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Physico-chemical Treatment of Nutrition Processing Industrial Wastewater

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----------***ABSTRACT***----------
Industry produces large quantities of highly polluted wastewater containing toxic substances, organic and inorganic compounds such as: heavy metals, pesticides, phenols and derivatives thereof, aromatic and aliphatic hydrocarbons, halogenated compounds, etc., which are generally resistant to destruction by biological treatment methods. Food industry uses large amounts of water for many different purposes including cooling and cleaning, as a raw material, as sanitary water for food processing, for transportation, cooking and dissolving, as auxiliary water etc. The Nutrition Processing Industry is committed to improve their environmental performance and to meeting or exceeding the requirements of all applicable environmental laws and regulation.
The main objectives of this study are investigate the different possible treatment techniques to treat the effluent wastewater prior to its discharge to the public sanitary network and to comply the Egyptian Environmental Regulation (Decree 44/2000) in order to protect the environment and to gain benefits as much as possible from the wasted materials and identify opportunities for introducing pollution prevention measures and best method for waste minimization as cleaner production system. Alternatives for management and treatment of the discharged industrial wastewater 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. Special attention will be given to low cost alternatives due to the limited budget allocated by industry for the wastewater management.
Treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater effluent of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using two proposed streams of techniques; Physical Treatment "Gravity separation" flowed by Chemical Treatment "Chemical Coagulants".
Based on the analysis and treatability study of the alternative Physical Treatment by Gravity Settling, it is clear that the BOD and COD are still not complying with the regulatory limits for the discharge to the sewer system. Accordingly, equalization and gravity settling is not considered a feasible alternative for treatment of the industrial wastewater discharge. Moreover, based on the above calculations, using the chemical treatment after equalization and gravity settling while enhance the quality of the wastewater effluent but it is still does not assist in complying with the regulatory limits. It is resulted in reduction of COD, BOD, and oil and grease by 45 to 81 %, 57 to 85%, and 69 to 100% respectively. The recommended that the effluent quality can be enhanced by studying the pH value effect and studying the effect of adding cationic and anionic polymer.
KEYWORDS: *Chemical and Physical Treatment, Industrial Wastewater Treatment, Food Industry*

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I. INTRODUCTION:

Over the years, the improper disposal of industrial effluents has been a major problem and a source of concern to both government and industrialist. In general, industrial wastewaters may contain suspended, colloidal and dissolved (mineral and organic) solids. In addition, they may be either excessively acid or alkaline and may contain high or low concentrations of colored matter. These wastes may contain inert, organic or toxic materials and possibly pathogenic bacteria. These wastes may be discharged into the sewer system provided they have no adverse effect on treatment efficiency or undesirable effects on the sewer system. It may be necessary to pretreat the wastes prior to release to the municipal system or it is necessary to a fully treatment when the wastes will be discharged directly to surface or ground waters [1].

In most cases the disposal or discharges of effluents, even when these are technologically and economically achievable for particular standards, do not always comply with pretreatment requirement and with applicable tonic pollutant effluent limitations or prohibitions. The consequence of these anomalies is a high degree of environmental pollution leading to serious health hazards. Unfortunately, in most developing countries, effluent quality standards imposed by legislation (where they exist) are sometimes easily flouted [2].Whereas the nature domestic wastewater is relatively constant, the extreme diversity of industrial effluents calls for an individual investigation for each type of industry and often entails the use of specific treatment processes. Therefore, a thorough understanding of the production processes and the system organization is fundamental.Industrial wastewaters are considerably diverse in their nature, toxicity and treatability, and normally require pre-treatment before being discharged to sewer. Food processing in particular is very dissimilar to other types of industrial wastewater, being readily degradable and largely free from toxicity. However, it usually has high concentrations of biological oxygen demand (BOD) and suspended solid [3].

