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Full Length Research Paper

A full-scale biological aerated filtration system application in the treatment of paints industry wastewater

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This study was carried out to evaluate an existing treatment technology for wastewater treatment unit from a paint production factory. Biological aerated filter is a good technique for reducing land used in the purpose of wastewater treatment. Influent discharged from this factory ranged between 50–120 m^3/day with an average of 70 m^3/day. This unit composed of primary and secondary sedimentation tanks, gravel filter and finally sand anthracite (3:1 by volume) filter. Aeration units and two submersible pumps were equipped for aerobic treatment and sediments removal. The unit influent was characterized by average values of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5) and total suspended solids (TSS) were 1711±795, 748±180 and 3821±1621 mg/l, respectively. Primary sedimentation of the wastewater for six hours reduced the COD, BOD, and TSS by 43, 26, and 76%, respectively. The treated wastewater characteristics are in compliance with the Egyptian law which regulates the discharge of industrial wastewater to the sewerage system. The results from each treatment process proved to be efficient for the treatment of such wastewater.

Key words: Paints wastewater treatment, Biological aerated filter and water quality.

INTRODUCTION

Paints classification can be made on many different basis; one convenient method is to classify paints based on their primary solvent for waste reduction and disposal. Using this approach, paints can be classified as water based, organic solvent based or powder (dry) and without solvent (Körbahti et al., 2007). A large variety of pigments and extenders of different grades are used for different functional requirements and they vary widely from synthetic to natural minerals, organic, inorganic to metallic, and depending upon the source of raw materials (Debnath and Vaidya, 2006). Paint is generally considered as a mixture of pigment, binder, solvent and additives, and the type and proportion of each component in the mixture characterize the properties of a particular paint. The components of paint also determine the characteristics of the waste generated in its manufacture and use (Körbahti and Tanyolac, 2009).

The biological aerated filter (BAF) system was widely applied all over the world as a novel wastewater treatment system due to its advantages relative to other systems (Allan et al., 1998). Conventionally, BAF is submerged media wastewater treatment reactors that combine oxic biological treatment and biomass separation by depth filtration (Mendoza-Espinosa and Stephenson, 1999). It adopts a granular media as the support for microbial biofilms that also provides the depth filtration action. BAF was commonly applied to the treatment of primary-treated wastewater or municipal wastewater for tertiary nitrification alone. BAF offers a small footprint alternative to conventional oxic process and it can be operated at high loadings of biochemical oxygen demand (BOD) as compared with trickling filters and activated sludge processes. In a single unit operation of BAF, carbonaceous BOD removal, solids filtration and nitrification can be achieved (Clark et al., 1997). In addition, BAF can be applied to the treatment of

