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BIOCHEMICAL TREATMENT OF TEXTILE INDUSTRIAL WASTEWATER

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ABSTRACT

Textile industry production of a wide range of polluting dye waste is considered one threatening polluting water industry. The accelerated development of textile industries is enhancing higher rate of water pollution in the environment. A treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques. The main objectives of this study to management and control of liquid and solid wastes in the industry as well as find a sustainable solution for the textile industrial wastewater in order to comply with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network.

The results of the analysis indicated that the wastewater is characterized by its high temperature, COD and relatively high alkalinity. COD values ranged from 993 to 1606 mg/l with an average value of 1047 mg/l depending upon the on-going operations. Corresponding BOD values varied from 235 to 600 mg/l with an average value of 422 mg/l. Oil & grease concentrations, of more than 90% of the samples exceeded the consent standards. In general all examined samples were not complying with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network.Accordingly, treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using the proposed stages of treatment includes primary treatment (plain settling), chemical treatment, and biological treatment. As results from the treatability study, the most appropriate treatment techniques were conducted by chemical coagulation using ferric chloride and lime followed by sedimentation brings the wastewater quality to the acceptable limits. The results obtained, the use of Ferric Chloride aided with Lime is the highly effective dose to reduce COD, BOD, TTP, TSS, and O&G level by almost 57%, 64%, 33%, 14.5%, and 8.7% respectively. The quality of the treated effluent is complying the regulatory limits for discharging industrial effluent to public sewer. As a conclusion, from the study, it is concluded that the physico-chemical treatment process is the most reliable alternative treatment method for this kind of industry.

Keywords: Textile Industry, Biological Treatment, Chemical Treatment, Industrial Wastewater Treatment, Cleaner Production.

I. INTRODUCTION

In wastewater treatment, removal of resistant organic compounds and hazardous inorganic material such as the heavy metals is paid a special attention. The effluents from dyes, textile, and pulp and paper industries are densely colored due to the presence of residual dyes which are designed to be resistant to environmental conditions like light, effects of pH and microbial attack and are micro toxic to aquatic life since they significantly affect photosynthetic activity in aquatic life by reducing light penetration **[1]**.Among the most important sources of water pollution, industrial wastes are of great concern. Textile industry production of a wide range of polluting dye waste is considered one threatening polluting water industry **[2].** The accelerated development of textile industries is enhancing higher rate of water pollution in the environment **[3].**There is a major concern about the discharge of textile dye effluent after textile processing owing to consumption of the large volumes of water. For the discharge of colour effluent, discharge of colour is also included in the water quality standards in Malaysia **[4].** Textile dye wastewater treatment is still a main concern owing to the synthetic nature of dyes, which is very difficult to treat with conventional treatment techniques **[5].**In recent years, the

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textile industry has devoted important effort to minimize wastewater produced during preparation, dyeing, and finishing processes. These effluents show, in general, high amounts of organic matter, conductivity, and color **[6, 7].**

It is of great interest to treat textile effluents owing to aesthetic and hazardous effects on receiving waters. Many research works have been carried out to develop an effective treatment technology, but owing to the mixture of different dyes in dye wastewater, no solo technique is effective for the removal of dyes from dye wastewater **[4].**Many studies have been done on purification methods of industrial wastewater containing hazardous substances such as azo dyes that are chemically stable and hardly biodegradable under aerobic conditions. Wastewater treatment using advanced oxidation process is of the safest methods in this field **[2].** A number of hazardous synthetic dyes (cationic as well as anionic) have been manufactured with high production rate. Their wide use and untreated discharge from the industries are found to be the prominent sources of water pollution. The relatively high use of dyes is observed in Asian countries. To eliminate their negative impacts, the extensive use of nanomaterial was observed for oxidative degradation/removal of dyes from wastewater **[8].**

