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ORIGINAL ARTICLES

Management of Industrial Wastewater (Case Study)

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ABSTRACT

This study is carried out to propose an appropriate treatment technology for wastewater discharged from pasteurized liquid egg factory and wood furniture production factory. All allocated in an Egyptian industrial city. The two factories discharge their wastewater into the public sewage network. This study represents a reference and useful guideline for the treatment of such kind of wastewater and could be applied by similar industries. The results showed that the wastewater discharged from pasteurized liquid egg production factory was highly contaminated with organic pollutants in terms of COD and BOD. Chemical coagulation using ferric chloride aided with polymer gave better results than the biological treatment using activated sludge, the removal efficiency of the chemical coagulation reached 94% for both COD and BOD. The low removal efficiency of the activated sludge treatment was due to gel foaming and emulsifying properties of egg proteins. The results showed that the wastewater discharged from wood furniture production factory was highly contaminated with soluble organic pollutants. Treatment using activated sludge produces an effluent in compliance with the national regulatory standards for wastewater discharge into the public sewage network.

Key words*:* Pasteurized liquid egg, wood, chemical treatment, biological treatment, wastewater

Introduction

The need for a sustainable environmental management system for different groups of industrial wastewater has long been identified by the Egyptian Environmental Affairs Agency. The Egyptian food industry looks lucrative for foreign investors, due to its large market size and unsaturated market. With the population of 85 million, Egypt is the largest market in the Arab world. Pasteurized liquid egg products have become increasingly popular, especially in food service establishments. This is because of its capability of food preservation for longer periods that allow delivery of intact products to users. Whole eggs are removed from the shells and sold as a liquid to restaurants and institutions. The yolk, the egg white and whole-egg products are pasteurized in their raw form, if it is sold as a liquid or frozen product. The egg white is used as foaming agent in food industry (Raikos *et al*, 2007) and for the production of the most common commercial foaming ingredients (Nicorescu *et al*, 2011). Pasteurizing eggs reduces the risk of contamination from pathogenic bacteria, such as Salmonella, which can cause severe illness and even death. Pasteurized eggs can be used in many recipes that are not thoroughly cooked. In the food sector, processing wastewater is characterised with high-strength organic and nutrient contents. These organic wastes are biodegradable in nature and could be handled by the microorganisms. Biological treatment is widely used for food-processing wastewater either by using anaerobic (Moises *et al*,2010; Moody and Raman 2001), aerobic or combination of both (Austermann-Haun *et al*, 1999; Mulkerrins *et al*, 2004).

Huge amount of wastewater is generated from pasteurized liquid egg production. This kind of industry generates about 9.46 million cubic meters of wastewater per year all over the world, which contains high organic loads associated with egg losses. Untreated egg processing wastewater was discharged directly into municipal sewers or applied to cropland (Crickenberger R.G. and Carawan, 1991; Walsh, 1994). Nowadays, these practices are no longer acceptable for food companies according to establishment of environmental regulations (Xu *et al*, 2002). Pervious researches indicated that precipitation/coagulation process is good for the treatment of such kind of wastewater while ultrafilteration process is useful for waste minimization from egg processing wastewater (Xu *et al*, 2002; Scott 1995; Beszedits, 1982). Further researches prove the possibility of recovering useful by-products from wastewater as means of alleviating waste disposal problems has attracted increased interest in recent years (Xu *et al*, 2002).

Over the past decade the Egyptian wood furniture industry has witnessed rapid progress, becoming one of the country's fastest growing and most promising industries. Egypt displays a dynamic furniture industry, which has proven more and more successful on international markets. In particular, in the last decade production doubled, driven by a surge in exports, and output reached almost one billion US$. The increase in the

