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Sustainable solutions for urban wastewater management and remediation

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Sustainable development with environmental protection is one of the greatest challenges of the 21st century. There is a growing consideration of the sustainable development and environmental management in new industrial cities. Investigational aspects were carried out in El Obour city as Egyptian new industrial city for estimating the current wastewater problems as well as applying mitigation actions. Industrial inventory was constructed for selected industrial sectors as food, chemical and textile sectors including water consumption, materials and energy resources. Wastewater samples from different factories and lifting stations were analyzed for estimating the industrial effluent loads. The obtained data revealed that food sector represents the highest load for BOD and TSS with values of 80 ton BOD/day and 2.33 ton SS/day. For selected industrial sectors, cost-effective technology is applied to reduce the loads on the centralized wastewater treatment plant (WWTP) as well as on the lifting stations. Inorganic polymeric ferric chloride (POFC) coagulant gives higher removal efficiency for TSS and COD without pH control. Moreover, the chemicals cost for treating wastewater is reduced by 40 % with using POFC instead of conventional coagulants.

Keywords: Management, pollution loads, chemical treatment, urban wastewater, industrial wastewater

Introduction

The world is facing a global water quality and quantity crisis. Continual rapid industrialization and population growth are making demands on water resources and increasing the prohibited contaminated discharges to aquatic environment. This represents a global threat to human health and safety, with both immediate and long-term consequences for efforts to reduce poverty whilst sustaining the integrity of some of our most productive ecosystems **[1-4].** In Egypt the rapid increase in population growth continues for decades to become increased up to 150 million by 2050. This high population growth rate exaggerates the troubles revealed that fast deteriorating surface and groundwater quality **[5]**. Ministry of Water Resources and Irrigation (MWRI) stated that the value of water demand for the industry was 5.4 BCM/year within the year 2017. A small portion of that water is consumed through evaporation and during industrial processes (only 0.7 BCM) while most of that water returns polluted to the eco system. By the year 2020, required water for industry will be increased by 20% (6.48 BCM/yr). Since, all water applications require specific water quality thus, the current quality deterioration rate indeed increases the severity of the water problem and the treatment cost (i.e. treatment requirements) of using water at the levels expected in 2020 **[6].** Egyptian national industrial development strategy targets by the year 2025, Egypt becomes the leading industrialized nation in the Middle East and North Africa (MENA) region. This is required improvement the water quality and quantity and

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the new industrial cities are suitable in regard to the infrastructure and services **[7].** The Egyptian manufacturing sectors have a great contribution in economic output. The largest industrial sectors are textiles, food and beverages, and furniture followed by non-metallic minerals, metal production, chemicals and basic metals **[8]**. El Obour city is considered to be a second-generation of industrial city it has developed over the past 30 years as the largest industrial city in Egypt and depending mainly on the industrial activities as economic base. Although this industrial sector plays an instrumental role in revitalizing economic growth in the Egyptian economy but it considered one of the major sources of water pollution. The aim of our research is management of urban wastewater in an Egyptian city to minimize the industrial pollution loads through mitigate and/or treatment of industrial wastewater.

Materials and Methods

2.1 Study area and environmental inventory

El-Obour city is one of the new Egyptian cities with total area of sixteen thousands hectares and is located near east Cairo city. It consists of nine residential areas with total populations of 250000 P.E and four industrial areas. The city contains potable water treatment plant with capacity of 80000 m^3/d. However, it does not have wastewater treatment plant and its wastewater is pumped to Al-Gabel Al-Asfar wastewater treatment plant which is far about 21 kilometers from El-Obour city. The wastewater pumped to Al-Gabel AL-Asfar containing industrial wastewater which affects the sewerage pipes and treatment efficiency.

Inventory of industrial sectors in El Obour city was categorized according to Entec /TCOE Guideline [9-10]. To evaluate the environmental situation in the city; a template for collecting relevant data was designed; which include all activities, No. of Employees, raw materials, energy resources, energy consumption/day production quantity/ day and their hydraulic load. Cleaner production measures were applied in order to reduce hydraulic and organic load to achieve compliance with legislation.

2.2 Wastewater sampling and characterization

Wastewater samples were collected from each industrial sector in El-Obour industrial city. The samples were collected from final effluent of each factory. Also, wastewater samples were collected from four lifting pump stations that collect all wastewater to El-Obour city and pumped it to Al-Gabel Al-Asfar wastewater treatment plant. The collected samples analyzed for the pollution indicators stated in law 92/1962 and ministerial decree 44/2000 for discharge into public sewerage system. These analyzed parameters were total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), total phosphorous (TP), oil and grease, phenol, cyanide, settle able solids, hydrogen sulfide. The analyses of all parameters were conducted according to the standard methods **[11]**. Accuracy and precision of measurements were confirmed using external reference standards from Merck, and standard reference material and quality control sample from National Institute of Standards and Technology (NIST), were used to confirm all the instrument reading. All analyses were conducting in triplicate runs.