Industrial wastewater characteristics vary not only between the industries that generate them, but also within each industry. These characteristics are also much more diverse than domestic wastewater, which is usually qualitatively and quantitatively similar in its composition. On the contrary, industry produces large quantities of highly polluted wastewater containing toxic substances, organic and inorganic compounds such as: heavy metals, pesticides, phenols and derivatives thereof, aromatic and aliphatic hydrocarbons, halogenated compounds, etc., which are generally resistant to destruction by biological treatment methods. Food industry uses large amounts of water for many different purposes including cooling and cleaning, as a raw material, as sanitary water for food processing, for transportation, cooking and dissolving, as auxiliary water etc. In principle, the water used in the food industry may be used as process and cooling water or boiler feed water. As a consequence of diverse consumption, the amount and composition of food industry wastewaters varies considerably. Characteristics of the effluent consist of large amounts of suspended solids, nitrogen in several chemical forms, fats and oils, phosphorus, chlorides and organic matter [4].

There are many kinds of industry that generate wastewater effluents that contain a number of hazardous organic compounds. These most notably include oil refineries, coking plants, mining, agricultural activity, different manufacturing plants, such as food, textile, dyes, timber, pulp and paper, plastics, solvents, detergents, other chemicals and pharmaceutical industries, and thousands of laboratories worldwide. The chemical composition of industrial effluent discharges varies according to the particular kind of industry that has generated them. Many of these compounds are toxic, persistent organic pollutants (POPs) in the environment, which are generally resistant to natural environmental degradation, and also to conventional wastewater treatment (WWT) techniques [5].

Compared to other industrial sectors, the food industry uses a much greater amount of water for each ton of product [6]. Food and beverage industry is one of the major contributors to growth of all economies. In EU it constitutes the largest manufacturing sector in terms of turnover, value added and employment. However, the sector has been associated with various environmental issues including water usage and wastewater treatment.Food processing industry wastewater poses pollution problems due to its high COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand). Compared to other industrial sectors, food industry requires great amounts of water, since it is used throughout most of plant operations, such as production, cleaning, sanitizing, cooling and materials transport, among others. The wastewater streams with different levels of pollution load (low, medium and high contamination) are collected and treated in an on-site installation or in a municipal sewage treatment plant. Increasing food production will increase the volume of sewage and the cost of disposal for food processing plants and present difficult challenges for municipal wastewater treatment plant operators [7, 8].

Water usage in the food and drink industry is expressed either in volume of water consumed per finished product or per raw material processed. Food industry wastewater treatment by physicochemical method using Zinc Sulphate, Ferrous Sulphate and Ferric chloride has been reported. Where the reduction in COD has been obtained 60% with alum dose of 200 mg/L [9].The food & beverage (F&B) industry is among the most water intensive sectors with thousands of liters per hour of raw water requirement. The study integrates an ultra-filtration, reverse osmosis (RO) and ultraviolet (UV) unit with a target overall efficiency of about 55.6% [10].
The food processing wastewater shows large variation in BOD/COD, total solids and suspended solids, oil and grease, starch, sugar, color, preservatives, total nitrogen, total phosphates, chloride and sodium etc. This is due to the different additives used for different food products. Wastewater depicted COD/BOD and SS of 11220 mg/l, 6860 mg/L and 2210 mg/L respectively. From the studies it can be concluded that the food processing wastewater is easily amenable to physico-chemical treatment. The results obtained show that all the coagulants

used individually or in combination with polyelectrolyte can remove moderate to high degree of chemical oxygen demand, biochemical oxygen demand and suspended solids from the food processing wastewater. Lime individually also acts as an efficient coagulant and moreover it is very cost effective. Addition 0.3 mg/L of anionic polyelectrolyte magnafloc to 200 mg/L of lime resulted in good SS, COD and BOD removals [11].
Food processing industries usually discharge large volumes of wastewater characterized by high chemical oxygen demand (COD) or biological oxygen demand, large amounts of total suspended solids, and various inorganic constituents including nitrogen and phosphorus. The high organic load in the processing wastewater creates a pollution problem to water quality when discharged to rivers and lakes. A pilot-scale anaerobic/aerobic ultrafiltration system and a bench-scale anaerobic/aerobic system were tested to treat high-strength tomato-processing wastewater and bean-processing wastewater. The anaerobic/aerobic pilot-scale system achieved 99.4% SBOD removal, 91.9% NH3-N removal, and 100% phosphorus removal at an overall hydraulic retention time (HRT) of 1.5 days and solids retention time (SRT) of 5 days during the tomato canning season [12].