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exports/production ratio was really impressive rising from 3% in 2000 to 33% in 2011. Some of the reasons for this dynamism and improvement are: the long tradition of craftsmanship, investment and government supportive policies with the aim of building an internationally recognized furniture design and production industry. The furniture manufacturing process don't use large quantities of water but still generate wastewater which is mainly generated in the finishing stage, during the painting process (Scheneider *et al*, 2003). The painting of furniture normally is made in painting cabin surrounded by water curtains to control the emission of volatile organic compounds that are used as dye solvents and wood preservatives. The main pollution source comes also after cleaning /washing of machineries that apply specific preservatives and coating materials for wood surfaces, also the wood painting operations from the dying hood considered one of the main sources of pollution (Kaczala *et al*, 2009, Santos Lage *et al*, 2010). The processing wastewater generated from the wood furniture industry is characterized by high organic matter content and low content of macronutrients. The wastewater from the furniture industry is conventionally treated by coagulation/flocculation but it has shown low efficiency in the reduction of its toxic load (Blacksmith, 2003). Santos Lage *et al*, 2010 and Anselmo *et al*, 2010 investigated the biological treatment process (anaerobic-aerobic) with removal efficiency of 90% of organic matter. Kaczala *et al*, (2009) uses the sorption method using *Pinus sylvestris* sawdust as sorbent; the removal efficiency of organic matter reaches 54%.

This study proposed an appropriate treatment technology for wastewater produced from pasteurized liquid egg factory and wood furniture factory located in an Egyptian industrial city. The main objective is to address economic and environmental solutions and offering guidance on implementation across similar industries.

Material And Methods

A pasteurized liquid egg and wood furniture factories representing food and wood industrial sectors were selected for this study. The plants are located in Sadat new industrial city which is located between Cairo and Alexandria next to the Delta. The plants discharge their wastewater directly into the city sewerage system. Industrial auditing of the factories including plant activities, industrial processes and environmental status was carried out. The audits aimed to identify the main sources of pollution, hence selecting the most appropriate treatment method.

Sampling and Characterization of Wastewater:

Separate composite samples were collected from end-of-pipe effluent for each factory during the working days to avoid the variations in the pollution loads during day and night. This was done to get representative samples. The analyses were carried out according to the Standard Methods for Examination of Water and Wastewater (APHA, 2005) and covered pH, Chemical and Biological Oxygen Demand (COD& BOD), Total suspended solids (TSS), Total organic nitrogen (TKN), Total phosphorus (TP) and oil & grease.

Activated Sludge Treatment Unit:

Batch-type laboratory experiments were carried out using activated sludge process. Two litres plexiglass laboratory columns were used. The columns were inoculated with activated sludge (Mixed Liquor Suspended Solids (MLSS) from a municipal wastewater treatment plant. The MLSS in the columns were fed raw wastewater on daily basis under continuous aeration. Every day, aeration was stopped for 30 minutes to remove the treated effluent from the active biomass and add new wastewater feed. This process was continued till considerable amount of adapted sludge was produced. To study the effect of Hydraulic Retention Time (HRT) on the treatment process, several experiments were conducted. A fixed amount of sludge (3-4 g/l) was transferred to a different column to which the pre-treated wastewater was added. Dissolved oxygen concentration was adjusted to maintain a minimum concentration of 2 mgO_2/L. Samples of MLSS were collected at 0, 2, 4, 6, 8, 10, 12, 14, 16 and 24 hours of reaction time. The samples were left for 60 minutes to settle and clear supernatants were subjected for analysis of COD and TSS while the settled sludge was subjected for the analysis of MLSS.

Chemical Treatment:

Chemical treatment was applied using ferric chloride aided with anionic polymer using jar test procedure. The optimum values of pH and coagulant dose which gave the best removal of COD or pollutants were determined. The Wastewater were added to 1-Liter beakers and subjected to flash mixing (200 rotation per minute; rpm) for 2 minutes during which the desired doses of ferric chloride were added to the beakers. After 2 minutes flash mixing, the rotation speed reduced to slow mixing (40 rpm) for 15 minutes during which the desired doses of polymer were added to the beakers. Finally, the resulting flocks were allowed to settle for one hour and clear supernatants (treated effluent) were collected and subjected to analysis of COD and TSS while the settled sludge was subjected to measurement of sludge volume and analysis of MLSS. Each experiment was repeated five times for assuring accuracy of results.

Results and Discussion

1- Environmentalist Status Of The Investigated Factories:

The site survey and state records showed that 135 factories were operating in Sadat city in five industrial zones. These factories cover metal, textile, paper, plastics chemical, food, electrical, building & construction, wood and miscellaneous industries.

