable. Treatment alternatives were investigated using 24 hour composite samples collected from the inlet pipe of the existing treatment plant. Treatability studies were done for a period of 7 weeks. Treatability studies consisted of the determination of the coagulant or the chemical to be used for chemical treatment, the determination of the optimum doses of the coagulant, and the biological treatment of chemically treated wastewater. Treatment efficiencies were determined separately for each chemical treatment, and the subsequent biological treatment, and the overall treatment was also calculated.

Composite samples were taken by a timed sampler. The sampler was set to take 200 ml of wastewater every 30 minutes for 24 hours. The samples were taken from an open pipe which was located at the entrance of the treatment plant. The total amount of sample taken each day was 9600 ml.

Solutions or suspensions of $Ca(OH)_2$ (Merck), $FeCl_3.6H_2O$ (Horosan Kimya), $FeSO_4.7H_2O$ (Merck) and H_2O_2 (Merck) were used for chemical treatment. Jar tests (Jackson, 1993) were run with each coagulant, and with Fenton Reagent (Kuo, 1992; Lou and Lee, 1995) to determine the optimum doses and optimum conditions for chemical treatment.

The optimum doses of chemicals to be used for chemical treatment were determined and a series of experiments were done, treating samples of wastewater chemically first, and then biologically. These series consisted of 6 experiments using $Ca(OH)_2$, 10 experiments using Fenton Reagent and 10 experiments using $FeCl_3$ prior to biological treatment; therefore a total sum of 26 samples were treated biologically.

pH was measured with a Metrohm pH meter. COD (APHA, 1975) of the wastewater was determined by using Dr. Lange COD apparatus.

Biological treatability studies were done by using a fill-and-draw system, called batch reactor on a laboratory scale. The batch reactor consisted of a one litre beaker, an aquarium air pump, two stone diffusers, and plastic pipes. To grow activated sludge, 500 ml of wastewater were taken from the existing biological unit and mixed with 500 ml of raw wastewater in a beaker. COD and pH values of the mixture were measured at the beginning of the experiment. The mixture was aerated for about 24 hours with an aquarium air pump equipped with stone diffusers. On the second day, aeration was stopped, and the mixture was allowed to settle for 30 minutes. Samples were taken from the supernatant, and COD and pH were measured. Aeration was resumed, and this procedure was continued for 4 days. Neither supernatant nor sludge were poured out during this period. At the end of the 4th day there were 75 ml of activated sludge in the beaker after settling.

To start biological treatment, the supernatant of the previously chemically treated water was poured on the activated sludge obtained in the manner described above. The mixture was aerated for about 17 hours, aeration was stopped and the mixture was allowed to settle for 30 minutes. The supernatant of the mixture was analysed for COD and pH changes, and treatment efficiencies were calculated. The supernatant was drawn off and discarded and another batch of wastewater was added to the settled activated sludge.

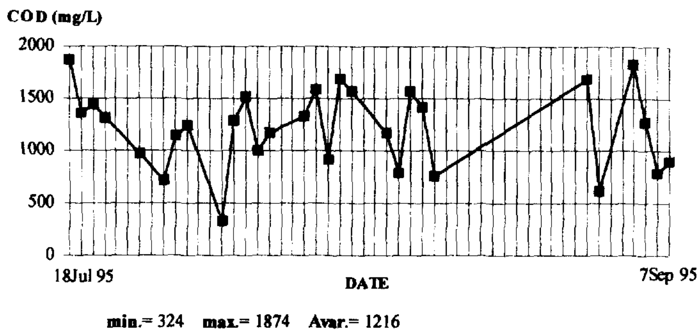

Figure 2. Daily COD variations of influent wastewater.

