Chemical - biological treatment of polyester textile wastewater (case-study)

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In polyester textile manufacture water is consumed during the different production operations such as fiber preparation, dying, washing, and finishing operations. Other purposes of water consumption are cooling, steam generation beside the domestic use. The aim of this study was determination of an efficient and economic method to treat the wastewater resulted from polyester textile industry. Misr-Spain Company for polyester textile, which located in Shobra El-Kheyma was the studied case. Samples of raw wastewater were withdrawn and analyzed according to the standard methods. The main features of the collected raw wastewater samples were the high value of temperature, pH and COD. A pilot plant was setup as chemical pretreatment followed by activated sludge reactor. The results showed that by using this system 69.3 % COD removal efficiency has been achieved at pH value of 7.38, retention time 18 hours and F/M ratio of 0.36 d-1.

يهدف هذا البحث إلى دراسة خصائص سوائل الصرف الصناعي الناتجة من صناعة أقمشة البولي أستر لإيجاد طريقة ذات كفاءة عالية واقتصادية لمعالجة هذا النوع من المخلفات وقد أختص هذا البحث بشركة مصر أسبانيا بمنطقة شبرا الخيمة كموضوع للدراسة. لتحقيق ذلك تم إنشاء نموذج للبحث المعملي يعتمد على المعالجة الكيميائية الأولية قبل البدء في المعالجة البيولوجية وكان أهم ما يميز هذا النوع من المخلفات هو ارتفاع درجة الحرارة وقلوية للأس الأيدروجيني والتركيز العالي للأكسجين الكيميائي المستهلك. وقد تم تغذية النموذج خلال فترة التجارب المعملية بسوائل الصرف الصناعي المجمعة من بيارة الصرف النهائية بالشركة. تم خفض الحمل العضوي قبل بدء المعالجة البيولوجية مع تثبيت أفضل زمن بقاء المياه في حوض التهوية. وقد أثبتت نتائج البحث المعملي لمعالجة سوائل الصرف الصناعي أن مادة البولي أستر تتأثر بتغيير قيمة الأس الأيدروجيني فباستخدام حامض كبريتيك لخفض الأس الأيدروجيني إلى ٤،٥٠ ينتج عن ذلك ترسيب البولي أستر الذائب وأن المعالجة الكيمائية الأولية تليها المعالجة البيولوجية ومده بقاء المياه في حوض التهوية تساوي ١٨ ساعة تحقق إزالة أكسجين كيميائي مستهلك إلى ٦٩،٣ % عند أس أيدروجيني قيمته ٧،٣٨.

Keywords: Polyester textile, Textile wastewater, COD, Chemical treatment, Biological treatment

1. Introduction

The polyester textile industry is a new technology of textile process using gray fabric made of pure polyester. Gray fabric, in woven or knitted form, is the basic raw material for textile processing. Some units produce their own fabric in their weaving production unit, whereas others get it from weaving mills and carry out only pretreatment, dyeing, printing and finishing operations [1].

In textile industry, the variety of raw materials, chemicals, processes and also technological variations applied to the processes produce complex and dynamic structure of environmental impact on textile industry. These dynamic structures not only affect the characterization and quantity of wastewater and the applied purification technologies but also make it being impossible to focus on a typical kind of wastewater and a standard purification technology. The basic goal of these purification technologies is to disperse the impurities out of the wastewater by one or a combination of physical, chemical or biological method [2].

The main objectives of this research were determination of the most effective method of wastewater treatment to achieve the limits to discharge to the sewer system with low cost. Moreover verifying the ability of the biological treatment process under aerobic conditions to digest the high load of the organic matter found in the polyester wastewater.

2. Materials and methods

2.1. The pilot plant

A pilot plant of activated sludge reactor as shown in fig. 1, was installed in the laboratory at Chemix company for scientific and industrial services to achieve the main objectives of this research. It consists mainly of:

2.1.1. Primary settling tank

Cylindrical tank was used as primary settling tank (diameter = 25cm, height = 60cm, tank volume = 10 liters). The sludge was collected in the bottom (the inverted conical part) in order to be disposed.