Main source is the extensive use of harmful dyes and dyestuffs in various sectors such as textile, cosmetics, paper, food processing and drug industries **[9].** The untreated discharged dyes (around 10%) impart an intense color even at a low concentration (less than 1 ppm), thereby making the water highly detrimental **[10, 11].** The dissolved oxygen level gets reduced because the molecules of dyes prevent sunlight to the bulk of water system. The contaminated water also has an increased biological oxygen demand **[11].**Textile effluents have complex compositions. The high concentrations of organic compounds with recalcitrant and non-biodegradable properties as dye **[12],** surfactants **[13]**, fabric softener, etc., as well as the presence of inorganic matter such as chlorine and chloride, sulfates, phosphates, carbonates, and metals **[14]**, produce high pH levels and make organic matter stable, making it difficult to remove from water. The denim garment industry is the principal sectors that use indigo blue dye, which is an organic compound that exhibits toxic properties in aquatic systems **[15]**.

Several conventional technologies have been used for the treatment of textile effluents, among them physical **[16]**, chemical **[17]**, and biological processes **[18**,**19**,**20]**. Although the physical-chemical treatments are in most cases able to remove the color of the textile effluents, bioprocesses have been demonstrated as less efficient, due to non-biodegradable and/or toxic nature of the effluents. Most of the biological, physical and chemical techniques used for dye removal work either via adsorption on solid supports, into sludge, or complete degradation of the dye molecule. Recently, the main techniques used to treat textile wastewaters are chemical or chemical-physical as membrane filtration, adsorption, ion exchange, electrolysis, advanced chemical oxidation and chemical reduction **[21].**Yun et al. studied the treatment of dye wastewater in aerobic submerged membrane bioreactor. They found that the average chemical oxygen demand (COD) and dye removal was 94.8 % and 86.6 %, respectively **[22].**

A large portion of water is consumed during various textile operations thereby discharging wastewaters with pollutants of huge environmental concern. The treatment of such wastewaters has promising impact in the field of environmental engineering. In this work, Fenton oxidation treatment was engaged to treat simulated textile wastewater. It was found relevant to use Fenton treatment for simulated textile wastewater. Viewing the results, Fenton treatment will prove as a reasonable method as a pretreatment to textile wastewater where direct biological oxidation is not possible due to the presence of recalcitrant organic molecules of dyes **[23].**Study is aimed at defining the best option of a combination of electrochemical and biological processes for tannery wastewater treatment. Placing the electrochemical reactor as a final polishing stage after the conventional biological aerobic sludge process (designed for the removal of COD) allows 80% reduction of the total volume of the plant **[24]**

Study was conducted to biologically treat wastewater discharged from the textile industry (textiles made of cotton and/or synthetic fiber) using sequencing batch reactor (SBR) technology (activated sludge process operating on batch mode). A bench-scale pilot plant was used to study the performance of SBR by monitoring the settleability and change in the constituents (chemical oxygen demand and solids) over time. Results of the study showed that textile wastewater has different types of pollutants: heat, basicity, suspended solids, organic and inorganic matter, and heavy metals **[25].** Over the past century, over 10,000 different synthetic dyes and pigments have been developed and applied for common use in industries such as textile dyeing, paper printing, plastics, and leather industries, with approximately 0.7 million tons of dyestuff manufactured each year

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[26]. Activated carbon included an array of Cu/Cu electrodes (AC-Cu) showed better results; in aqueous solutions, the removal efficiencies of dye were above 90% at 1.5 h, whereas for textile wastewater the dye removal efficiency reached 93% after 4 h of treatment **[27].**

Manufacturing of leather and leather goods produces numerous by-products, solid wastes, high amounts of wastewater containing different loads of pollutants and emissions into the air **[28]**.Removal efficiencies of Biological Treatment of Leather-Tanning Industrial Wastewater Using Free Living Bacteria were significantly and proportionally correlated with time regardless of bacterial species or parameters. However, bulk changes in all parameters were achieved within the first 24 h. The highest removals recorded were 86.7, 94.14%, 79.16, 95.64, 36.33, 93.66 and 44.91% for total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fat, oil and grease (FOG), ammonia (NH3), chromium (Cr) and hydrogen sulphide (H2S), respectively after only 24 h. On the other hand, total dissolved solids (TDS) and nitrates (NO3) recorded the highest increase (97.68 and 45.87%) after one and 7 days, respectively **[29, 30]**. The conventional biological treatment systems in use for tannery wastewater are either inadequate or less cost-effective due to the large variations in tanning practices and the kinds of chemicals used in the process. It has been well documented that sequencing batch reactor (SBR) system as an attractive option due to its greater flexibility and cost effectiveness **[31, 32]**.