Table 1: The Quantity and the Average COD & BOD Concentration of the Different Industrial Sectors In Sadat Industrial City.

Industrial sector	Number of factories	Wastewater production m^3/d	BOD Conc. mg O_2 /l.	COD Conc. mgO_2/l
Food	29	925	1715	3603
Building Material	9	1538	276	974
Metal	27	2096	603	3247
Chemical	18	144	572	2028
Wood	2	34	1610	2647
Textile	15	1490	319	1173
Electric	9	101	90	272
Plastic	16	36	363	778
Pulp &paper	5	32	112	266
Miscellaneous industries	4	142	60	232

Table (1) shows the BOD and COD concentrations in wastewater discharged from each industrial sector. The results showed that the highest polluted industries are the Food, wood and metal industries and its wastewater were not in compliance with the Egyptian standard for discharging to the sewerage system. The treatability study of the wastewater discharged from the two factories selected (Pasteurized liquid egg and wood furniture industry) in this study was investigated. Food and wood industries represent major portion of the Egyptian economy and that was the basis of selecting subject factories.

2- Case study 1: Pasteurized Liquid Egg Factory:

The factory produces pasteurized liquid egg was chosen as an example of food industrial sector. Pasteurized liquid egg products have become increasingly popular, especially in food-service establishments. The factory products include liquid egg whites, liquid egg yolks, and various blends of the whites and yolks. The factory uses 20 thousands egg/day. The production process in the factory depending on breaking the egg by machines and the liquid egg put into covered containers, then raising its temperature to 60°C for 3.5 minutes and cooling suddenly to 4°C for ultra-pasteurization and aseptic packaging techniques to extend their shelf life to about six weeks. It was observed that the wastewater is produced from rinsing process of the containers and the tubes which used to collect and transfer the product. The washing process uses water, sodium hydroxides and acids.

2-1- Wastewater Characteristics:

Physico-chemical characteristics of the wastewater discharged from the end of pipe effluent are presented in Table (2). The quantity of wastewater is 15m^3/day. The discharged wastewater from the factory contains high concentration of COD and BOD; which reached 8000 and 5725mg O_2/l, with average values of 5816 and 3742 mgO_2/l respectively. The wastewater was nearly alkaline in nature, the pH varied between 10.3 and 13.4. The wastewater contains considerable amounts of nitrogen with an average value of 275 mg N/L while total phosphorus was limited and records only 3.8 mg/L on average. This indicates that most of pollution source is coming from the egg white which is almost protein with very little amount (0.03%) of lipids (Li-Chan, Powrie and Nakai, 1995).

2-2- Biological Treatment Using Activated Sludge:

Biological treatment of industrial wastewater was carried out using activated sludge process. The ratio of BOD: N: P is 100:7:0.1, this indicates that the phosphorous concentration was not sufficient for the biological treatment process, therefore to compensate the deficiency of this nutrient phosphorous salts have been added to reach the exact ratio (BOD: P; 100:1). Analysis of the treated effluent indicated that the highest BOD and COD removal values were achieved at a retention time of 16 hours (Fig. 1). The average residual values of COD, BOD and TSS were 728, 325 and 195mg/l, respectively with a percentage removal value 83%, 85% and 82% respectively (Table 3). These values are in agreement with the standards set by Egyptian law for discharging wastewater into the sewerage system.

Table 2: Characteristics of raw wastewater (pasteurized liquid egg factory).

Parameters	Units	Min.	Max.	*Average	**Permissible Limits
pH		10.3	13.4	11.8	6-9.5
Chemical Oxygen demand	mg O_2/l	4011	8000	5816	1100
Biological Oxygen Demand	mg O_2/l	2425	5725	3742	600
Total suspended solids	mg /l	689	928	886	800
Phosphorous	mg P/l	1	6.5	3.8	25
Organic Nitrogen	mg N_2/l	176	370	275	100
Oil &Grease	mg/l	9	89	27	100
Sulphate	mg SO_4 /l	0	6.8	1.3	10

**Average of 10 samples*
*** Permissible limits set by the Egyptian law for wastewater Discharge into Public Sewerage System.*