2.1.2. Aeration tank

The rectangular aeration tank was divided into two equal square parts (30 cm × 30 cm and depth of water = 27 cm), volume of each part was 24 liters. The air diffusers were connected to the air blowers with polyethylene tubing.

2.1.3. Final settling tank

Cylindrical tank 10 liter volume was used as final settler (diameter = 25cm, height = 60cm). The sludge was collected in the bottom (the inverted conical part) in order to be recycled or disposed.

2.1.4. Feeding pumps

The pilot plant was provided with three pumps:

- The first pump was HANNA (made in Italy) model BL7913 with capacity 4 liters/hour at 5 bars. This pump was used to feed the primary clarifier settler from the feeding tank after adjusting the pH value.
- The second pump was HANNA (made in Italy) model BL7913 with capacity 4 liters/hour at 5 bars. This pump was used to feed the aeration tank from the feeding tank.
- The Third pump was PULSFEEDER (made in U.S.A.) model X100-XB capacity 0.47 liters/hour at 7 bars. This pump was used to return sludge from the final settling tank to the inlet of the aeration tank.

2.1.5. Air supply

The pilot plane was fitted with two air blowers model RENA 301 (France) each capacity up to 2 liter/sec to supply the compressed air for the two parts of the aeration tank.

2.2. Start up procedure

Initially the system was seeded with sludge obtained from the wastewater treatment plant at Coca Cola Egypt Company in Borg-Elarab (extended aeration treatment plant). The sludge was collected from the return sludge sump.

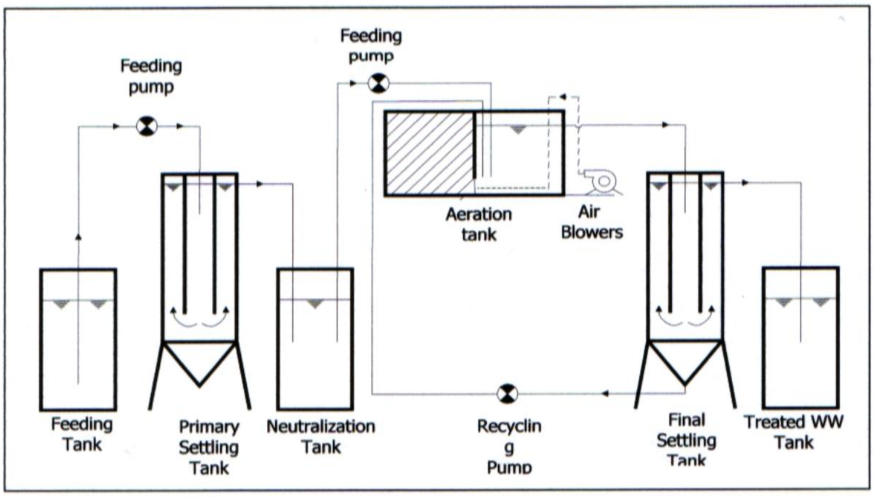

Fig. 1. Pilot plant –chemical-biological treatment.

During the start up period the reactor was fed with raw wastewater and all settled sludge in the final settler was returned into the aeration tank. The steady state conditions were considered achieved by the constancy of the measured parameters within 10 % during a period of 15 days. After this period the efficiency of treatment was almost stable.

2.3. Operating conditions

The operating conditions of the system were as follows:-

- The waste sludge from the mixed liquor suspended solids = 10 % of volume of the aeration tank.
- Sludge age = 10 days.
- The range of dissolved oxygen in the aeration tank was maintained within (1– 3 mg/L).
- Temperature was kept constant at 30 °C.
- The pH was maintained using sulfuric acid between 7.50 and 8.0.

3. Results

3.1. Characteristics of raw wastewater

Before the experimental work, different samples of raw wastewater were collected and characterized carefully to adapt the characteristics of the waste to meet the biological treatment requirements under aerobic conditions. The obtained results were tabulated in table 1.

The characterization of these different samples showed that many parameters are exceeding the allowed limits. This may be due to the use of different types of chemicals in the production processes. This case of polluted wastewater required a careful study to attain a suitable method of treatment.