II. STATEMENT OF THE ENVIRONMENTAL PROBLEM

The textile industry is committed to reducing environmental impacts of their activities, and to continuously improve their environmental performance and to meeting or exceeding the requirements of all applicable environmental laws and regulation. The industry has no wastewater treatment plant and the wastewater is discharged directly to the sewer system. The results of the lab analysis of the industrial wastewater effluent indicated that the wastewater is characterized by its high temperature and relatively high alkalinity. COD values and oil & grease concentrations of some examined samples are above the limits of the Egyptian Environmental Regulation (Decree 44/2000).In general most of the examined samples were not complying with the consent standards. Accordingly, the industry has to treat the wastewater prior to its discharge to the wastewater sanitary network.

III. OBJECTIVES OF THE STUDY

Environmental management projects require economic integrated approach including the combination of in–process, in–plant and end–of–pipe treatment modules to comply with environmental regulations.

The main objectives of this study to management and control of liquid and solid wastes in the industry as well as find a sustainable solution for the textile industrial wastewater in order to comply with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network to protect the environment as well asselecting the wastewater streams that need to be treated prior to its discharge, identifying the different possible treatment trains for the wastewater, conducting treatability analysis for investigating the feasibility of each of the identified trains, selecting the most suitable treatment train, and developing the basic design for the selected treatment train. The study is conducted through very precise characterization of the wastewater produced from the final effluent during the working shifts and application of appropriate treatment options for the end-of-pipe using different treatment techniques in order to protect the environment.

IV. MATERIALS AND METHODS

To achieve the above objectives the following tasks are considered the following: assessment of the liquid effluent in terms of flow and characteristics and suggest, if necessary, study thoroughly main sources of wastewater contaminants and to suggest any in-process and in-plant modifications to reduce pollution load prior the end-of-pipe treatment system, evaluate the current environmental conditions in the production and service units to determine the industry required to upgrade these units in order to reduce pollution load in the final effluent, data collection including the collection of information relevant to the different activities in the industry, collecting composite wastewater samples from the end-of-pipe industrial effluent, check on the compliance with national environmental regulation and legislation and description of the existing environmental situation in the industry, conduct a treatability study on the combined end-of-pipe effluents from the industry, suggest feasible alternative schemes for remedial measures combining in-process and in-plant modules to solve environmental pollution problems, as well as carry out evaluation for the feasible alternative schemes of the proposed treatment

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systems. Accordingly, an audit program was carried out to monitor the environmentally damaged activities, compliance with legislation, opportunities for reductions.

Description of the industry process:
The industry processes about 3000-3500 t/year of knitted fabric (95% cotton and 5% cotton blend). Ratio of 30-40% of the product is full white and 70-60% is colored product. Average annual major raw materials are: base chemicals (516 t); sodium chloride (900-1000 t); auxiliaries, (320 t) and reactive dyestuffs (80-100 t). Water consumption is estimated to be about 1800-2000 m3/day while the estimated wastewater effluent is about 1800 m3/day.

Sampling and characterization of wastewater
The main objective of the analysis is to investigate the compliance of the wastewater with the limits for discharge to the public sewer system, and in case of noncompliance identify and evaluate alternatives for management of the wastewater to reach compliance.For investigating the compliance of the discharged wastewater and identifying possible alternatives for its management, the sampling and analysis carried out through groups of composite samples were collected to conduct the chemical analyses and the treatability studies. The samples were taken from different waste streams from the industry. The analyses were carried out according to the Standard Methods for Examination of Water and Wastewater and coveredtemperature, pH, oil and grease,chemical and biological oxygen demand (COD and BOD), total dissolvedand suspended solids (TDSand TSS), soluble sulfides, phosphates and total nitrogen.