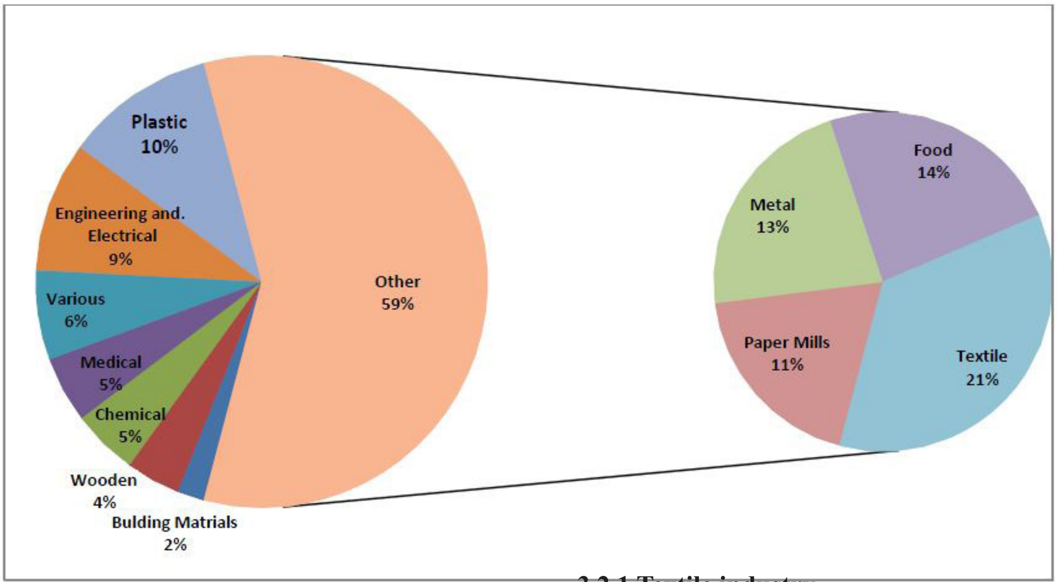
2.3 Chemical Treatment of wastewater

In order to minimize pollution loads, chemical treatment with jar test was applied. Jar testing is a method of simulating a full-scale wastewater treatment process, so operators can use jar test to help in determination of optimum operating conditions. This was intended to obtain the pH value and coagulant dosage required for the best removal of the pollutants. Ferric chloride and inorganic polymer (POFC) submitted patent No. 1096/2018 was selected as a competent coagulant for wastewater treatment. The analyses of treated effluent were conducted according to the standard methods **[11]**.

Results and Discussion

Insufficient urban wastewater management and lake of pollution prevention caused serious of environmental problems by clogging of sewage network, destruction of lifting pumps stations and deteriorating ground water. Since the aim of this study is to evaluate and management of pollution loads for some of selected industrial sectors with high pollution loads in El Obour city, physico-chemical analysis of wastewater produced from different factories takes place in addition to assessment the quality of wastewater in the four lifting stations to verify the quality of wastewater pumped from the city to Gabel Al-Asfer wastewater treatment plant. Application of some mitigation measures in order to reduce the industrial pollution loads. The major industrial sector in El Obour city was textile which represented 21% of total industrial plants. However, food, metal and paper mills industries have almost similar percent (14, 13, and 11 %) as shown in Figure (1), which represent 38 % of total industrial plants in El Obour city.

Fig.1. Different categories of industrial sector in El Obour industrial Zone



3.1 Implementation of environmental awareness and assessment of pollution loads for industrial sectors

Before the start-up of the study, environmental awareness workshop was organized for increase the importance of environmental management for pollution problems within factories, reduction of loads of pollutant on centralized WWTP. Detailed inspection conducted to record the industrial waste generated within the El Obour industrial city for 30 companies. This activity is critical for the effectiveness of research objective the verification of basic facility data is enhanced and validated within this objective. As mentioned above, the textile, food and paper mill industries represented 46 % of total industrial plants in El Obour Zone. Consequently, their own pollution loads may embody the major fraction of generated wastes. Therefore, detailed environmental loads of individual sector are determined.

3.2 Monitoring and management of pollution loads in different industrial sectors

3.2.1 Textile industry

Textile industry is one of the major consumers for water and non-biodegradable chemicals during the processing at various stages**[12].** The discharged wastewater from textile industries contains different types of dyes, which shows low biodegradability **[13].** Also, the direct discharging industrialized effluent into municipal wastewater produces turbulence in biological treatment processes. The effluents produce high concentrations of inorganic salts, acids and bases in biological reactors leading to the increase of treatment costs **[14]**. Many methods have been reported for removing color from dye wastewater, among which coagulation is a widely used process. Coagulation–flocculation is a commonly exploited procedure for treating water and wastewater due to its high efficiency and low cost **[15].** Besides, dyes are reduced by coagulation–flocculation without decomposing which produce further toxic compounds **[16].**

Characterization of textile industrial wastewater produced from ten wastewater treatment plants indicated that there are compliance with permitted standards as each company has his own wastewater treatment plant. The pH of the industrial effluents was ranged from 6.5 to 9.8. The variation of pH is due to different types of dye stuff used in the dyeing process for the various textile industries **[17].** The total dissolved solid is indicator for the sum of ionic components of discharge. The average level of TDS in the textile discharge was found to be 1105 mg/L. The elevated concentration of TDS is not proper for aquatic organism and agriculture. Also, textile discharge has daily pollution loads on the final discharge to wastewater treatment plant WWTP reached to 25.5 ton/day for COD, 10.6 ton/day for BOD as shown in Figure 2. However, total suspended solids (TSS) denote particulates in waters. Detection of TSS is vital due to their responsibility for holding pollutant into aquatic environment. The average value daily and annual load of TSS in the effluent was found to be 1.02 ton and 309 ton, respectively as shown in Figures (2-3).

