Industrial Food Processing Wastewater Treatment by Modified Moving Bed Biofilm Reactor (MBBR)

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Abstract— The environmental impact of the food industries is associated with its high water consumption, variety and amount of organic loading which are releases in the wastewater. Wastewaters from cleaning and finishing operations in the food industry are generally high in both organic and nutrient content. Industrial activities generate wastewater contain toxic and non-biodegradable compounds that affect and influence the efficiency of wastewater conventional treatment techniques. In this paper biological treatment was used, so we constructed a pilot plant. This pilot plant was designed to improve the quality of the effluent so we constructed and perform a modification of moving bed biofilm reactor with alternating anaerobic/anoxic/aerobic stages. Samples were collected during 2016 from the raw wastewater of Senyoreta potatoes and snacks factory in Tanta, El Gharbya governorate, Egypt. The samples were analyzed following standard procedures for the determination of: chemical oxygen demand (COD), biochemical oxygen demand (BOD5), total suspended solids (TSS), total nitrogen (Total-N) , total phosphorus and other parameters. The results indicated that the quality of wastewater is very high concentrated with pollutants. The average removal efficiency for effluent from a modified moving bed biofilm reactor in terms of chemical oxygen demand (COD), biochemical oxygen demand (BOD5), total suspended solids (TSS), total nitrogen (Total-N) and total phosphorus was 99%, 98%, 98%, 87% and 91%.

Keywords— Biological treatment, biological nutrient removal, Food processing, Industrial wastewater, moving bed biofilm reactor (MBBR), pilot plant.

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1. Introduction

Freshwater is a vital natural resource that will continue to be renewable as long as it is well managed. Preventing pollution from domestic, industrial, and agro-industrial activities is important to ensure the sustainability of the locale's development. During the last century a huge amount of industrial wastewater was discharged into rivers, lakes and coastal areas. Water pollution occurs when potential pollutants in these streams reach certain amounts causing undesired alterations to a receiving water body. This resulted in serious pollution problems in the water environment and caused negative effects to the eco-system and humans life (Gugała et ea.,2015). The impact of industrial wastewater discharges on the environment and human Population can be tragic at times. The wastewaters from industry are generally highly concentrated with organic and inorganic pollutants (Trapani et al.,2010).

Examples of industrial wastewaters include those arising from food processing industries. Compared to other industries sectors, the food industry uses a much greater volume of water for each ton of product. Wastewater generated from food manufacture has distinct characteristics that distinguish it from common municipal wastewater as it is biodegradable and nontoxic. Food wastewater is widely known for its high concentration of biochemical oxygen demand (BOD) and suspended solid (SS). The constituent of food and wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, milk and meat products and due to the seasonal nature of food processing (Onet, 2010). Food processing-industrial wastewaters can be very strong in terms of pollutant concentrations and hence can contribute significantly to the overall pollution load imposed on the environment. Moreover the characteristics of wastewater depict wide variation due to the variation in the type of products manufactured (Emara et al., 2014). Effluent streams from food processing may have a high biochemical and chemical oxygen demand (BOD and COD) resulting from organic wastes entering into the wastewater stream, and from the use of chemicals and detergents in various processes including cleaning. In addition, effluent may contain pathogenic bacteria, pesticide residues, suspended and dissolved solids such as fibers and soil particles, nutrients and microbes, and variable pH (Emara et al., 2014).Potato chips are one example of a food processing prepared by deep fat frying. The production of potato chips, tortilla chips, and other related snack foods is a growing. Vegetables and other raw foods are cooked by industrial deep fat frying and are packaged for later use by consumers.

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The batch frying process consists of immersing the food in the cooking oil until it is cooked and then removing it from the oil. When the raw food is immersed in hot cooking oil, the oil replaces the naturally occurring moisture in the food as it cooks. Batch and continuous processes may be used for deep fat frying. In the continuous frying method, the food is moved through the cooking oil on a conveyor (Hooshyari; et al; 2009) The process for chips or any other food processing plants normally use immense volume of water, yielding large amounts of wastewater that must be treated. Excessive water use and wastewater production results in economic and environmental burdens to the industry. The food manufacturing wastewater contains high concentrations of several organic compounds including carbohydrates, starches, proteins, vitamins, pectines and sugars which are accountable for high chemical oxygen demand (COD) and suspended solids. The wastewater resulted from a series of processes (cleaning, cutting, slicing, washing, frying, salting, coating and packing) is one of the significant source in environmental pollution. (Kobya et al., 2006) Biological processes are effective and environmentally sound alternative to the chemical treatment of wastewater (Mulkerrins et al., 2004). Biological processes based upon suspended biomass (i.e., activated sludge processes) are effective for organic carbon and nutrient removal in municipal wastewater plants. But there are some problems of sludge settleability and the need of large reactors and settling tanks and biomass recycling (Pastorelli et al., 2011) .Biofilm processes have proved to be reliable for organic carbon and nutrients removal without some of the problems of activated sludge processes(Qdegaard et al., 2012). The Moving Bed Biofilm Reactor (MBBR) is a highly effective biological treatment process that was developed on the basis of conventional activated sludge process and biofilter process. It is a completely mixed and continuously operated biofilm reactor, where the biomass is grown on small carrier elements that have a little lighter density than water and are kept in movement along with a water stream inside the reactor. Researchers have proven that MBBR possesses have many excellent traits such as high biomass, high COD loading, strong tolerance to loading impact, relatively smaller reactor and no sludge bulking problem. These processes, with their economic advantages over physical and chemical treatment methods, have been widely used in existing wastewater treatment plants to overcome the eutrophication problem in receiving waters (Chen et al., 2008).