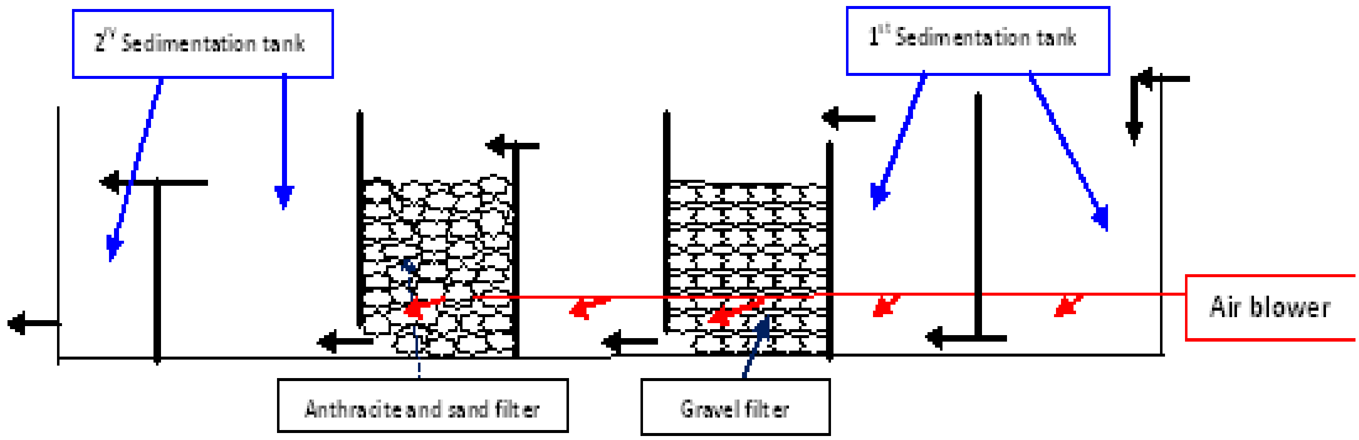

Figure 1. Schematic diagram of industrial wastewater treatment plant with direction of influent flow (black arrows).

refractory wastewater such as textile and oil field wastewater using attached biomass on media (Chang et al., 2002; Zhao et al., 2006).

Water-based paints generally consist of organic and inorganic pigments and dyestuffs, extenders, cellulosic and non-cellulosic thickeners, latexes, emulsifying agents, anti-foaming agents, preservatives, solvents and coalescing agents (Dey et al., 2004). The paint wastewater are characterized by including substantial organic matter, high salinity, sulfate rich and high suspended solid (Aboulhassan et al., 2006).

The aim of the study was to evaluate the performance of the wastewater treatment plant processes. Assessment of chemical and biological loads of treated effluent and compared to Egyptian guidelines were done. The evaluations were performed on total suspended solids removal in the system. The effectiveness of the system was also verified by observing the effluent microbial load during an operation period.

MATERIALS AND METHODS

An industrial wastewater treatment plant with a biological aerated filter (BAF) system was set up under ground in Alexandria chemical and paints company (VELVET), Alexandria, Egypt. Wastewater discharged ranged between 50–120 m^3/day with an average of 70 m^3/day. The major source of pollution in this factory is due to cleaning of the vessels and ground cleaning in different places. Paints wastewater was containing high concentrations of suspended solids, pigments color and oil and grease. The hydraulic retention time (HRT) and dissolved Oxygen (DO) were the key points in the system. The main system was composed of filtration with two sedimentation tanks as as shown in Figure 1. Aeration units and two submersible pumps (4 hp) at the end of primary sedimentation and (2 hp) in between two filters)] were equipped for aerobic treatment and sediments removal.

Sedimentation (S1 & S2) and filtration (F1 & F2) took place in the treatment process. There were two filters with the same dimensions, Gravel one (F1) and the Anthracite sand filter (F2). Each filter was 220 cm in height, 200 cm in width and 200 cm in length. The filter was packed with mixture of anthracites and sand beds which was approximately 3.64 m^3. The F2 was composed from anthracite (5-15mm) and sand (1.0-1.5 mm) and the ratio was 3:1 in volume. Air was provided to primary sedimentation tank and F1 & F2 to maintain the concentration of dissolved oxygen (DO) of 5 mg/l. The primary sedimentation tank was (6h HRT) and had a water barrier in the middle of S1 tank. The secondary sedimentation had the same dimensions of primary tank but the water barrier set at 400 cm away from filter. The sludge was been dredged every one month by submersible pumps to drying lagoon.

Water samples

Continuous wastewater samples were collected from wastewater treatment plant during monitoring period of 6 months (February 2007 – July, 2007). The composed samples were obtained through working hours (8 h) and the Table 1 shows the average and standard deviation for influent data during the studying period. The five sampling points were selected to represent influent, primary sedimentation, grave filtrate, anthracite sand filtrate and effluent.

Physical and chemical analyses of water samples

For physicochemical analyses, wastewater composed samples were collected in sufficient amount in polypropylene bottle and stored under cooling conditions. All the physical and chemical analyses were determined by the procedures recommended in the Standard methods for the examination of Water and Wastewater (APHA, 2005). pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5) and total suspended solids (TSS) were detected.

Microbiological analyses of water samples

Nutrient agar was used for the total viable count bacteria and represented as cfu/1ml. Detection of coliform groups was based on the selective media (M-Endo broth and m–FC broth, Difco) and represented as cfu/100 ml. Membrane filter technique was used for detection according to standard methods (APHA, 2005).