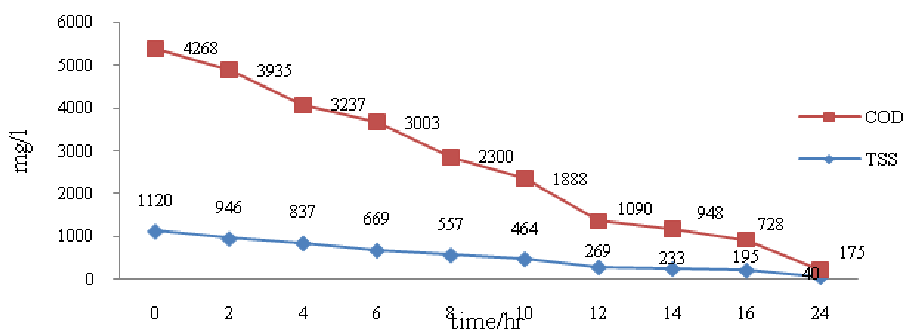

Fig. 1: The optimum detention time of the biological traetment pasteurized liquid egg factory.

Table 3: The Characterization Of The Treated Wastewater Using Activated Sludge At 16 hr Detention Time (Pasteurized Liquid Egg Factory).

Parameters*	unit	Raw wastewater	Treated Effluent	% Removal	** Permissible limits
pH		10.2	8		6-9.5
Chemical Oxygen demand	mgO_2/l	4268	728	83	1100
Biological Oxygen demand	mgO_2/l	2548	370	85	600
Total suspended solids	mg/l	1120	195	83	800
Phosphorous	mg P/l	30	4	86	25
Organic Nitrogen	mgN/l	212	25	88	100
Oil & Grease	mg/l	23	2	91	100

* *Average results of five samples*
*** Permissible limits set by the Egyptian law for wastewater Discharge into Public Sewerage System.*

2-3-Chemical Treatment:

Chemical treatment of the wastewater using Ferric Chloride in combination with anionic polymer was carried out. To determine the optimum coagulant dose and pH value, a series of experiments using Jar test procedure were carried out. The results obtained indicated that the optimum dose of Ferric chloride ($FeCl_3.6H_2O$) was 600mg/l aided with 6.5mg/l of anionic polymer at pH 7.4 (Fig. 2).

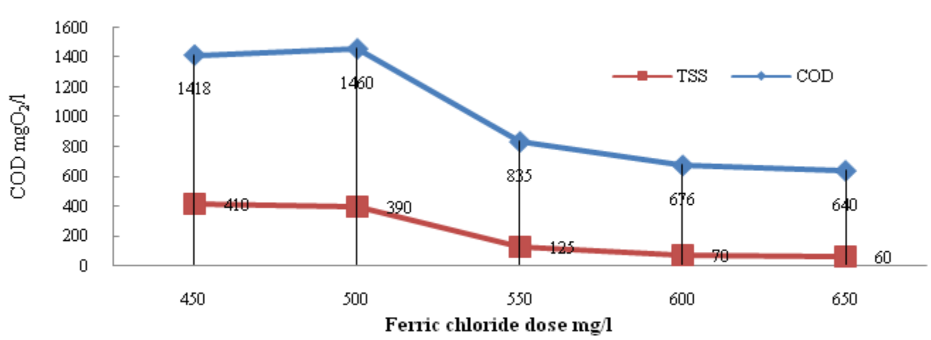

Fig. 2: Performance of the diffrent doses of ferric chloride pasteurized liquid egg factory.

The results presented in Table (4) showed that; the characteristics of the treated effluent comply with the permissible limits set by the Egyptian Law. Residual COD, BOD and TSS were 650mg O_2/l, 278mgO_2/l and 110mg/l respectively. Based on the laboratory results for both the biological and the chemical treatment, it was suggested that the chemical treatment gave better results than the biological treatment. As mentioned previously most of the pollution source is from the egg white which could be denatured by physical or chemical stress. This is why chemical coagulation gave good results. On the other hand the presence of egg white which has foaming ability (Lechevalier *et al*. 2007; Song *et al*. 2009) which may cause foaming problems in the aeration tanks of the biological activated sludge system. This could be explained that the hen proteins have unique functional properties such as gelling, foaming (egg white) and emulsifying (egg yolk) properties (Mine, 2002). The present study results are in line with the previous researches has indicated that precipitation/coagulation and ultrafilteration processes were good methods to treat wastewater from egg processing, (Beck *et al.*1974; Beszedits,1982; Xu *et al* 2002). The anionic polymer helps the destabilization of colloidal and emulsified particles which represented as the amino acids and proteins which found with a high percentage in the egg (Kiosseoglou 2003). Based on the laboratory results an engineering design for chemical treatment system was developed Fig. 3.