The study clearly established the utility of the combined technology for the effective treatment of real industrial wastewater. Fenton oxidation and ultrasound-based pretreatment have been applied to improve the treatment of real industrial wastewater based on the use of biological oxidation. Maximum COD and BOD removal efficiency of about 43.2 and 20.4 %, respectively, was obtained, with the corresponding BOD5/COD ratio increasing from 0.496 to 0.695 in 40 min of pretreatment which confirmed good degradability for aerobic oxidation. Overall maximum COD removal efficiency of 96.9 and 97.9 % has been obtained in 40 h HRT using aerobic biological treatment of industrial effluent which was previously treated for 40 min by Fenton and US/Fenton/stirring, respectively [13]..

Anaerobic technology has improved significantly in the last few decades with the applications of differently configured high rate treatment processes, especially for the treatment of industrial wastewaters. High organic loading rates can be achieved at smaller footprints by using high rate anaerobic reactors for the treatment of industrial effluents [14]. A novel anaerobic–aerobic integrative baffled bioreactor supplied with porous burnt-coke particles was developed for the treatment of potato starch wastewater by Wang et al. (2009). This bioreactor was found to be effective for the removal of COD (88,4–98,7%) and NH3–N (50,4 to 82,3%), in high-strength starch wastewater [15].

Cheese manufacturing units of smaller capacities either dispose wastewater directly in the sewerage system or they store it until it is transported for further treatment. So far, the anaerobic digestion process that leads to the production of biogas has been extensively studied in scientific publications and applied in large treatment plants [16].

Fruit and vegetable processing industry is characterized by relatively high water consumption which leads to the production of relatively high wastewater generation. Based on the recording of the existing situation in Greece, it was observed that the treatment of waste and wastewater from the fruit and vegetable industry in Greece is in line with the environmental requirements while waste and by-products are usually given as animal feed. Based on the recording of the existing situation in Greece, it was observed that all industrial units operate biological wastewater treatment plants mainly applying the activated sludge process [17].

The down flow stationary fixed film (DSFF) reactor contains solid packing similar to anaerobic filters but is operated in the down flow mode, the wastewater enters from the top and flows downwards [18]. The aim of this work is to study the treatment of synthetic sugar wastewater by a down flow stationary fixed film (DSFF) reactor. BOD and COD removal increased as the HRT decreased from 48 to 12 h. BOD and COD removal was 79 and 81.8 % respectively at 12 h HRT. Thus DSFF reactor can be used for treating sugar wastewater and for producing biogas. A decrease in the COD and BOD removal efficiencies were observed at 6 h HRT [19].

Study is carried out to propose an appropriate treatment technology for wastewater discharged from a flavor production factory. Industrial wastewater discharged from this factory ranges between 50–70 m3/d with an average value of 60 m3/d. therefore the treatment has been carried out on the end-of pipe wastewater. The wastewater is characterized by high values of COD, BOD, TSS and Oil and grease 4646, 2298, 1790 and 626 mg/l respectively. The results from each treatment process proved to be efficient for the treatment of such wastewater. The treated wastewater characteristics are in compliance with the Egyptian law which regulates the discharge of industrial wastewater to the sewerage system. The RBC was selected and installed by the factory as it has the advantage of low operating and maintenance costs. The factory RBC performance was monitored; characteristics of the treated effluent in terms of oil and grease, COD, BOD and TSS were 27, 362, 139 and 95 mg/l, respectively [20].

Chocolate industry is among the most polluting of the food industries in regard to its large water consumption. Chocolate is one of the major industries causing water pollution. Considering the above stated implications an attempt has been made in the present project to evaluate one of the Effluent Treatment Plant (ETP) for Chocolate waste. Samples are collected from three points; Collection tank (CT), outflow of Anaerobic Contact Filter (ACF) and Secondary clarifier (SC) to evaluate the performance of Effluent Treatment Plant. Parameters analyzed for evaluation of performance of Effluent Treatment Plant are pH, COD, and BOD. The COD and BOD removal efficiency of Effluent Treatment Plant were 98.7 and 99.4 % respectively. Hence it is pH is also perform of 29.3% increase [21].