2. Material and Methods

2.1Potatoes and snacks industry wastewater

The Potatoes and snacks industry wastewater (PSIW) used was obtained from Senyoreta factory in Tanta, El Gharbya governorate, Egypt. which produces potatoes and snacks chips, the PSIW characterized by high chemical oxygen demand (COD), biochemical oxygen demand (BOD5), total suspended solids (TSS), total nitrogen(Total-N) and total phosphorus and other parameter, the reason for high pollutants, is the process that involves: washing and peeling of fresh potatoes then brining, slicing, blanching, drying, frying and finally packing (Rajinikanth et al.,2013). The streams of wastewater were directed into raw wastewater tank located on site before being discharged to the municipal sewer. The wastewater was used in this study was collected from the raw wastewater tank for 6 months. A laboratory-scale pilot plant consisting of modified MBBR pre-treatment and multimedia filter post-treatment was utilized for the treatment.

2.2. The pilot plant

A four-stage process consisting of biological MBBR (anaerobic, anoxic and aerobic) treatment stages which containing carriers in the anaerobic, anoxic and aerobic zones of the bioreactor followed by a multimedia filter separation unit as shown in fig. 1, 2 and can take 400 liter. The pilot plant was fed with industrial wastewater from raw wastewater of Senyoreta factory outlet to the primary settler treatment then to the first chamber anaerobic zone.

2.2.1 The first stage

The anaerobic zone dimensions of the anaerobic chamber were 50cm long, 20cm wide and 55cm high and the working volume was 55L. Phosphate was released and COD was partially consumed under anaerobic condition. Then, it went through the anoxic zone.

2.2.2 The second stage

The anoxic zone which has dimensions 50cm long, 20cm wide and 45cm high, the working volume was 45L.the anoxic zone allowed the nitrogen removal and minimized the effect of the nitrate. Then it went through the aerobic zone.

2.2.3 The third stage

The aerobic zone which has dimensions 50cm long, 40cm wide and 40cm high, the working volume was 80L. The aerobic zone had the purpose of the organic matter oxidation. Then, it went through the secondary settler which has dimensions 50cm long, 20cm wide and 40cm high. The working volume for the pilot plant was 400L.

2.2.4 The fourth stage

The outlet of the bioreactor was led into multimedia filter consisting of three layers sand filter, granular activated carbon and sheet from polypropylene with pore size of 5µm, the permeate was extracted through the membrane to collect into the effluent tank .

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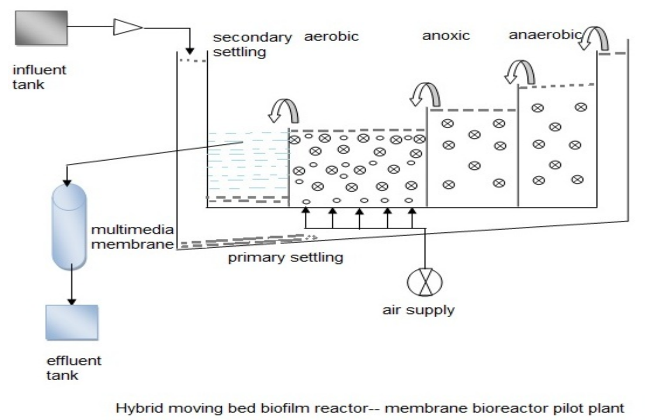


Fig(1)Diagram of the experimental pilot plant. Modified moving bed biofilm reactor, containing carriers in the anaerobic, anoxic and aerobic zones of the bioreactor (MBBR).

Fig(2) picture of the experimental pilot plant. Modified moving bed biofilm reactor, containing carriers in the anaerobic, anoxic and aerobic zones of the bioreactor (MBBR).