Table 4: Characteristics of the Treated Wastewater Using 600 mg/L Ferric Chloride Aided with 6.5 mg/L Anionic Polymer. (Pasteurized Liquid Egg Factory).

parameters	unit	Raw wastewater	Treated wastewater	% removal	Permissible limit
pH		10.2	7.2		6-9.5
COD	mgO_2/l	4268	650	91	1100
BOD	mgO_2/l	2548	278	89	600
TSS	mg/l	1120	110	90	800

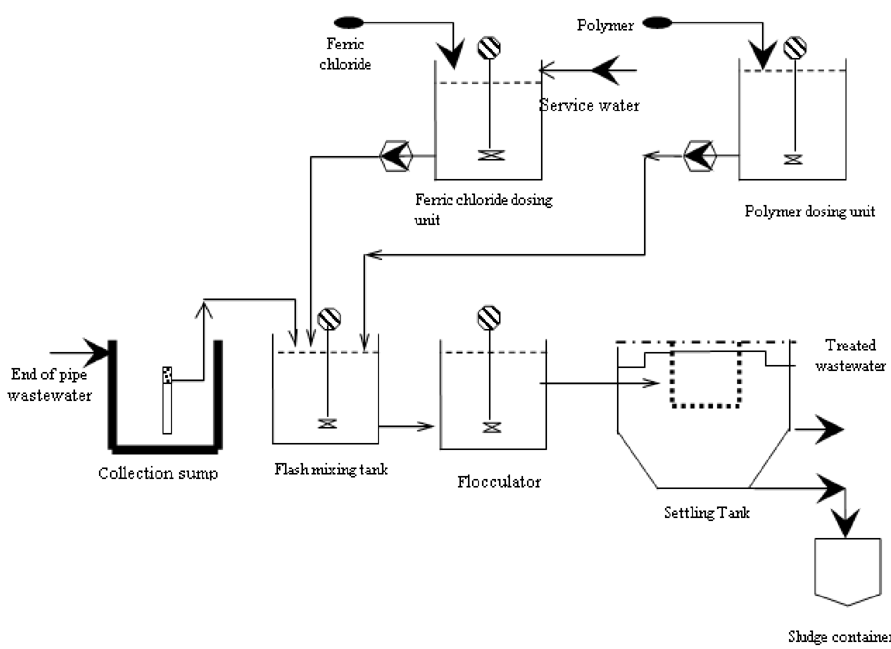

Fig. 3: Schematic Diagram of the Chemical Treatment Unit.

3- Case Study 2: Wood Furniture Factory:

The second case study was wood Furniture factory. The factory produces wood furniture. The production process consists of cutting, perforation, burnishing, forming, painting, assembling and packing. The painting is made in a cabin surrounded by water curtains to control emission of chemical vapor of dyes and solvents. The main source of wastewater is the dying cabin and floor washing. The quantity of wastewater produced is 25m^3/day.

3-1- Wastewater Characteristics:

The physicochemical analyses of the end-of-pipe wastewater indicated that it carries significant concentration of COD and BOD which reached 4380 and 2820 mgO_2/l with an average values of 2740 and 1724

mgO_2/l, respectively (Table 5). These figures are not complying with the Egyptian regulatory standards for discharging to the sewerage system. In spite of the high concentration of COD; the average total suspended solids was 162 mg/l this indicated that the organic pollutants is mainly in the soluble form and for this reason the activated sludge treatment was considered as the best treatment process for this kind of waste.

Table 5: Characteristics of wastewater from the end-of-pipe (wood furniture factory).