Treatability Study andTreatment Procedure
The treatability study and analysis was conducted on the composite samples collected from industry effluent for investigating the feasibility of each of identifying the different possible treatment trains, selecting the most suitable treatment train need to be treated prior to its discharge to the sewer system. As well as treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using the proposed stages of treatmentincludes primary treatment (plain settling), chemical treatment, and biological treatment.

V. RESULTS AND DISCUSSION

Characterization of Liquid Wastewater and Assessment of Compliance of Industrial Wastewater
For investigating the compliance of the discharged wastewater, the sampling and analysis carried out for the wastewater in the industry was conducted as composite samples and analysis of the wastewater effluents.The results of the analysis indicated that the wastewater is characterized by its high temperature, COD and relatively high alkalinity. COD values ranged from 993 to 1606 mg/l with an average value of 1047 mg/l depending upon the on-going operations. Corresponding BOD values varied from 235 to 600 mg/l with an average value of 422 mg/l. Oil & grease concentrations, of more than 90% of the samples exceeded the consent standards. In general all examined samples were not complying with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network. Analysis of the composite wastewater samples from wastewater effluentsis shown in following tables and figures representing the minimum, average and maximum values of analysis results.

Table 1: the Minimum, Average and Maximum Values of Sample Analysis

Parameters	**Min.**	**Average**	**Maximum**	**Law 93/62 & Decree 44/2000** For discharging to Public Sewer
Temp	48.54	53.1	57.5	43
PH	9.5	9.2	10.2	6.5 - 9
BOD, mg/l	235	422	600	600
COD, mg/l	993	1047	1606	1100
TSS, mg/l	65	132.4	238	800

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Parameters	Min.	Average	Maximum	Law 93/62 & Decree 44/2000 For discharging to Public Sewer
TDS, mg/l	3534	4859	9344	NA
O&G, mg/l	103	133.5	198	100
Sulfides, mg/l	3.2	6.9	18	10
Total Nitrogen (TKN), mg/l	10.26	20.57	28.56	100
Phosphates (TP), mg/l	0.26	3.3	4.8	25

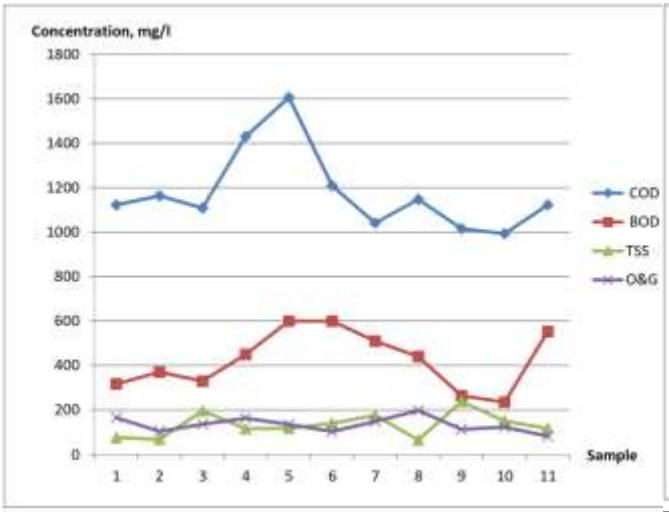

Figure 1-a: Pollutants Concentrations (COD, BOD,TSS,O&G)