Fig.2 Daily pollution loads for textile industries on WWTP

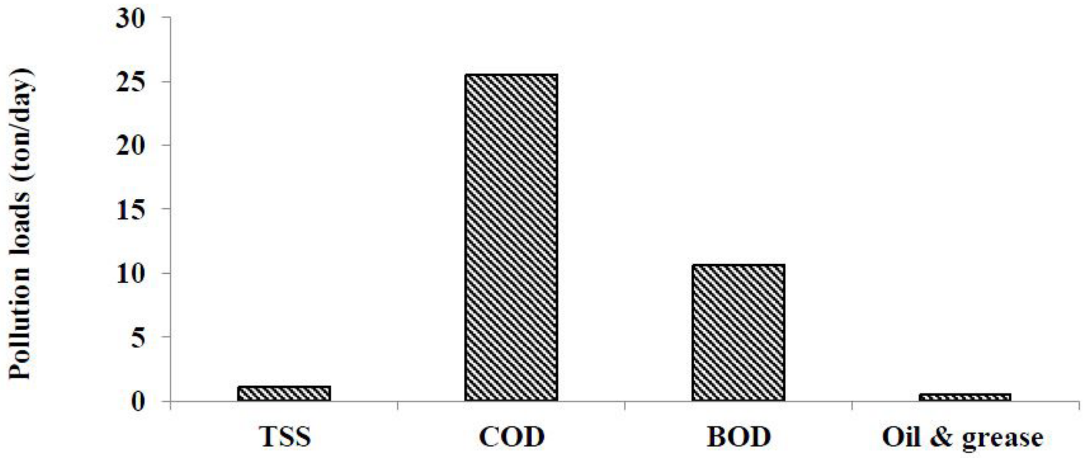
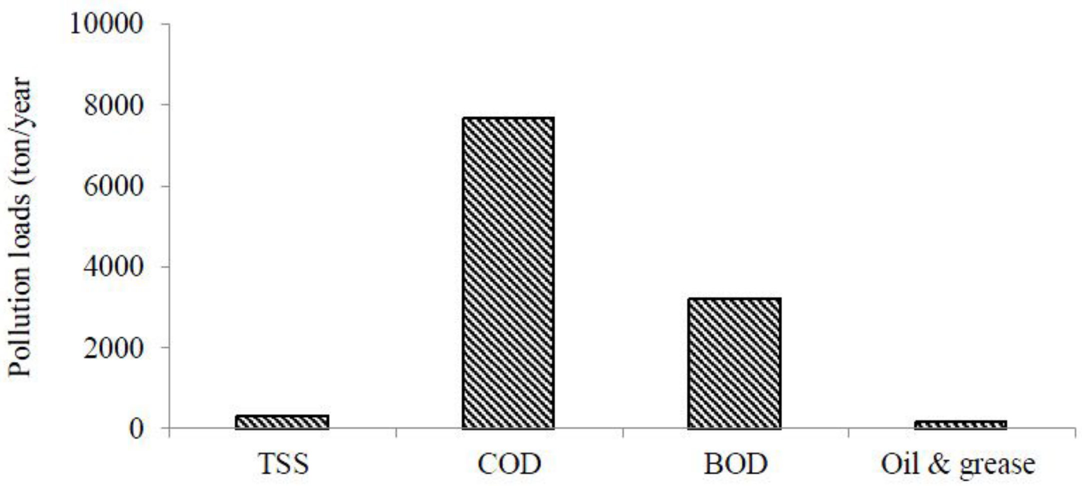


Fig.3 Annual pollution loads for textile industries on WWTP



Whether compliance with the environmental legislation, treated wastewater reuse in the industrial process or minimize water consumption and mitigation of pollution loads are necessary. Therefore, flow segregation was conducted in the textile dyeing sequence to reduce the pollution loads as well as reuse is feasible. There are several different distinct stages; scouring, neutralization, dyeing, acid wash, softening and rinsing. According to the characteristics of different streams, the textile effluent is segregated, managed and neutralized prior to discharge into wastewater treatment plants as well as sewer system, which reduce the running cost of the treatment plant.

3.2.2 Food industries

Food manufacturing is consuming huge amounts of water and generates large quantities of wastewater as well. Food industries effluent typically contains high concentration of different contaminants which require further treatment **[18]**. Most of contaminants are organic matters, suspended solids and oil. Effluent characteristics arising from food industry are dependent on the sort of product, the manufacture processes, operation procedures, and consequently the quantity of recovered water. Food industries discharge has daily and annually pollution loads on the final discharge to wastewater treatment plant WWTP reached to 200.2 ton/day and 60087 ton /year for COD, 80.6 ton /day and 24204 ton /year for BOD while the average values daily and annual loads of TSS in the effluent were found to be 13.3 ton and 3989 ton, respectively as shown in Figures (4-5).