Parameters	Units	Min.	Max.	*Average	**Permissible Limits
pH		7.1	8	6.5	6-9.5
Chemical Oxygen demand	mg O_2/l	2183	4380	2740	1100
Biological Oxygen Demand	mg O_2/l	1250	2820	1724	600
Total suspended solids	mg /l	67	153	106	800
Phosphorous	mg P/l	1.5	10	2.5	25
Organic Nitrogen	mg N_2/l	17	67	47	100
Oil &Grease	mg/l	15	80	67	100

*Average of ten samples

*** Permissible limits set by the Egyptian law for wastewater Discharge into Public Sewerage System.*

3- 2- Biological treatment using activated sludge:

The wastewater was treated using activated sludge process. The characteristics of the wastewater indicated that there is a deficiency in the nitrogen and phosphorous; the BOD:N:P was calculated as 100:1.7:0.09; similar results was also obtained by Santos Lage (2010), therefore to compensate this deficiency of nutrient; phosphorous and nitrogen salts (potassium di-hydrogen phosphate and urea salt) had been added to reach the exact ratio (BOD: N: P; 100:5: 1). The activated sludge with a concentration of 3.5 g /l was adapted to the wastewater in a sequence batch reactor (growth column) for a month. The reactor was fed with the raw wastewater from the end of pipe at 24 hours retention time. Every day, aeration was stopped for one hour and supernatant was replaced by new wastewater feed. The sludge concentration in the reactor was kept at 3.5 g/l by daily analysis and removal of the excess sludge. After the adaptation period the effect of hydraulic retention time on the removal process and treatment efficiency was investigated to estimate the optimum hydraulic retention time. The reactor was fed with the raw wastewater and aerated for 24 hours while 50-ml samples were collected at 2 hours time interval. The collected samples were left for one hour settling time and subjected for the analysis of sludge volume and MLSS concentration of the sludge, COD and BOD of the clear supernatant. Analysis of the treated effluent indicated that the highest BOD and COD removal was achieved at a retention time of 12 hours (Fig. 4). The average residual concentration of the COD, BOD and TSS was 215, 88 and 64 mg/l with an average percentage removal value 93%, 95% and 55% respectively (Table 6). These values are in agreement with the standards set by Egyptian law for discharging treated wastewater into the sewerage system.

Table 6: The Characterization of The Activated Sludge Treated Effluent at 12 hr Detention Time (Wood Furniture Factor).

Parameters*	Unit	Raw wastewater (after the addition of the nutrients)	Treated Effluent	% Removal	** Permissible limits
pH		7.4	6.9		6-9.5
Chemical Oxygen demand	mgO_2/l	3100	215	93	1100
Biological Oxygen demand	mgO_2/l	2100	88	95	600
Total suspended solids	mg/l	115	64	55	800
Phosphorous	mgP/l	15	7	57	25
Organic Nitrogen	mgN/l	144	34	77	100
Oil & Grease	mg/l	42	14	62	100

* *Average results of five samples.*

*** Permissible limits set by the Egyptian law for wastewater Discharge into Public Sewerage System.*

4. Conclusion:

1. Characteristics of the industrial wastewater determine the adequate treatment system, specially, solubility, toxicity and biodegradability of the pollutants.
2. In pasteurized liquid egg industry chemical treatment of wastewater gave better results than the biological treatment using activated sludge. This is due to gel foaming and emulsifying properties of egg white proteins.
3. Biological treatment of the wood furniture industry wastewater using activated sludge produces an effluent in compliance with the national environmental standards for wastewater discharge into public sewage network. This is due to existence of organic pollutants in the soluble form.

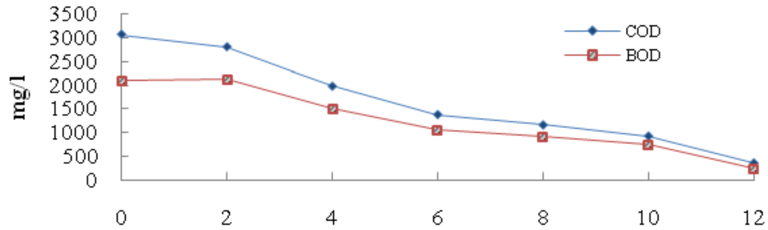

Fig. 4: Optimum detention time, wood furniture factory.

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