Table 1. The averages and standard deviation of raw water different parameters.

Parameter	Average	±SD
pH	8.73	±0.67
COD (mg/l)	1711	±795
BOD_5(mg/l)	748	±180
TSS (mg/l)	3821	±1621
Total viable count (cfu/ml)	848750	±195731
Total coliform (cfu/100ml)	64125	±37147
Fecal coliform (cfu/100ml)	29210	±31877

COD, Chemical oxygen demand; BOD, biochemical oxygen demand.

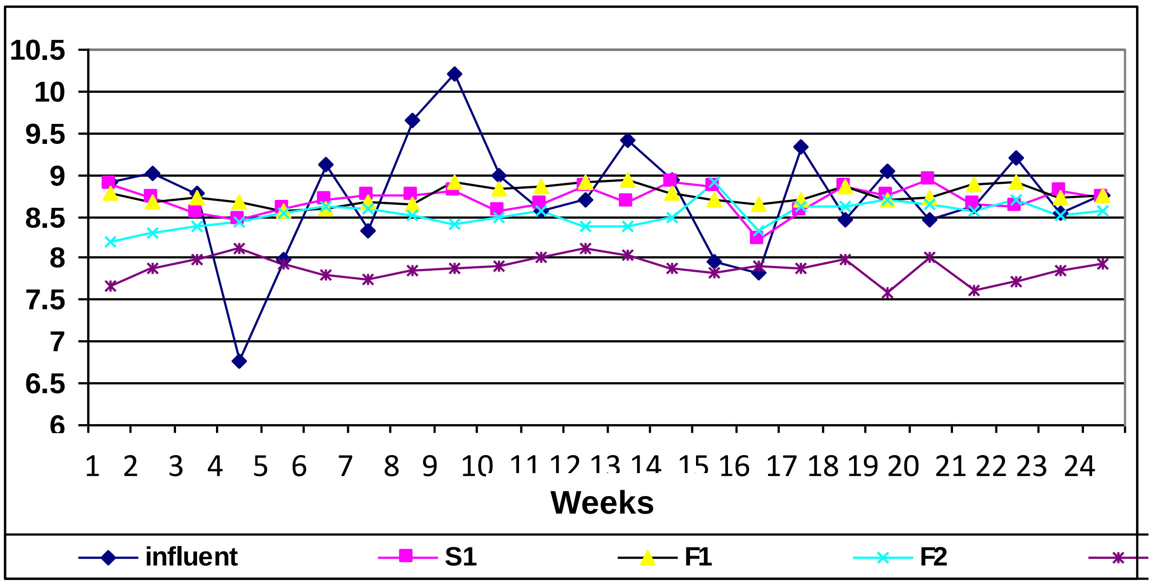

Figure 2. Weekly measurements of pH for different water treatment steps.

RESULTS AND DISCUSSION

Plant evaluation was carried out to determine the effects of the wastewater treatment plant on COD, BOD_5 and TSS removals, and pH change of the industrial paints wastewater, as well as on microbial load removal. Also, the effects of different treatment steps on different parameters were done. Through work program with the sedimentation biological filtration plant, water quality monitoring was performed during the study period from February 2007 – July, 2007. The characteristics of the raw wastewater samples are given in Table 1. Large fluctuations of the pollutants concentrations in the influent were the major challenge to this wastewater treatment plants due to the changes in work schedule in the factory. The COD, BOD_5, TSS values were 1711 ± 795, 748 ± 180, 3821 ± 1621 mg/l, respectively. All water parameter were higher than the Egyptian guidelines for industrial wastewater discharge. Thus, the aerated biological filtration was applied for removing the pollutant component in the samples as well as affecting the COD and BOD fractions of wastewater. The microbial characteristics of the raw wastewater samples were 848750 ± 195731 (cfu/ml), 64125 ± 37147 (cfu/100 ml), 29210 ± 31877 (cfu/100 ml) for total viable count, total coliform and fecal coliform, respectively.