The manufacturing of cheese demands 1.05 – 3.6 m3 of water per m3 of milk processed while for the manufacturing of beer 2,5 – 6,4 hl of water are consumed for each hl of produced beer. Used water is eventually end up as wastewater except for the proportion which is used as a raw material e.g. for beer production. Although the pollution load depends on the type of industry, a common characteristic of all food and beverage sectors studied was the high values of organic content of wastewater. The highest values in terms of COD were observed for the wastewater occurring from the olive oil production process (400g/L) and from the cheese production process (77g/L) while high values were also observed for slaughterhouses (2-10g/L, considering blood is gathered separately), chip production process (4.3-9.3g/L) and beer industry (2-6g/L). Due to the high organic content, the biological processes are commonly applied for the treatment of wastewater of those industries. In particular, the application of anaerobic process is the predominant treatment process using UASB reactors [22].

II. DESCRIPTION OF THE NUTRITION PROCESSING INDUSTRY:

The industry is a global leader in branded foods and beverages production in Egypt. The main product of industry plant is biscuits and snack cakes. The production line is segmented into three main categories: cakes, biscuits, and condiments. The cakes category includes the following brands Choco Nity, Choco Nity Deluxe, Super Nity, and Family Cake Highty. The biscuits category consists of Rasco “white cookies filled with vanilla”, RascoHarakat “white impression cookies filled with cocoa”, and Borio “brown cookies filled with vanilla cream. The condiments category includes mayonnaise, ketchup, and mustard.

III. STATEMENT OF THE ENVIRONMENTAL PROBLEM:

The Nutrition Processing Industry is committed to improve their environmental performance and to meeting or exceeding the requirements of all applicable environmental laws and regulation.The analysis of the industrial wastewater effluent, the average values of pH, settleable solids, BOD, COD and oil and grease are above the limits of the Egyptian Environmental Regulation (Decree 44/2000). Accordingly, the industry has to treat the effluent wastewater prior to its discharge to the public sanitary network.

IV. OBJECTIVES OF THE STUDY:

The main objectives of this study are investigate the different possible treatment techniquesto treat the effluent wastewater prior to its discharge to the public sanitary network and to comply the Egyptian Environmental Regulation (Decree 44/2000) in order to protect the environment and to gain benefits as much as possible from the wasted materials and identify opportunities for introducing pollution prevention measures and best method for waste minimization as cleaner production system.

V. MATERIALS AND METHODS

To achieve the required objectives, the study is conducted to quantify the major pollutants (Temperature, pH , BOD, COD,TSS, TDS, Settleable matter and oil & grease) of the final effluent discharged to the public sewer system and study the ability to remove oil and grease of processing wastewater pollutants by chemical and physical techniques.The study was following some steps and approaches as evaluate the current environmental conditions in the production and service units to determine the possible treatment techniquethrough different activities including qualitative and quantitative estimation of solid and liquid wastes, collecting composite wastewater samples from the end-of-pipe industrial effluent (the samples were analyzed by specialized laboratory and the results are used for selection of the most appropriate alternative schemes), check on the compliance with national environmental regulation and legislation and description of the existing environmental situation in the industry, and studying the different approaches for pollution prevention and suggesting possible end-of-pipe treatment modules.

5.1 Flow Measurement

A monitoring program was conducted focusing on measuring the flow rate at the manhole (round pipe, 12 inches) of the final discharge effluent during 48 hours during daily shifts.

5.2 Characterization of Effluent Wastewater

A monitoring program was conducted focusing on the quality of final wastewater discharged into a public sewer system. The sampling team collected 18 times composite samples and one time automatic sample from septic tank. The collected sample was analyzed for Temperature (T), pH, Total suspended solids (TSS), Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (CODcr), Oil & Grease, total dissolved Solids (TDS) and Settleable matter. Temperature and pH were considered as field measurements, while the rest items are considered as laboratory analysis. The parameters were analyzed for wastewater discharges are compared to the required limits of the Egyptian Environmental Regulation (Decree 44/2000) concerning the discharge final effluent to public sewer system.