Fig.4 Daily pollution loads for Food industries on WWTP

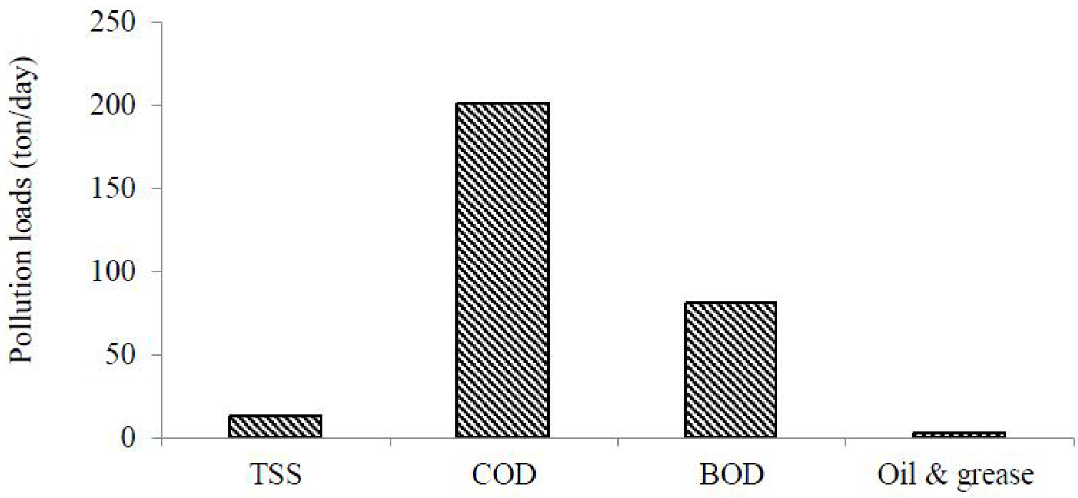
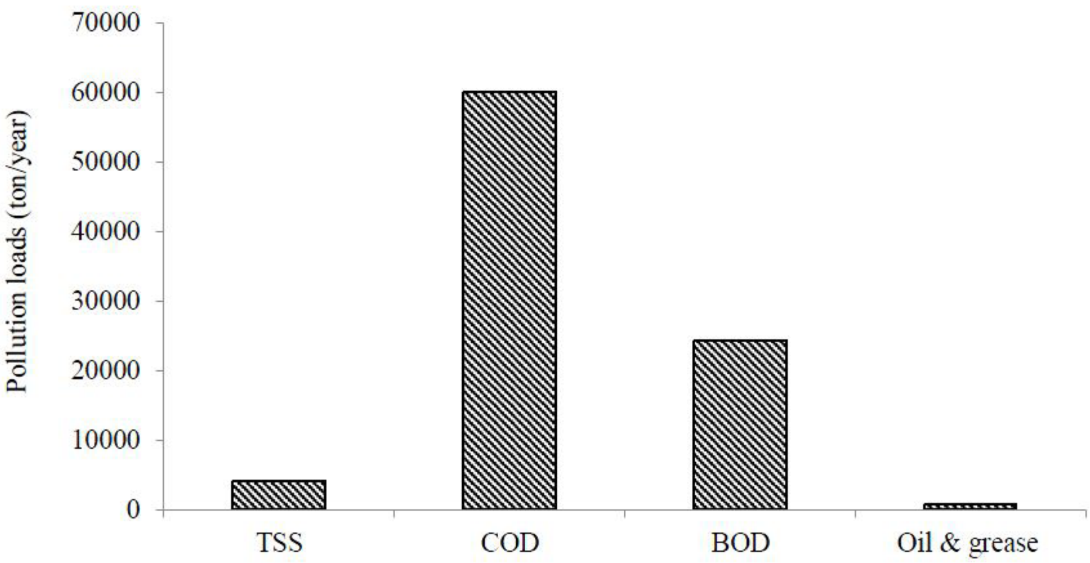
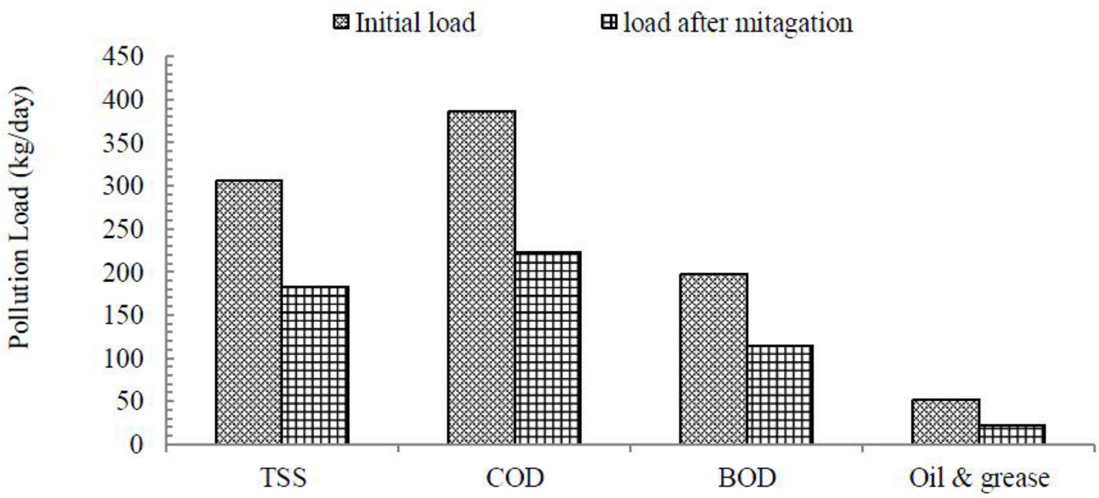


Fig.5 Annual pollution loads for Food industries on WWTP



One factory of food industry for the manufacturing and packaging of butter and natural margarine is selected as model for application of management and remediation of pollution loads. Implementation of good housekeeping in handling and manufacturing process through 1) controlling leakage in production lines and repairing connection between the feeding lines and the mixers, 2) prevention seepage of raw material during refitting the connection of two feeding. 3) Applying good and productive maintenance with definite schedule for all connection. Moreover, Application of cleaner production procedure in manufacturing process reduced the pollution loads as shown in Figure (6).The TSS, COD and oil & grease loads are decreased by 40, 43 and 58 % after applying of these onsite aspects.