Figure 2 shows the changes in pH based on weekly measurements which is very important for biological reaction. Influent average with standard deviation pH values was 8.73 ± 0.67 with high fluctuation that represented changes in wastewater quality. Under aerobic biological conditions, the pH of effluent recorded lowest values. The average and standard deviation values for S1, F1, F2 and effluent were 8.71 ± 0.16, 8.76 ± 0.11, 8.52 ± 0.15 and 7.88 ± 0.14, respectively. With the continuous treatment steps, there was more pH stability. Effluent pH ranged from 7.56 to 8.11 that have to be considered more controllable for effluent than

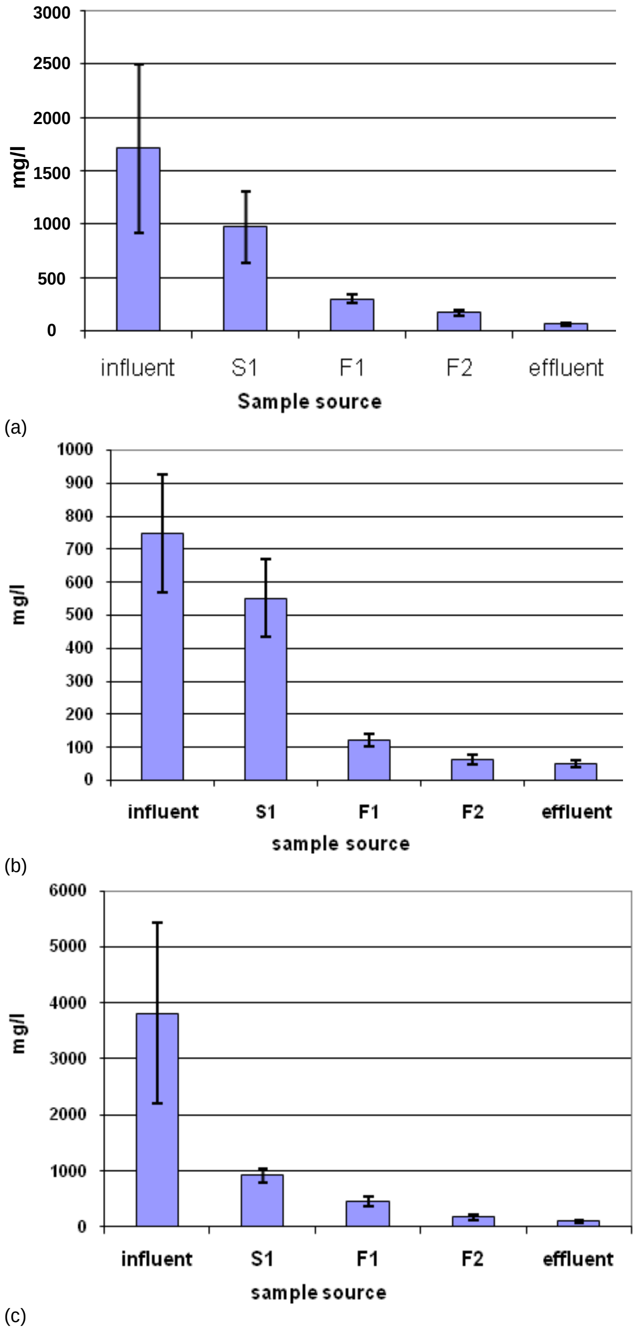

Figure 3. Average and standard deviation of chemical oxygen demand (a), Biochemical oxygen demand (b) and Total suspended solids (c) for different treatment steps.

influent. In this study the direct discharge of Effluent with pH average of 7.88 can be accepted through the Egyptian guidelines.

Physicochemical parameters

The major source of pollution in this factory is due to cleaning of the vessels and ground cleaning in different places. Sedimentation tanks and biological aerated filters technology for the industrial wastewater treatment plant in Alexandria (Egypt) were examined for their maximum achievable physicochemical parameters. The industrial wastewater treatment unit has been carried out close to receiving tank. The first step, different wastewaters were collected in receiving tank. TSS ranged from 2400 to 10500 mg/l for influent and other parameters as shown in Table 1. Influent wastewater quality was more fluctuated than Effluent.