5.3Treatability Study andTreatment Procedure

Treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater effluent of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using two proposed streams of techniques; Physical Treatment "Gravity separation" flowed by Chemical Treatment "Chemical Coagulants" as following:

Physical Treatment "Gravity separation": Acidified Sample (>2 pH) pour in a separator funnel and live withstand for 73 hrs then supernatant are taken for check the considered pollutants. Chemical Treatment "Chemical Coagulants": Pour 500 ml sample in a 1000 ml beaker and agitate for 10 min, neutralize sample's pH by adding 0.4 gram NaOH, then agitate again for 10min. Add 100 ml Ferrous Sulfate (FeSO4.7H2O – 100 ppm Fe), then agitate again for 10 min leave it withstand for 15 min to precipitate coagulant then supernatant are taken for check the considered pollutants.

VI. RESULTS AND DISCUSSION

6.1: Assessment of the WastewaterEffluent

For investigating the compliance of the wastewater effluent, the sampling and analysis carried out for the wastewater in the industry was conducted as composite samples and analysis of the industrial wastewater effluent. As results from the analysis, it concluded that the quality of all parameters of the final industrial wastewater effluent comply with the Egyptian Environmental Regulation (Decree 44/2000), except high amount of the BOD_5, and COD_{cr} in all examined samples than the permissible limit or it was so much near to the action limit.Also the amount of oil and grease, BOD & COD for septic tank sample is exceed the permissible limit of the Egyptian Environmental Regulation (Decree 44/2000).

6.2: Identification of Possible Treatment Schemes

Alternatives for management and treatment of the discharged industrial wastewater 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 stated above, treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater effluent of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using two proposed streams of techniques; Physical Treatment "Gravity separation" flowed by Chemical Treatment "Chemical Coagulants".The following tables and figure illustrate the effect of proposed treatment on the different wastewater pollutants.