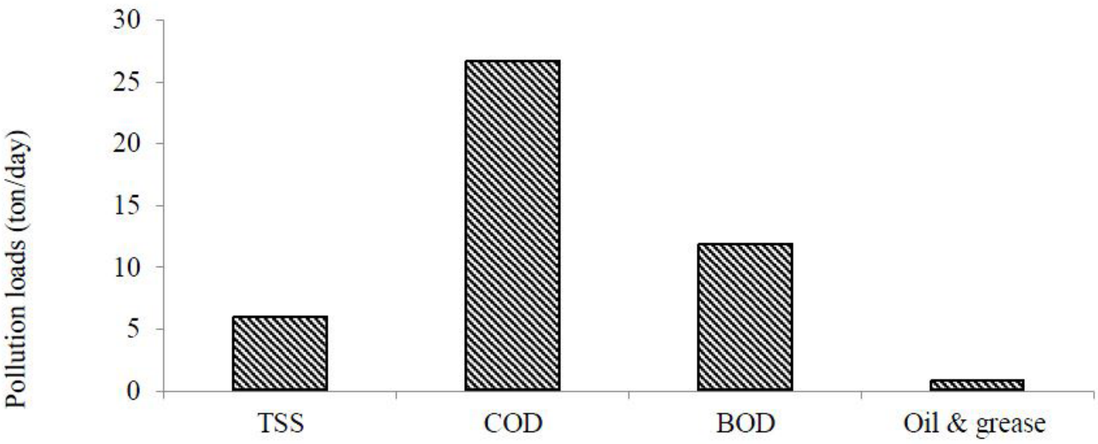
Fig.6 Reduction of Pollution loads for Food industries



3.2.3 Paper mill industries

The paper industry is a chemical process industry with major impact on the environment. The potential pollutants from a pulp and paper mill can be classified into wastewater effluents, air pollutants, solid wastes and noise pollution [**19-20**]. Paper mill industries effluents have daily and annually pollution loads on the final discharge to wastewater treatment plant WWTP reached to27 ton/day and 7986 ton O_2/year for COD and 12 ton /day and 3539 ton /year for BOD while the average value daily and annual load of TSS in the effluent was found to be 6 ton and 1761 ton, respectively as shown in Figures (7-8).

Fig. 7 Daily pollution loads for paper mill industries on WWTP



Laboratory study was carried out using jar test for wastewater of one of selected paper mill factories. Chemical treatment was conducted using different metal-based coagulant. Treatment trial of composite wastewater samples is investigated with different doses and types of coagulant which range from 100 - 250 mg/L of commercial ferric chloride and POFC with different dose range from 0.5-1 mL/L (28-56 Fe mg/L) and Figure (9) represented the removal efficiency of different coagulants alongside the cost. Figure (9) revealed that POFC coagulant has higher removal efficiency for TSS and COD than that of ferric chloride without pH control. As well application of POFC reduced the chemical cost for treating paper mill wastewater by 40 %. It is obvious that the using of iron-based polymer provided high removal efficiency comparing with ferric chloride at low irons dose and at pH complying with Ministerial Decree 44/2000. Finally, POFC is promising coagulant for treating paper mill wastewater and it's a cost-effective material in chemical treatment.