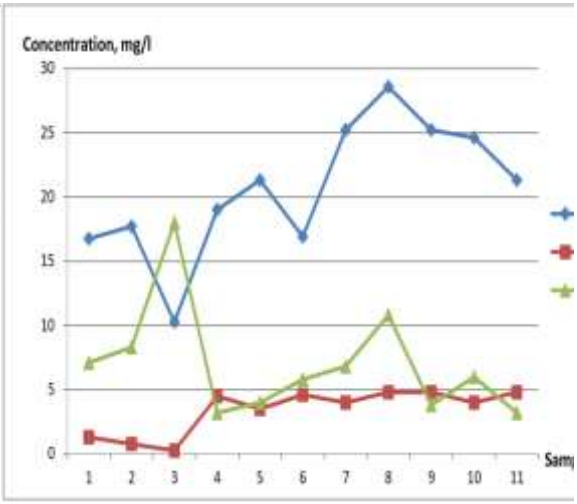

Figure 1-b: Pollutants Concentrations (TKN, TP, Sulfides)

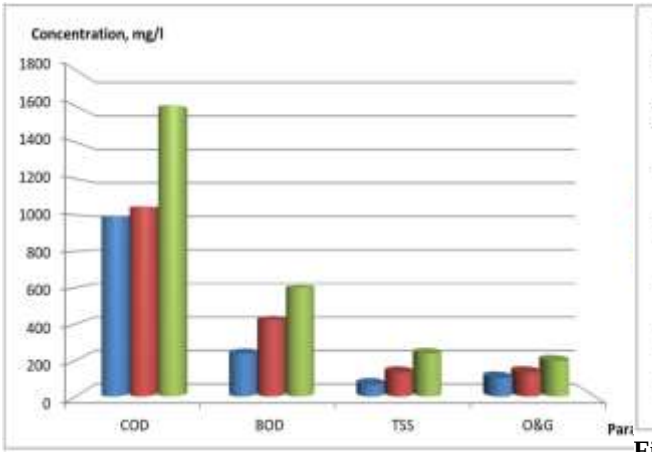

Figure 2: Limits of Biological, Chemical Oxygen, and Total Suspended Solids Concentrations

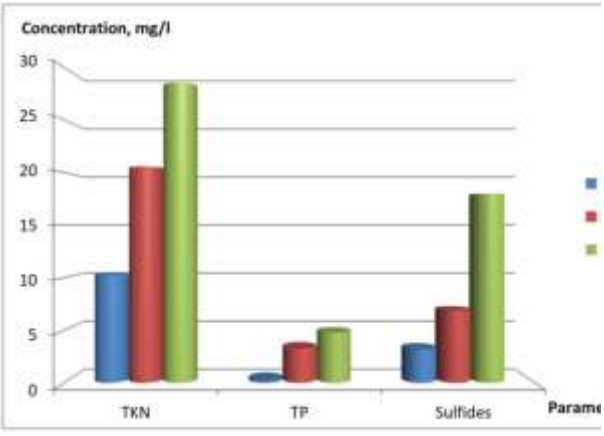

Figure 3: Limits of Total Nitrogen, Phosphates, and SulfidesConcentrations

Treatability Study and Identification of Possible Treatment Schemes

Alternatives for management and treatment of the discharged wastewater effluentsto the limits of the Egyptian Environmental Regulation (Decree 44/2000) will be identified and assessed to investigate their feasibility from environmental and technical perspectives. The most appropriate treatment techniques were conducted using

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proposed stages of treatment includes primary treatment (plain settling), chemical treatment, and biological treatment using a bench scale biological reactor.

- ***Chemical Treatment (Coagulation/Sedimentation)***

The coagulants used for this study were: ferric chloride, ferric chloride aided with lime, ferrous sulphate and ferrous sulphate aided with lime. The optimum pH-value and coagulant dose were determined for each coagulant. The Jar-Test was used for this purpose. Characteristics of the chemically treated effluent were determined after 60 minutes settlement. Samples for analyses were taken by means of a suction device allowing the withdrawal of accurate amounts from all jars at the same time.