Figure 3 shows the average and standard deviation of COD, BOD_5 and TSS for influent, S1, F1, F2 and effluent during the study period. The study of the effect of complete treatment system on the COD, BOD_5 and TSS removals, indicated that the second filter enhance clearly the pollution removal more than when one filter was used alone. Furthermore, second filter and secondary sedimentation enhance the COD, BOD_5 and TSS removal efficiencies more than Filtration only. The residual pollutants in treated wastewaters plant using multiple steps had great advantage more than one step treatment. The results pointed out that the water used during paints process was not drained into specialized drainage channels but with administration department drainage. Hence, organic load is drained into collection system that is directed to the wastewater treatment plants for treatment in order to be refined. In addition, the results indicated that special filters are not used in that industry to refine water before disposal in drainage channels.

Figure 3 (a, b and c) reveals the variation of COD, BOD_5 and TSS in the full scale system treatment steps. It is clear that the primary sedimentation step was the limiting step factor of paints wastewater treatment. The average and standard deviation for COD, BOD_5 and TSS effluent were 66.92 ± 12.81, 50.4 ± 11.8 and 91.17 ± 25.48 mg/l, respectively. At maximum influent COD, BOD_5 and TSS values, the treatment plant performed 98.7, 94.2 and 98.2%, respectively. Effluents were considered more controllable for different parameters than influent. In this study, the direct discharge of effluent COD, BOD_5 and TSS values could be accepted through the Egyptian guidelines.

After treatment by the combined biological system, COD of the final effluent was steadily reduced to below 100 mg/L. Most of the organic compounds in the treated wastewater which discharged from each factory could dissolved extracellular polymer substances and/or soluble microbial products (Rosenberger et al., 2006; Jarusutthirak and Amy, 2006; Liang et al., 2007; Geng and Hall, 2007).

Microbial analysis

After each treatment step effluent was monitored specially the microbial contents to avoid non-acceptable