Fig. 8.Effect of annually pollution loads for paper mill industry

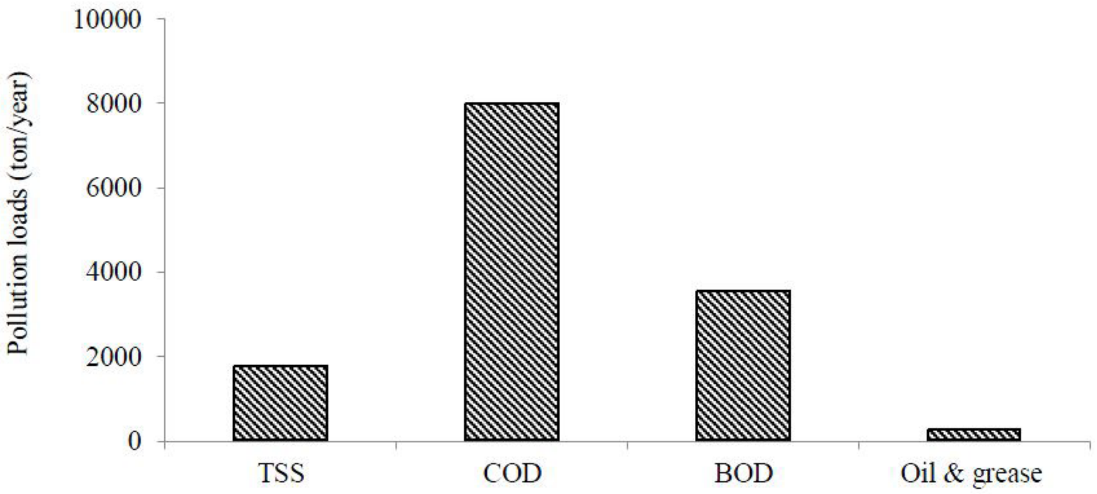
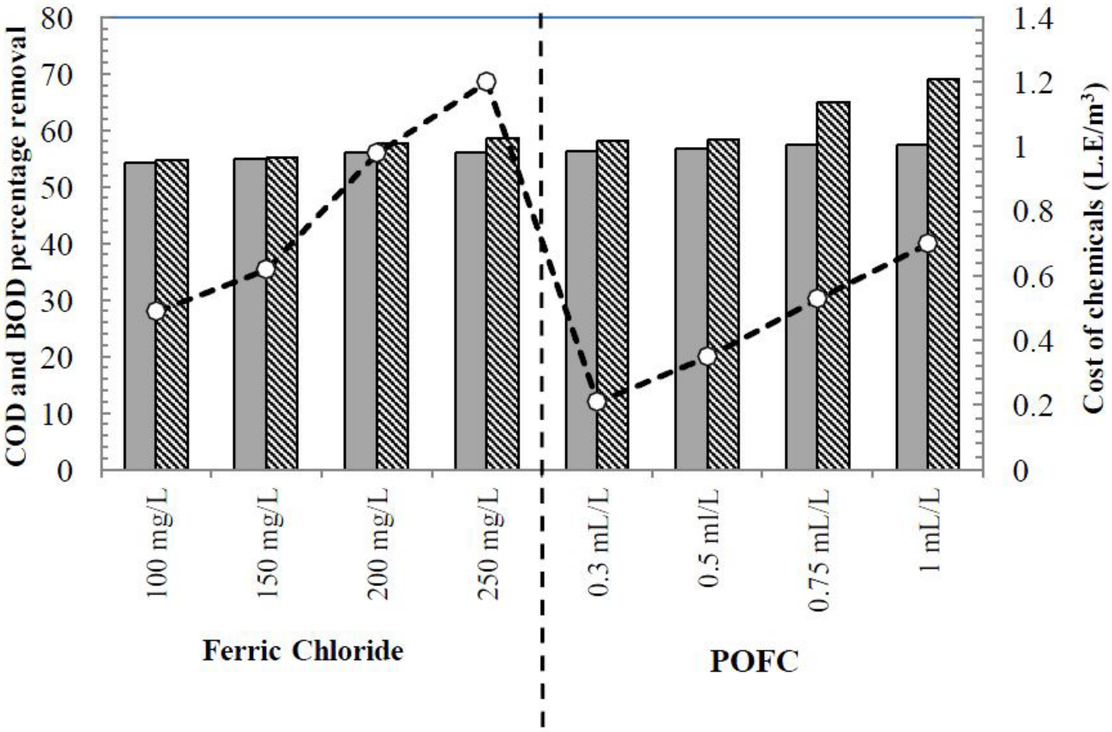


Fig. 9. Removal efficiency using different coagulant and dose for treating of paper mill industry and cost



3.3 Management and treatment of collected wastewater in lifting pump stations

The results obtained from different industries indicated that food industry is the highly polluted industry than paper mill then the textile. Figure (10) indicates the pollution loads produced from the mentored pollution industrial sector and actual pollution load pumped to Al-Gabel Al-Asfer wastewater plant. The results indicated that the pollution load is almost the same and the little difference was attributed to receiving of domestic wastewater which represent about 18% of received water in the lifting pump stations. Therefore, assessment for the pollution loads from combined wastewater in lifting station is necessary. Also, the application of cost-effective technology is investigated for reduction of loads on the centralized WWTP. The average characteristics of combined wastewater indicated that non-compliance with Ministerial Decree 44/2000, which discharges directly to El-Gabel El-Asfer wastewater treatment plant the centralized wastewater treatment plant (Figure 11). To secure the trouble shooting, suggested chemical treatment is applied using coagulation precipitation technology for reducing loads that affect the efficiency of WWTP **[21-24]**. Figure (12-13) represented the removal efficiency of different coagulants for removal of COD and TSS at different coagulant dose. It is obvious that the using of iron-based polymer gives high removal efficiency comparing with ferric chloride at low coagulant dose and at pH complying with Ministerial Decree 44/2000 (See. Figure 13)

Fig.10.Contribution of pollution loads from different industrial sectors per day

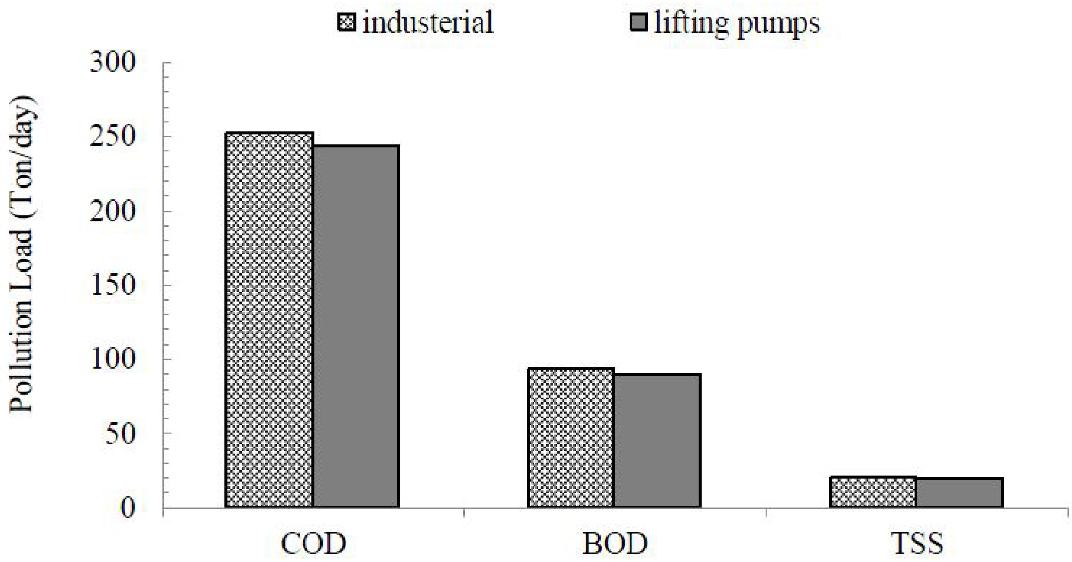


Fig.11. The average characteristics level of wastewater pumped directly to centralized wastewater treatment plant