Use of Ferric Chloride aided with Lime:Available data indicated that the optimum pH-value was 8.5. The highest COD removal was achieved using ferric chloride and lime doses of 300 mg/l and 87.5 mg/l, respectively. Pendent on the predetermined optimum conditions complete analyses of the chemically treated effluent was carried COD and BOD removal rates reached 57 % and 64 %, respectively. Oil & grease and extractable matter by chloroform removal values were only 8.7 % with corresponding average residual values of 75 mg/l. This is attributed to the fact that pigments are extracted with chloroform. However, the quality of the treated effluent is complying with the consent standards as shown in the following table-2.However, the results show that the use of Ferric Chloride aided with Lime is the highly effective dose to reduce COD, BOD, TTP, TSS, and O&G level by almost 57%, 64%, 33%, 14.5%, and 8.7%respectively.The quality of the treated effluent is complying the regulatory limits for discharging industrial effluent to public sewer.

Table 2: Efficiency of chemical coagulation/sedimentation using Ferric Chloride aided with Lime

Parameter	Unit	Industrial wastewater	Av. Treated effluent	Standards Limits	% Removal
pH	----	10.1	8.45	6-9.5	----
COD	mg/l	1122	483	1,100	56.95
BOD	mg/l	552	200	600	63.7
TP	mg/l	4.8	3.2	25	33.3
TSS	mg/l	117	100	800	14.5
Oil & Grease	mg /l	82.2	75	100	8.7

Use of Ferrous Sulfate Aided with Lime:The ferrous sulfate dose of 250 mg/l aided with 200 mg/l lime, are the optimum values. COD and BOD removal rates reached 30% and 45.7 , with a corresponding average residual values of 753 and 300 mg/l, respectively. Oil & grease and extractable matter by chloroform removal values reached 54.9% with a corresponding average residual values of 37 mg/l. It is worth mentioning that the pH-value of the treated wastewater was higher than the consent standard. Therefore, adjustment of the pH was carried out using sulfuric acid (1.0 ml/l Sulfuric acid 30%). The results of the test are given in the following table-3. The quality of the treated effluent is complying the regulatory limits for discharging industrial effluent to public sewer.

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Table 3: Efficiency of chemical coagulation/sedimentation using Ferric Sulfate aided with Lime

Parameter	Unit	Industrial wastewater	Av. Treated effluent	Standards Limits	% Removal
pH	----	10.1	8.45	6-9.5	----
COD	mg/l	1122	753	1,100	32.9
BOD	mg/l	552	300	600	45.7
TP	mg/l	4.8	2.4	25	50
TSS	mg/l	117	228	800	14.5
Oil & Grease	mg/l	82.2	37	100	54.9

- ***Biological Treatment:***

Nitrogen and phosphorus concentrations of the wastewater were adjusted to satisfy the ratio BOD (100): N (5): P (1), by the addition of ammonium di-hydrogen phosphate. Biological treatment of the end-of-pipe effluent was carried out using batch laboratory experiments. To develop sludge which is acclimatized on the waste under consideration, activated sludge from a near-by municipal wastewater treatment facility was fed twice a day with a mixture of domestic and industrial wastewater for one week. This was followed by two-week operation using only industrial wastewater. The sludge weight ranged from 3-4 mg/l and the aeration time ranged from 1 to 3 hours. Dissolved oxygen concentration was adjusted to maintain a minimum concentration of 2.0 mg/l. The characteristics of the biologically treated effluent, as indicated by COD and TSS were determined after 60 minutes settlement. Sludge analysis was also carried out. The results obtained indicated that three hours detention time achieved COD, BOD and Oil & grease removal equivalent to 63%, 72.8% & 83.5, respectively. Increasing the aeration period to 3 hr. did not exert significant effect on the quality of the treated wastewater (Table-4).Sludge analyses showed that the sludge volume index was 85, which is an indication of a good sludge quality.