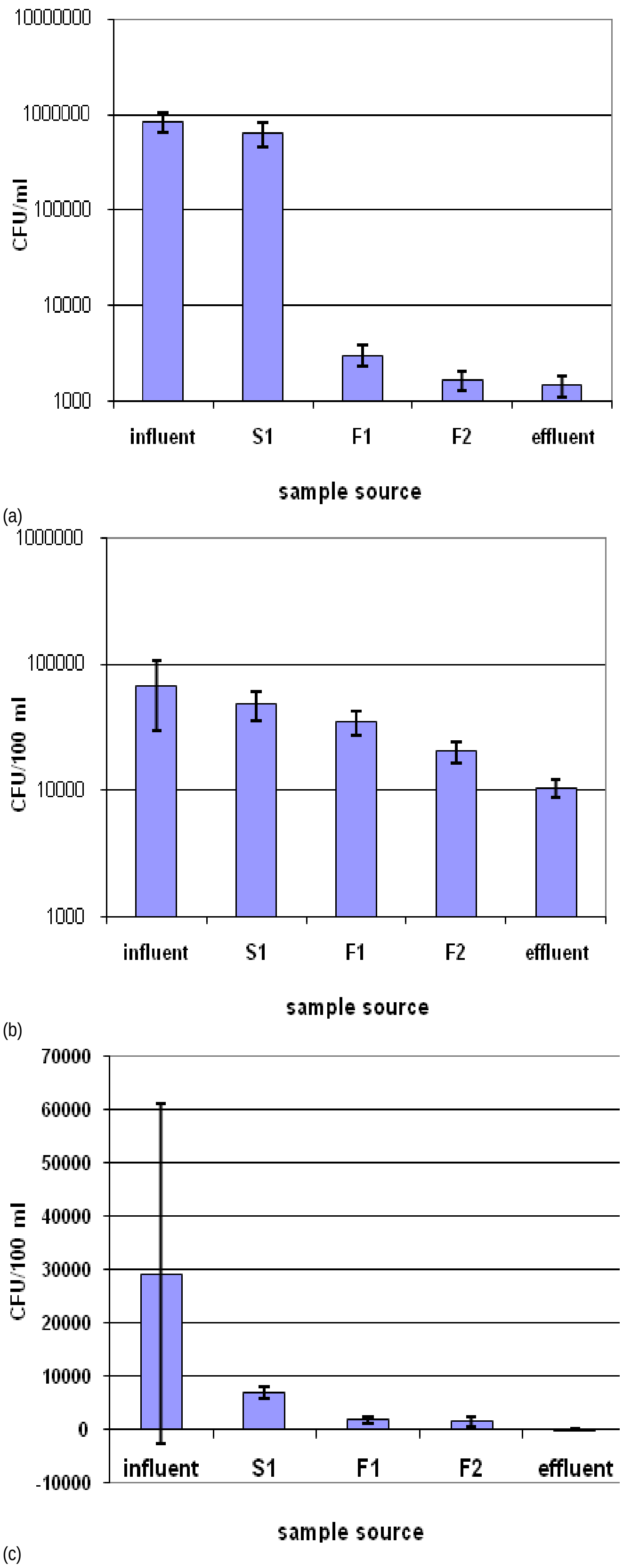

Figure 4. Average and standard deviation of total viable count (a), total coliform (b) and fecal coliform (c) for different treatment steps.

odors resulting from anaerobic conditions. Also, dissolved oxygen was maintained more than 5 mg/l for aerobic conditions. Figure 4 shows the average and standard deviation for influent, S1, F1, F2 and effluent microbial contents during studying period. The fluctuation of microbial contents in influent vary and reveals the variation of total viable count, total coliform and fecal coliform in the full scale system treatment steps. The average and standard deviation for total viable count was 848750 ± 195732 and 1495 ± 365 cfu/ml for influent and effluent, respectively. The effluent average and standard deviation of total coliform and fecal coliform were 10673 ± 1831 and 98.5 ± 45.5 cfu/100 ml, respectively.

As shown in Figure 4a, b and c, the results can observe as follows: The primary sedimentation step had great effect on the fecal coliform more than total viable counts and total coliforms with the dissolved oxygen more than 5 mg/l. At the maximum influent, total viable count, total coliform and fecal coliform values, the treatment plant performed 99.89, 92.1 and 99.9%, respectively. Total coliform gradually removed and the net removal results were less than total viable count and fecal coliform. In this study, the direct discharge of effluent microbial contents can be complied with the Egyptian guidelines.

Performance evaluation

For the treatment, two methods were tested: Sedimentation and filtration. In the filtration processes, two different filters were installed for the optimization of treatment conditions such as gravel filter and anthracite sand filter. The main aim of using different filters was to obtain optimum practicable treatment condition. To assess the efficiency of biological treatment on paint industry wastewater treatment, the following parameters are considered: TSS, chemical oxygen demand, Biochemical oxygen demand and the microbial load. Figure 5 shows the effect of different treatment processes on the industrial paints wastewater. The removal percent after primary sedimentation were 43, 26, and 76% for the COD, BOD, and TSS, respectively. The final removal percent after application of the treatment system for COD, BOD_5, TSS, total viable count, total coliform and fecal coliform were 96.09, 93.26, 97.61, 99.82, 84.37 and 99.66, respectively.

The resulting COD removal rate was around 21%. At considerably high pH values (pH > 12), on the other hand, only a rate of 16% COD removal was attained. This insufficient COD removal rate is the primary reason for the oxidation study. The higher oxidant dose and longer reaction time increase the COD removal rate up to nearly 90% (Kurt et al., 2006).