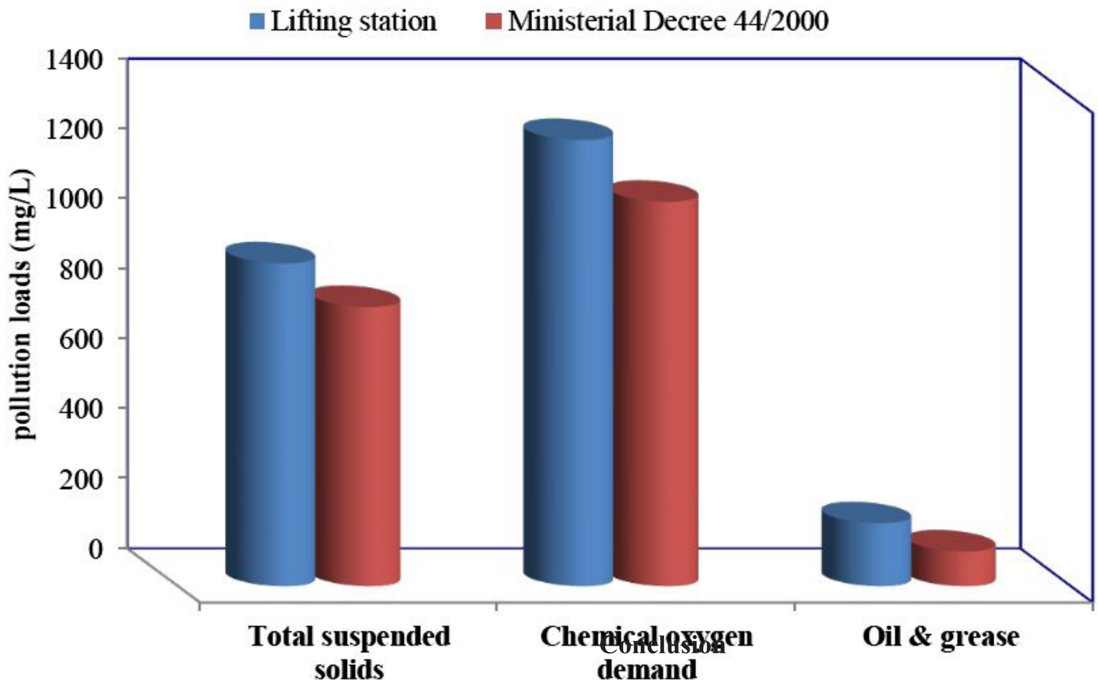


Fig.12 Effect of coagulant dose on removal of pollution loads of wastewater from lifting station