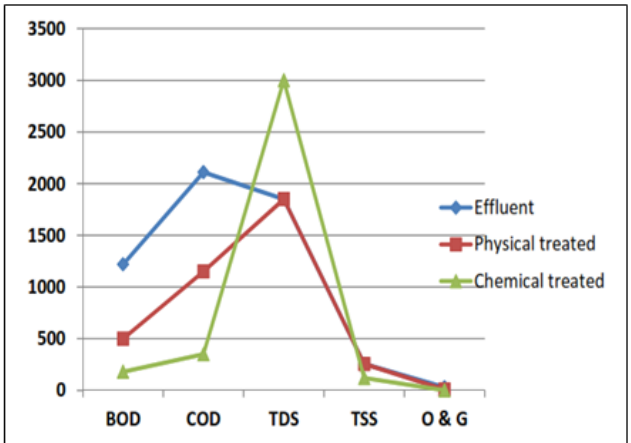

Figure 1-a: Average Wastewater Effluent Quality, 1st Week

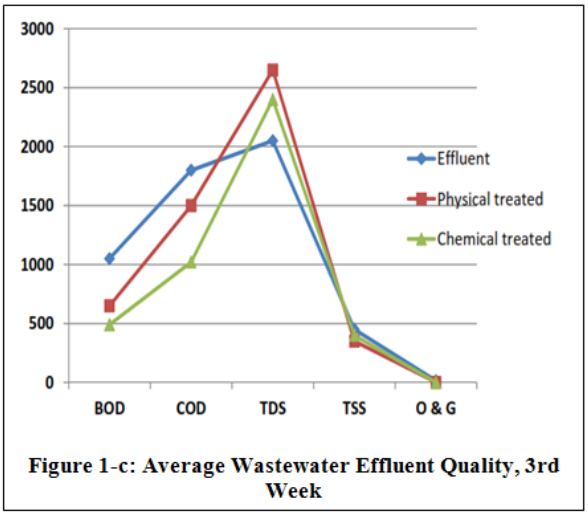

Figure 1-c: Average Wastewater Effluent Quality, 3rd Week

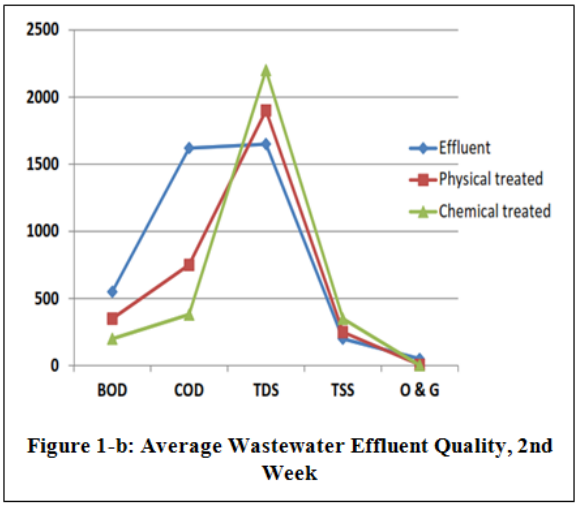

Figure 1-b: Average Wastewater Effluent Quality, 2nd Week

Effluent Quality after the Physical Treatment: The quality of the final industrial water effluent to the public sewer system results of laboratory measurements shows that The COD_{cr} amount are not comply with the Egyptian Environmental Regulation (Decree 44/2000). The Physical treatment eliminate the amount of COD_{cr} from (13 to 22 %), BOD from (37 to57%) and oil and grease from (70 – 100%).

After Chemical Treatment: The use of chemical coagulants (ferrous sulfate) is used to break emulsion .i.e. this coagulant serve to decrease the interfacial tension between the dispersed oil phase and the wastewater. The quality of the final industrial water effluent to the public sewer system results of laboratory measurements shows that the CODcr amount are not comply with the Egyptian Environmental Regulation (Decree 44/2000). The Chemical treatment eliminates the amount of COD_{cr} from (45 to 81 %), BOD from (57 to85%) and oil and grease from (69 – 100%). This elimination recovery percent can be enhanced by studying the pH value effect and studying the effect of adding cationic and anionic polymer.