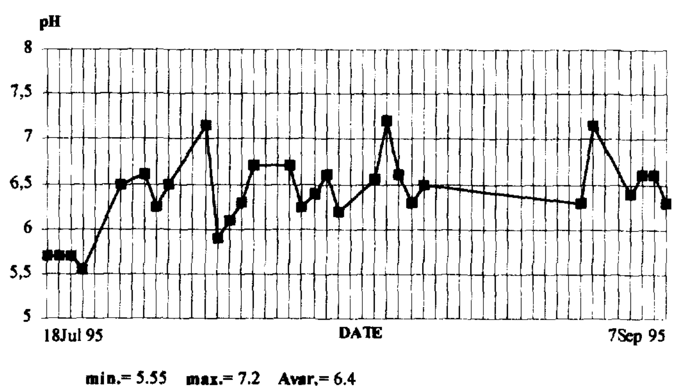

Figure 3. Daily pH variations of influent wastewater.

RESULTS AND DISCUSSION

The characterization studies of the wastewater for the 7 week period showed that COD and pH values are variable. COD changes between 324 mg/l and 1874 mg/l and pH changes between 5.70 to 7.20. Figure 2 shows the COD variations and Figure 3 shows the pH variations of the wastewater.

The chemical treatability studies of the influent wastewater were done with $Ca(OH)_2$, $FeCl_3$ and Fenton Reagent. The optimum dose of $FeCl_3$ was determined to be 200 mg/l by Jar test experiments. By using $Ca(OH)_2$, the optimum pH was around 11. The doses required varied between 100 mg/l to 500 mg/l. In order to determine the optimum doses of Fenton Reagent jar tests were done. The results showed that the optimum dose of $FeSO_4$ was 600 mg/l and the optimum dose of H_2O_2 was 80 mg/l.

The supernatants of the previously chemically treated wastewaters were used for biological treatment. A comparison of the various treatment efficiencies with respect to the coagulant used for the various chemical treatments, together with the corresponding biological treatment efficiencies are shown in Table 1, and the range of treatment efficiencies obtained using various chemicals are given in Table 2.

Table 1. Summary of treatment efficiencies with respect to coagulant

Coagulant	COD in. (mg/L)	COD after Che.Tr (mg/L)	COD after Bio.Tr (mg/L).	Chem. Treat. Effici. %	Biolog. Treat. Effici. %	Total Remo. Effici. %
Fenton	610	320	34	48	89	94
	788	320	65	59	80	92
	912	585	188	36	68	79
	1174	567	76	52	87	94
	1410	672	63	52	91	96
	1514	1038	220	31	79	85
	1572	838	82	47	90	95
	1576	1150	89	27	92	94
	1684	1150	78	32	93	95
	1688	1282	113	24	91	93
$FeCl_3$	610	400	17	34	96	97
	788	450	40	43	91	95
	788	400	40	49	90	95
	1174	674	<60	43	min 91	min 95
	1278	984	60	23	94	95
	1410	722	47	49	93	97
	1572	908	50	42	94	97
	1576	1182	41	25	97	97
	1684	1262	45	25	96	97
	1826	1460	44	20	97	98
$Ca(OH)_2$	610	368	19	40	95	97
	788	454	33	42	93	96
	904	664	51	27	92	94
	1278	1016	55	21	95	96
	1684	1290	44	23	96	97
	1826	1464	70	20	95	96

Table 2. Treatment efficiencies ranges with respect to coagulant

Coagulant	Range of Chemical Treatment Eff. %	Range of Biological Treatment Eff. %	The Range of Overall Treatment Efficiency %
Fenton	24 -59	68 -93	79 - 96
$FeCl_3$	20 - 49	90 - 97	95 - 98
$Ca(OH)_2$	21 -42	92 - 96	94 - 97

The results of chemical treatment efficiencies show that Fenton Reagent has the highest COD treatment efficiencies, but after biological treatment the overall treatment efficiencies are higher for the wastewaters which were chemically treated with $Ca(OH)_2$ and $FeCl_3$.

According to the amount of sludges, iron sludge production (9.9 m^3/day) is less than lime sludge production (21.6 m^3/day). As a result, using $FeCl_3$ as a coagulant in chemical treatment will be more economical, and also more effective for COD removal.