Table 3: Efficiency of biological treatment via activated sludge

Parameter	Unit	Industrial wastewater	Av. Treated effluent		Standards Limits	% Removal	
			after 2 hrs.	after 3 hrs.		after 2 hrs.	after 3 hrs.
pH	----	10.1	7.5	7.5	6-9.5	----	----
COD	mg/l	1122	410	401	1,100	63	64
BOD	mg/l	552	150	138	600	72.8	75
TKN	mg/l	21.3	17.9	16.8	100	15.9	21.1
TP	mg/l	4.8	3	3.6	25	37.5	25
TSS	mg/l	117	110	106	800	6	9
Oil & Grease	mg/l	82.2	13.6	12	100	83.5	86.8

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The Full Scale Plant Design and Construction:

The main objective of the laboratory scale study was to develop the information needed for the design of a full scale treatment system. Based on extensive laboratory scale test findings, a full scale plant (1800 m3/day) has been designed. Our goal was to design a system capable of producing effluent meeting the requirements for wastewater discharge into the public sewage network. The suggested treatment sequence of the end of pipe effluent wastewater from the factory shall comprise of:equalization tank for wastewater retention to ensure constant quality, feeding of coagulant, flash mixing of coagulant with wastewater in a mixing tank, flocculation of the effluent from the flash mixing tank in baffled flocculation tank, and sedimentation tank. TheSchematic and flow diagram of the treatment system is shown in Figures 4 and 5.