The influent and effluent samples were collected daily from the aeration tank and the settling tank. All the parameters were determined in accordance with The American Standard Methods for the Examination of Water and Wastewater (The 20th Edition 1998) [3], using required laboratory equipments and SPECTROPHOMETER HACH 2010 [4].

3.2. Chemical treatment

The use of coagulants such as Ferric Chloride [$FeCl_3$] and Aluminum Sulfate [$Al_2(SO_4)_3$] is well known in textile wastewater treatment as a method of chemical treatment. Experimental work has been done to show the effect of these coagulants on wastewater of polyester textile at different pH values. The pH value of the raw wastewater gradually was reduced to the normal value by using diluted sulfuric acid and then the wastewater was subjected it to different dosages of coagulants at different pH values [5]. The obtained results from this research were as follows in table 2.

Table 1
Characteristics of end of pipe wastewater

Parameter	Units	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
BOD_5	mg/l	1645	1771	1974	1866	1715
COD	mg/l	2570	2810	3012	2984	2670
pH		10.82	10.91	11.14	10.85	9.83
Oil & grease	mg/l	29.2	18.8	24.4	32.6	36.8
Temperature	°C	48	42	46	45	39
TSS	mg/l	254	310	367	288	288
TDS	mg/l	1098	1180	1231	1056	1254
Total solids (calculated)	mg/l	1352	1490	1598	1344	1542
PO_4	mg/l	28	24	15.8	21.2	26.8
Ammonia (N)	mg/l	14.2	14.6	10.7	14.9	12.3
Nitrate (N)	mg/l	13.2	15.8	11.9	16.8	12.8
Total Nitrogen (calculated)	mg/l	27.4	30.4	22.6	31.7	25.1
Sulfide	mg/l	14.4	16.3	17.7	28.8	22.3
Color	PtCo	156	185	210	213	192
Surfactant	mg/l	0.06	0.1	0.04	0.07	0.05

Table 2
Effect of Coagulants at Different pH Values

pH value	COD value of		Alum dose mg/l			$FeCl_3$ dose mg/l		
	Raw WW	At pH adjust.	1.0	1.5	2.0	1.0	1.5	2.0
5.0	1422.3	944.3	827.2	760.7	724.3	670.5	625.3	589.3
5.5	1568.7	1120.3	1010.3	934.3	877.3	875. 7	793.3	742.8
6.0	2048.7	1534.8	1406.5	1322.5	1245.3	1250.7	1169.3	1126.3
6.5	2338.7	1826.5	1698.0	1485.7	1459.2	1550.5	1478.8	1409.2

The above results were the average values of six different samples. It was released that the reduction of pH value is necessary to gain the maximum COD removal. This means that the efficiency of the coagulants increases at low pH value, as shown in fig. 2. The maximum removal efficiency was 37.6 % by using 2mg/l of Ferric Chloride at pH value of 5.0. Putting into consideration the economic factor, the cost of using acids to reduce the pH value of the raw wastewater beside the use of coagulants is more expensive than the use of diluted sulfuric acid only. Moreover the addition of chemicals will increase the total dissolved solids of the wastewater.

3.3. Optimization of pH value

In order to optimize the pH value, which gives the best results for settlement of, dissolved polyester three different collected samples were used. The COD values were measured at different pH value, then the relation between the COD removal and different pH values were plotted as shown in fig. 3.

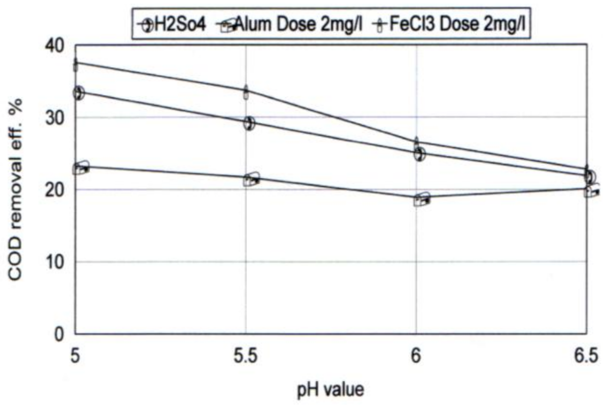

Fig. 2. Effect of different coagulants at different pH value on COD removal efficiency %.