The chemical treatment units were designed for a batch and a continuous system. Because the existing treatment plant is a continuous system, the chemical treatment units were first designed as continuous; but since the wastewater flowrate is small (180 m^3/day), the chemical units were also designed for a batch system. Table 3 shows the volumes of chemical treatment units and the design parameters for the batch and continuous system.

Table 3. Design parameters and volume of units for continuous and batch system

SYSTEM	Continuous				Batch
	Units				
	pH Adj.	Rapid Mix.	Slow Mix.	Settling	
DESIGN PARAMETERS	t=1 min.	t=1 min.	t=30 min	t=60 min.	*F=15 min. R=30 min. S=60 min. D=15 min.
VOLUME (m^3)	0.125	0.125	2.5	7.5	7.5 * 2

In the continuous chemical treatment system, there will be four tanks; pH adjustment tank, rapid mixing tank, slow mixing tank, and settling tank, and the volumes of the tanks will be very small (pH adjustment unit 0.125 m^3, rapid mixing unit 0.125 m^3, slow mixing tank 2.5 m^3, and settling tank 7.5 m^3). Operational problems may occur for small tanks. The batch system will consist of two tanks, each having a volume of 7.5 m^3.

Batch coagulation and flocculation performed in sequencing parallel tanks is generally more efficient than continuous flow treatment. Also batch treatment processes can be easily modified to ever changing conditions (Grau, 1991).

The width of the belt filter was calculated to be 0.75 m from the amount of sludge production; this belt filter can be operated manually, since sludge production is relatively low (9.9 m^3/day).

The biological treatment system following chemical treatment, could be an extended aeration system. This system would also eliminate possible toxic substances, and less sludge would be produced. A view of the recommended treatment plant is given in Figure 4.

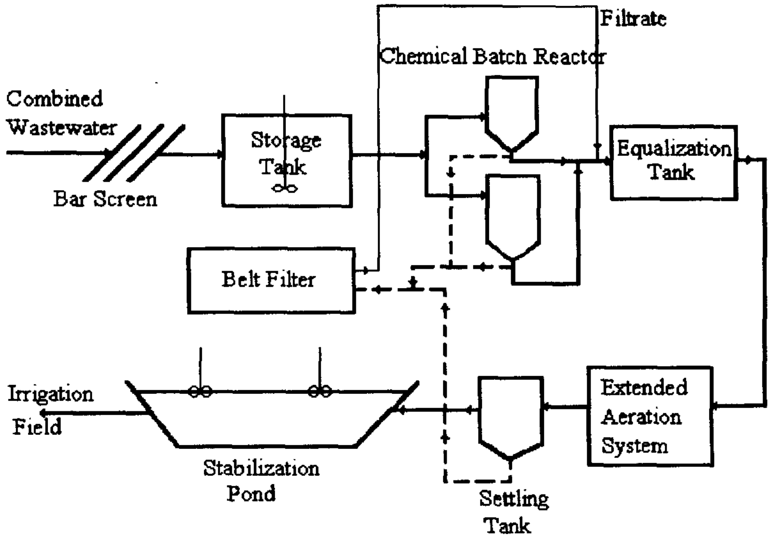

Figure 4. Flow scheme for recommended wastewater treatment plant.

CONCLUSIONS

Great improvements in biological treatment were accomplished by using chemical pretreatment in cigarette factory wastewaters. From the point of view of economics, treatment efficiency, and sludge production, the most suitable coagulant for chemical treatment was determined to be iron III chloride. It should also be noted that very high biological treatment efficiencies were obtained after such pretreatment. Considering the relatively low flowrate in the cigarette factory, a batch system for chemical pretreatment should be preferred over a continuous system. Also there should be an equalization tank since the wastewater characteristics are variable. The biological treatment should be an extended aeration system since possible toxic substances might inhibit the biological activity during shorter retention times.

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