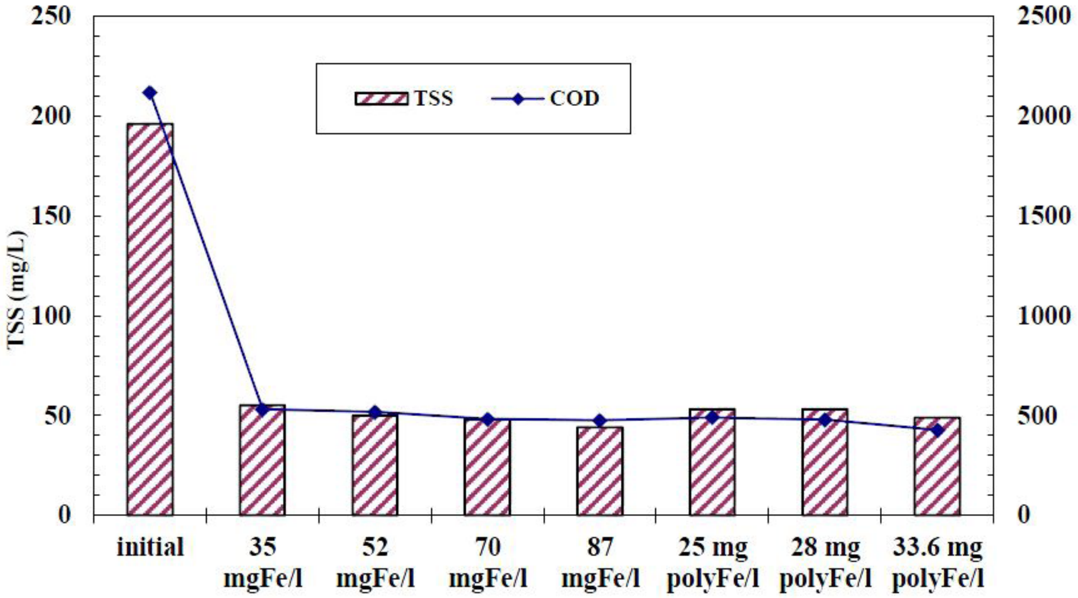
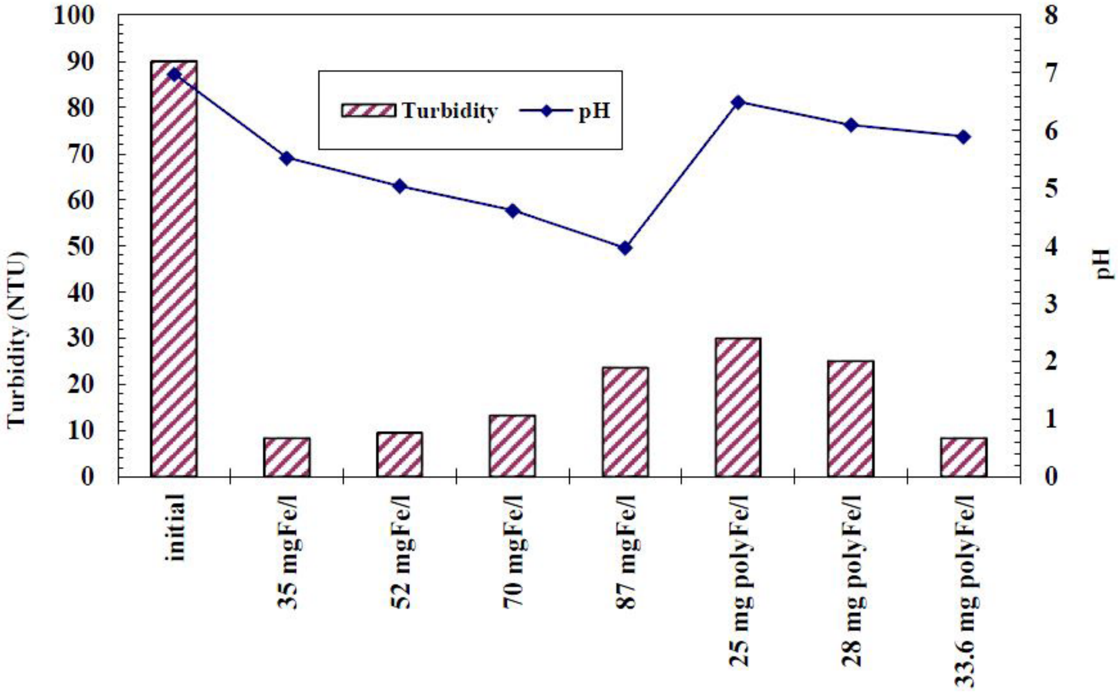


Fig.13 Effect of coagulant dose on pH and turbidity removal of wastewater from lifting station



Assessment of the current situation in El Obour city was carried out for achievement of sustainable management of industrial wastewater. Complete industrial inspection of the selected companies was carried out for different industrial sectors. The results indicated that most of wastewater produced from these factories was violating the permissible limits of ministerial decree 44/2000. Moreover, the wastewater samples from lifting stations were analyzed for estimation of the loads of different industrial effluent. The obtained data revealed that food sector has higher loads for BOD and TSS in the generated wastewater in industrial Zone with values of 80 ton BOD/day and 13.2 ton SS/day. Applied onsite mitigation aspects such as cleaner production procedure reduced the pollution loads of TSS, COD and oil & grease by 40, 43 and 58 % in food manufacturing process. For selected industrial sectors, cost-effective technology is applied to reduce hydraulic and organic loads on the centralized wastewater treatment plant as well as on the lifting station.

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حلول مستدامة لإدارة ومعالجة مياه الصرف بالمناطق الحضرية

تولى مصر إهتماماً متزايد للتنمية المستدامة والإدارة البيئية في المدن الصناعية الجديدة حيث تعد حماية البيئة والتنمية المستدامة من أعظم تحديات القرن الحادي والعشرين وقد تم إختيار مدينة العبور كمدينة صناعية مصرية جديدة لتقييم مشاكل مياه الصرف الصناعى وكذلك تطبيق إجراءات تخفيف احمال التلوث . تم إجراء المراجعه البيئية وتقييم المخلفات الصناعيه لقطاعات صناعية مختارة مثل قطاعات المواد الغذائية والكيميائية والنسجية وتضمن ايضا استهلاك المياه والمواد وموارد الطاقة . وكذلك تحليل عينات مياه الصرف الصحي من مختلف المصانع ومحطات الرفع لتقدير الأحمال الصناعية السائلة. وأوضحت الدراسه أن قطاع الصناعات الغذائية يمثل أعلى أحمال عضوية متمثله فى تركيزات الأحتياج الأكسوجينى الحيوى والمواد العالقة الكلية بقيم 80 طن / يوم و 2,33 طن / يوم على الترتيب. وقد تم تطبيق تقنية فعالة من حيث التكلفة على القطاعات الصناعية المختارة لتقليل الأحمال على محطات الرفع ومن ثم على محطة معالجة مياه الصرف المركزية (WWTP) . بتطبيق تكنولوجيا المعالجه الكيميائية (التخثير والترويب) بإستخدام مختر كلوريد الحديديك البوليمري غير العضوي (POFC) المحضر معمليا و الذى اثبت كفاءة عالية فى إزالة والمواد العالقة الكلية (TSS) و الإحتياج الأكسجينى الكيميائى (COD) بدون التحكم في درجة الحموضة وعلى ذلك إنخفضت تكلفة المواد الكيميائية لمعالجة المياه الصرف بنسبة 40 ٪ بإستخدام POFC بدلاً من إستخدام المخثرات التقليدية .