For the first filter was filled with gravel and the influent average values were COD: 974 mg/l, BOD: 553 mg/l, TSS: 918 mg/l and had removal rates of 69.2, 77.9 and 49.8%, for COD, BOD and TSS, respectively. However, the second filter filled with anthracite and sand had

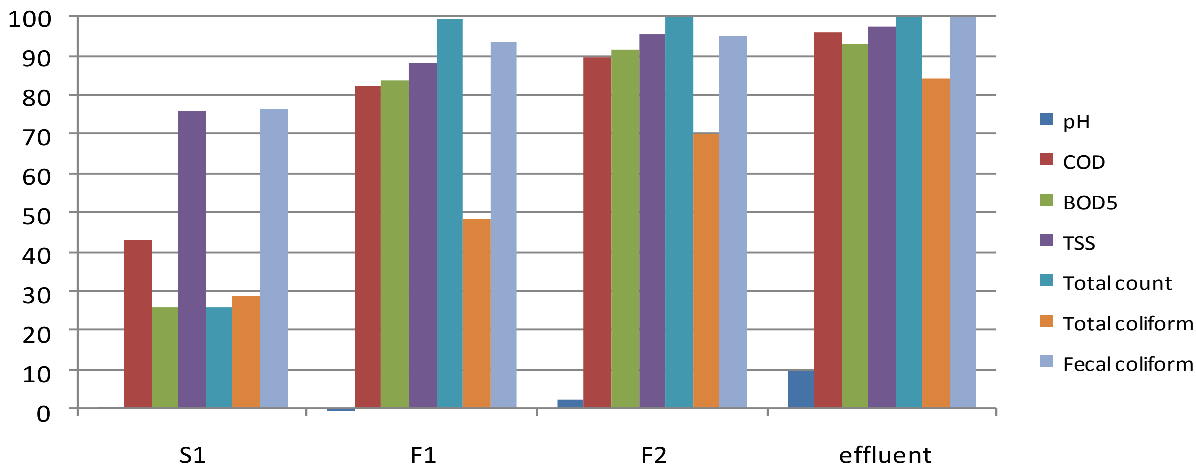

Figure 5. Reduction percent of different parameters under different treatment steps (S1, F1, F2 and final effluent) during studying period.

removal rates of 41.1, 49.6 and 61.1% for COD, BOD and TSS, respectively. The COD and BOD represent the soluble and insoluble pollutants so, the first filter had removal rate better than the second one. For TSS that represents the suspended solid, the removal rate of the second filter had more efficiency than the first one.

The paint wastewaters are characterized which include substantial organic matter, high salinity, sulfate rich and high suspended solid. In principle, the wastewater does not meet the proposed effluent standards. In order to meet these trade-related demands and to respect acceptable environmental standards, it is necessary to subject the effluent to an appropriate treatment. BOD/COD index indicates that a biological treatment seems to be difficult, and then a physicochemical process is required (Aboulhassan et al., 2006). The primary sedimentation and filtration system had great advantages for paints industry wastewater. For the treatment of raw wastewater with BAF system, SS should be removed properly from the wastewater because the SS of influent deteriorates the BAF performance by interfering with mass transfer of oxygen and substrates to biofilms (Hong-Duck et al., 2008). Westerman et al. (2000) initiated that BAF process in treating swine wastewater in which flushed wastes were primarily collected in the settling basin and the overflow from the settling basin was used as the influent for BAF process.

However, filter clogging is a major problem in the continuous operation of filters (Bodkhe, 2008). Two submersible pumps were installed for backwashing and monthly sediments removal to prevent filter clogging.

Conclusion

This case study of wastewater treatment in a water-based paint manufacturing plant succeeded to solve effluent discharge problems to receiving water. The results of wastewater treatment plant influent parameters represented the paints manufacturing waste situation. The influent pollutants including chemical and biochemical load and suspended solids have concentrations higher than Egyptian guidelines concentration.

As a general trend, the outlet pH decreased down to pH 7.88 ± 0.14 from 8.73 ± 0.67. The COD, BOD_5 and TSS removals percent were 96.09, 93.26 and 97.61%, respectively. All detected concentrations of effluent COD, BOD_5 and TSS were within the limits. The rate of the microbial contents removal was less than physicochemical quality because the system depended on biological treatment.

The aerated biological filtration helped to reduce pollution forms which were dissolved and refractory in the paints industry wastewater. This technology was succeeded to obtain significant removal of suspended solids through sedimentation and filtration processes without the addition of any chemicals. During the fieldwork, visually wastewater colors were observed at the location of sample. The water color completely disappeared after anthracite sand filtration step.

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