The figure clarified that a sudden settlement of the dissolved polyester has been attained at pH value of 4.50, the COD removal efficiency approximately for the three samples was doubled at pH 4.5. Increasing the sulfuric acid dose to reduce the pH value to 2.0 increased the COD removal efficiency. From the view of economic side it is recommended to reduce the acid dose to decrease the running cost, so the pH value selected was kept at 4.50.

3.4. Chemical - biological treatment

In order to decrease the value of the non-biodegradable organic matters before the biological treatment, pH value of the wastewater was optimized at 4.50 using diluted sulfuric acid and then transferred to the first settling tank. The clarified wastewater was colleted through an overflow pipe into another tank and its pH value was adjusted again using diluted caustic soda (NaOH) to raise pH value to 7.5 – 8.5, to start the biological treatment at a suitable pH value. Fig. 4 shows the schematic diagram of the chemical – biological treatment. After the chemical treatment, the Hydraulic retention time of the aeration tank was adjusted to be 18 hours under the following conditions:

- The influent flow rate =1.33 l/hr
- Recycle sludge ratio =20%
- The hydraulic retention time =18 hr
- Adjusted temperature =30 °C
- Dissolved Oxygen value =2 - 4 mg/l
- Volume of aeration tank = 24 liter

$$F/M = \frac{mg.BOD/d}{mgMLSS} = \frac{Q_{in} \times BOD_{in}}{V \times MLSS} \quad d^{-1} \text{---}[1]$$

$$F/M = \frac{1.33 \times 24 \times 0.64 \times COD_{in}}{24 \times MLSS} = \frac{0.85 \times COD_{in}}{MLSS} \quad d^{-1}$$

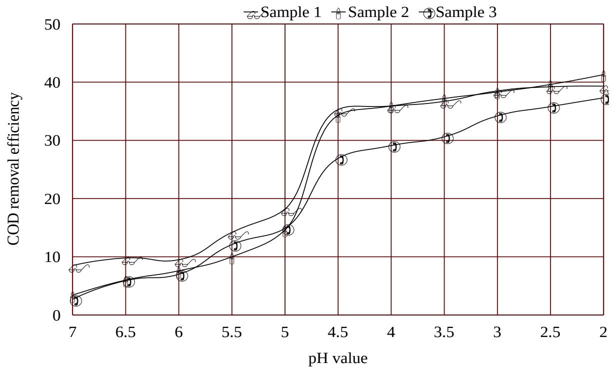

Fig. 3. Relation between pH value and efficiency of COD removal.

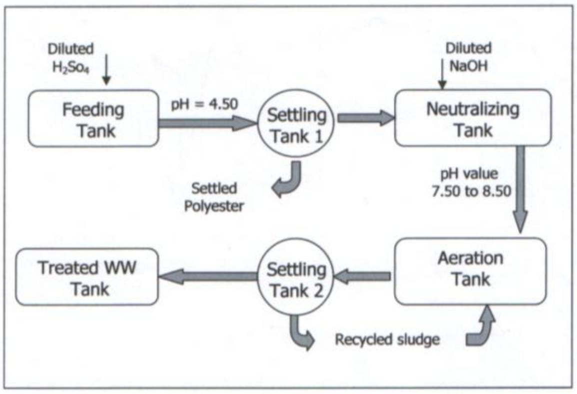

Fig. 4. Schematic diagram of the chemical-biological treatment system.

Where,

F/M is the food to microorganisms ratio,
MLSS is the mixed liquor suspended solids, and
Q is the flow of wastewater.

During this process the COD values were measured daily at the following points:

• First feeding tank, to measure COD of the raw wastewater before treatment.
• The neutralization tank, to measure the COD after settling of the polyester and before the biological treatment.
• The final collecting tank of the treated wastewater after the biological treatment.