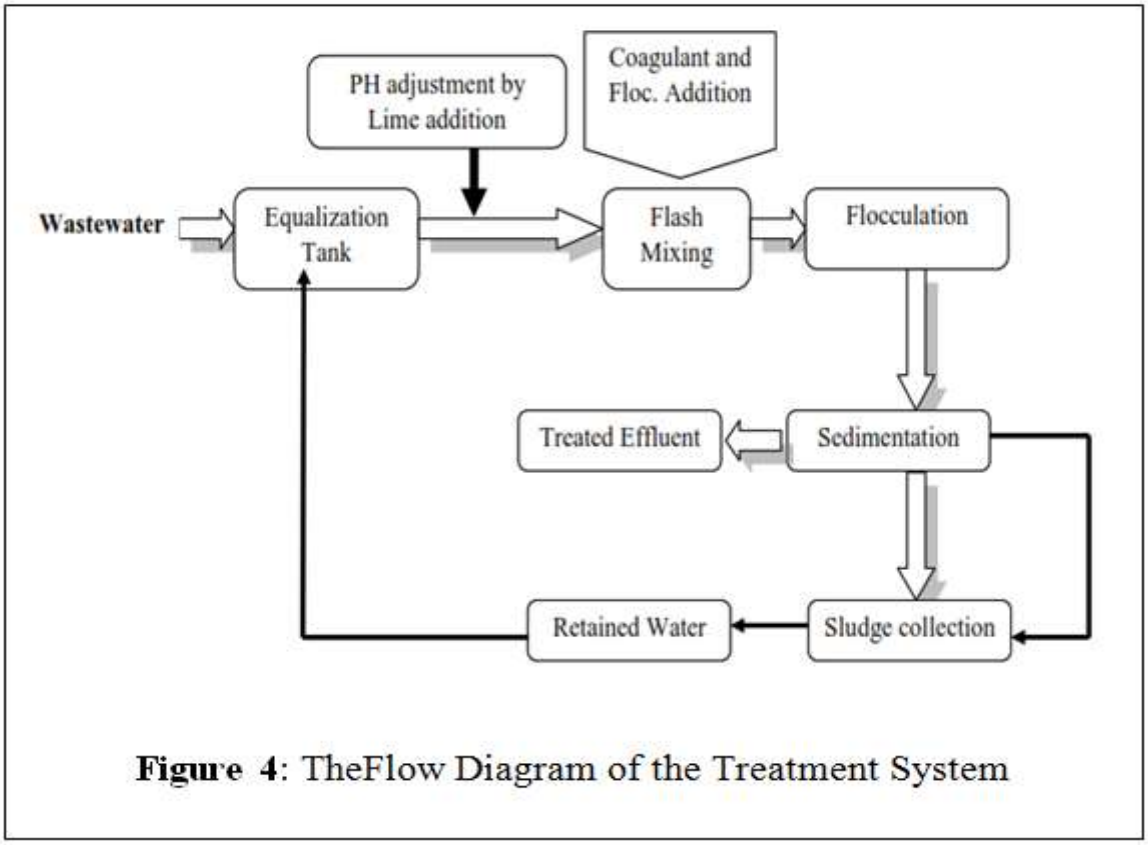

Figure 4: TheFlow Diagram of the Treatment System

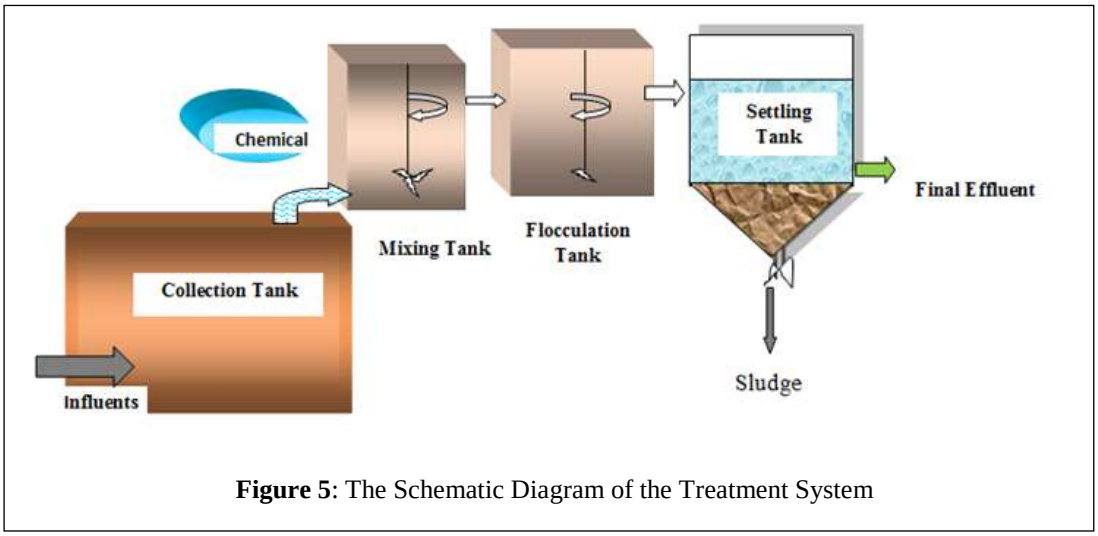

Figure 5: The Schematic Diagram of the Treatment System

VI. CONCLUSION AND ASSESSMENT OF THE TREATMENT ALTERNATIVES

The results obtained show that most of the pollution parameters exceed the limits set by law 93/1962 and decree 44/2000 for discharging waste effluent to public sewer.The wastewater is characterized by its high temperature, COD and relatively high alkalinity. COD values ranged from 993 to 1606 mg/l with an average value of 1047 mg/l depending upon the on-going operations. Corresponding BOD values varied from 235 to 600 mg/l with an average value of 422 mg/l. Oil & grease concentrations, of more than 90% of the samples exceeded the consent standards. In general all examined samples were not complying with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network.Alternatives for management and treatment of the discharged wastewater effluents to the limits of the Egyptian Environmental Regulation (Decree 44/2000) will be identified and assessed to investigate their feasibility from environmental and technical perspectives. As results from the treatability study, the most appropriate treatment techniques were conducted bychemical coagulation using ferric chloride and lime followed by sedimentation brings the wastewater quality to the acceptable limits.The results obtained,the use of Ferric Chloride aided with Lime is the highly effective dose to reduce COD, BOD, TTP, TSS, and O&G level by almost 57%, 64%, 33%, 14.5%, and 8.7% respectively. The quality of the treated effluent is complying the regulatory limits for discharging industrial effluent to public sewer. As a conclusion, from the study, it is concluded that thephysico-chemical treatment processis the most reliable alternative treatment method for this kind of industry

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