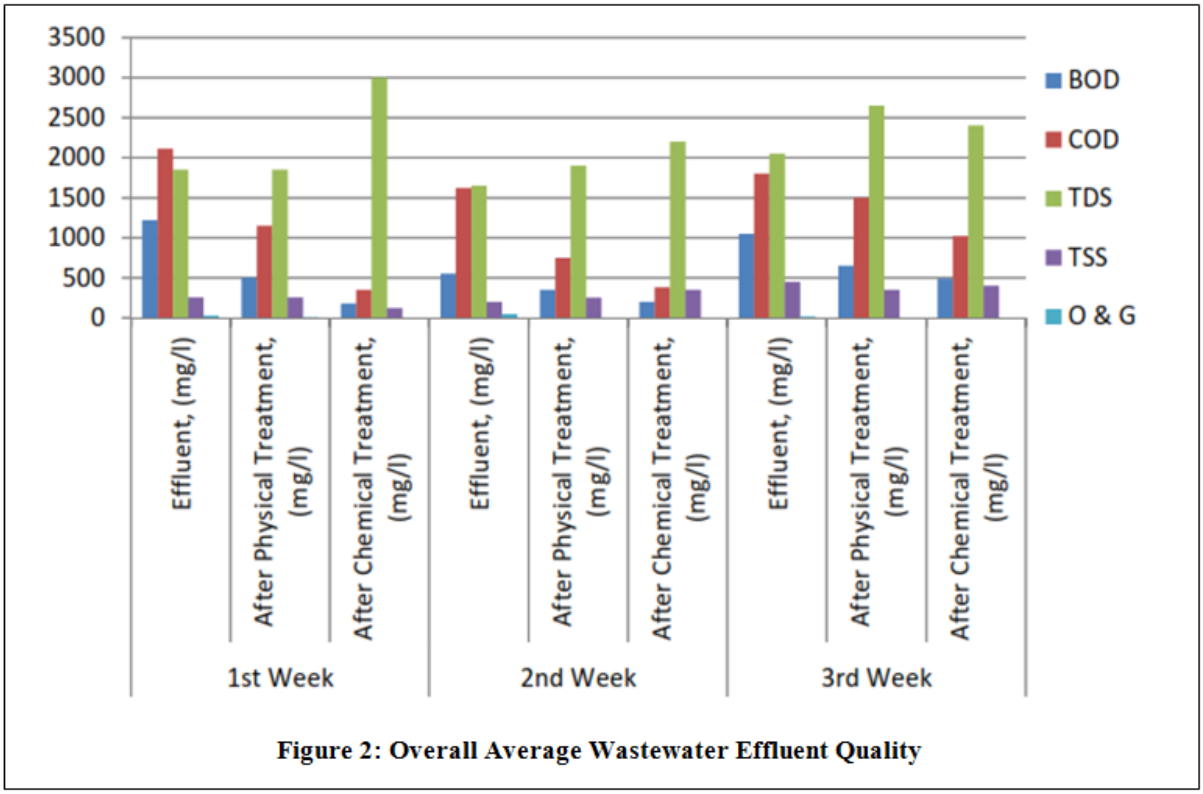

Figure 2: Overall Average Wastewater Effluent Quality

Table 1: Average Effluent Characteristics

Parameter, (mg/l)	**Effluent,** (mg/l)		**After Physical Treatment,** (mg/l)		**After Chemical Treatment,** (mg/l)	
	Range	Average	Range	Average	Range	Average
BOD	550-1220	940	350-650	500	180-490	290
COD	1620-2110	1840	750-1500	1130	350-1020	583
TDS	1650-2050	1850	1850-2650	2135	2200-3000	2530
TSS	200-450	305	250-350	285	120-400	290
O & G	15-50	32	2-8	5	0-2	0

Table 2: Effluent Removal Efficiency

After Physical Treatment		
Parameter	Units	R.E
BOD	%	37-57
COD	%	13-22
Oil and Grease	%	70-100
After Chemical Treatment		
Parameter	Units	R.E
BOD	%	57-85
COD	%	54-81
Oil and Grease	%	69-100

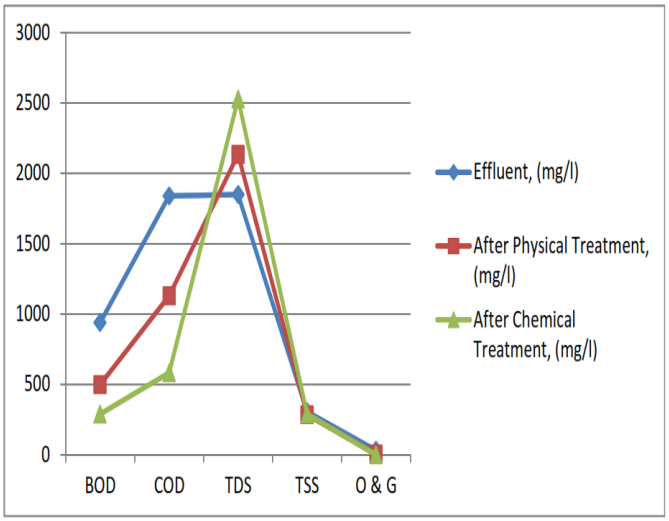

Figure 3:Overall Average Wastewater Effluent Quality

VII. CONCLUSION AND ASSESSMENT OF THE TREATMENT ALTERNATIVES

Based on the analysis and treatability study of the alternative Physical Treatment by Gravity Settling, it is clear that the BOD and COD are still not complying with the regulatory limits for the discharge to the sewer system. Accordingly, equalization and gravity settling is not considered a feasible alternative for treatment of the industrial wastewater discharge. Moreover, based on the above calculations, using the chemical treatment after equalization and gravity settling while enhance the quality of the wastewater effluent but it is still does not assist in complying with the regulatory limits. It is resulted in reduction of COD, BOD, and oil and grease by 45 to 81 %, 57 to 85%, and 69 to 100% respectively. The recommended that the effluent quality can be enhanced by studying the pH value effect and studying the effect of adding cationic and anionic polymer.

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