4. Discussion

The results obtained from this process, chemical pretreatment followed by biological treatment at hydraulic retention time (HRT) of 18 hours showed a noticeable improvement in the treatment as a whole. This improvement can be summarized as follows:

4.1. COD removal efficiency

The chemical pretreatment using sulfuric acid gave COD removal efficiency up to 39.8%. Biological treatment after the chemical treatment also improved, the COD removal up to 49.9 %. The total COD removal efficiency of the whole treatment process reached 69.3 % in average as shown in fig. 5.

4.2. F/M ratio

As shown in fig 6, the F/M ratio has been improved due to chemical pretreatment. The maximum value of F/M ratio was 0.404, the minimum value was 0.358, and the average value was 0.382. These results compiled with the standard treatment, which recommend that F/M ratio must be in the range of 0.2 to 0.4 day^{-1} [6].

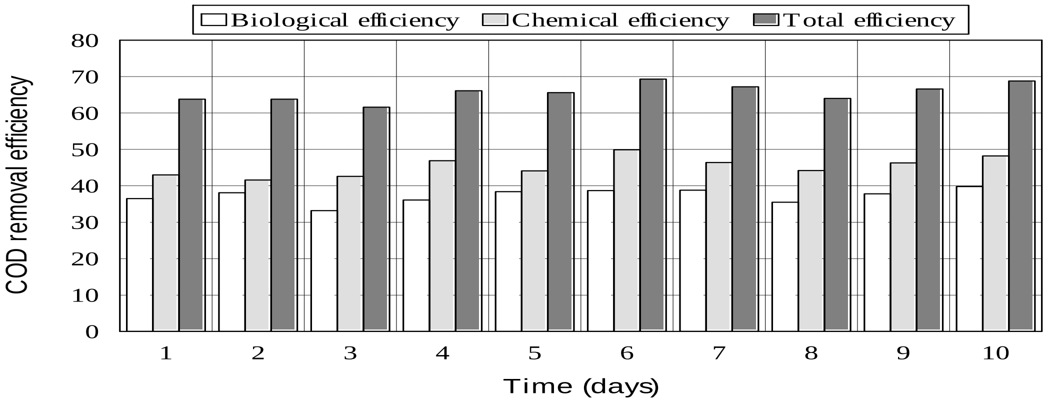

Fig. 5. performance of chemicl-biological treatment process.

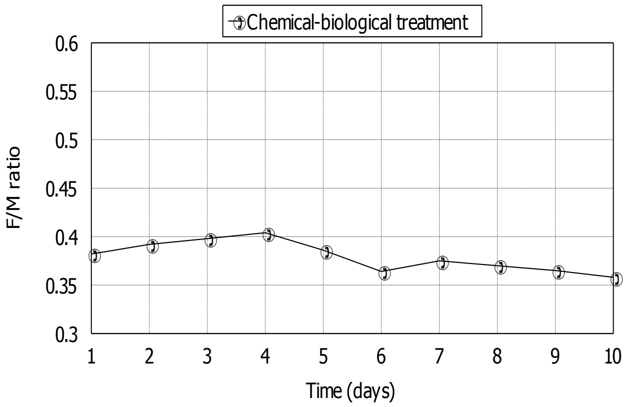

Fig. 6. Improvement of F/M ratio.

As the value of F/M ratio was varying between 0.30 to 0.40, the operating system can be classified as conventional activated sludge.

5. Conclusions

The results obtained from experimental work showed that:

• As economic point of view the hydraulic retention time in the aeration tank was 18 hours.
• Polyester is very sensitive to pH value, using sulfuric acid to reduce pH value up to 4.50 forces dissolved polyester to precipitate.
• Combined treatment process, chemical treatment followed by biological treatment at HRT 18 hours fulfilled the law legislation.
• The recommended treatment method obtained from this research using both chemical and biological methods, has the following advantages:
• The running cost of the chemicals is very low compared with the use of coagulants and coagulants aid.
• The low HRT would reduce the capital cost of the treatment unit compared with other hydraulic retention times.
• In the field, the required dose of sulfuric acid can be easily controlled using pH controller unit.

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