2.3. Sampling and analysis

Samples were collected from the influent, the effluent of the secondary settler and effluent of the multimedia filter tank every month for 6 months. Temperature and PH were measured by METTLER PH meter model (TOLEDO), TDS was measured by JENWAY conductivity meter model (4510), COD,TN and TP by DR2000, BOD5, TSS all measured in accordance with standard method (APHA 2005).
All samples were analyzed in science center for detection and remediation of environmental hazards(SCDREH)in faculty of science AlAzhar university and analyzed also in central laboratory of water and wastewater in ElGharbia Company of water and wastewater.

3. Results

3.1.Potatoes and snacks industry wastewater characteristic

Table 1 represents the chemical analysis results for PSIW from the effluent of senyoreta factory for 6 months from January to June 2016 to evaluate the characteristics of the industrial wastewater

TABLE 1

Item	jan	feb	mar	apr	may	jun
Temp	17	22	24	26	29	33
PH	7.1	6.4	6.3	7.12	6.98	7.05
TSS	850	960	1050	955	980	930
TDS	600	740	850	620	930	850
BOD	1500	1850	1600	1530	1700	1800
COD	3100	3220	3200	3140	3200	3210
T.N	44	41	43	42	44	40
Amm	40	39	41	40	42	39
O&G	400	410	410	400	405	400
Phosphate	13	10	12	11	14	10

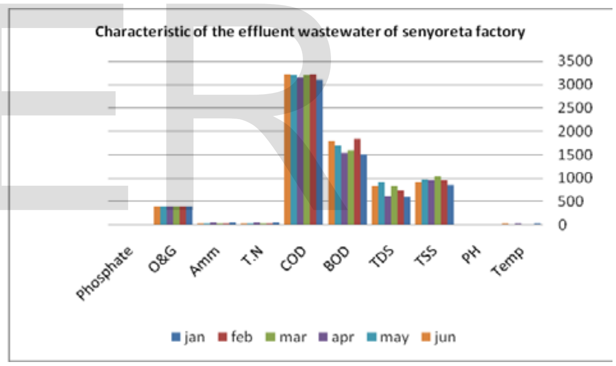
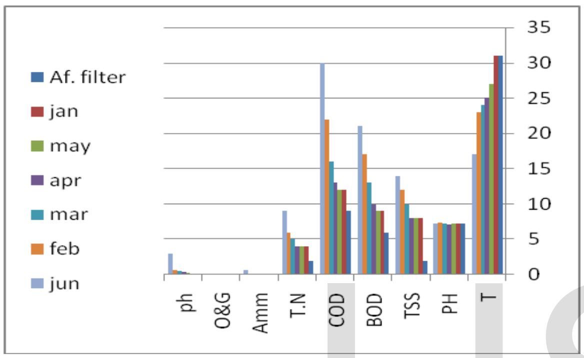


Figure 3 demonstrate the varies in the pollutants in industrial wastewater of PSIW of senyoreta factory during 6 months from January until June 2016.

Table 2 represents the results after treatment with four stages: anaerobic, anoxic, aerobic and filtration, for 6 months from January until June 2016 to evaluate the treatment .the sample was taken in different retention time, it was taken after 10,8,6 hours and the best hydraulic retention time is: 1 hour in anaerobic, 1hr in anoxic and 4hr in aerobic equal 6 hrs.

TABLE 2

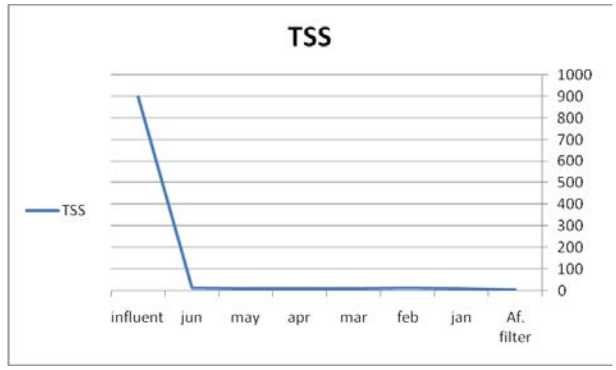
Item	jun	feb	mar	apr	may	jan	Af. filter
T	17	23	24	25	27	31	31
PH	7.24	7.34	7.23	7.16	7.21	7.23	7.23
TSS	14	12	10	8	8	8	2
TDS	450	435	433	425	430	430	430
BOD	21	17	13	10	9	9	6
COD	30	22	16	13	12	12	9
T.N	9	6	5	4	4	4	2
Amm	.6	0	0	0	0	0	0
O&G	0	0	0	0	0	0	0
ph	3	.6	.5	.4	.3	0	0



Fig(4)demonstrate that the evaluates of the treated wastewater of PSIW of senyoreta factory after treatment with pilot plant in our study, shows the removal of pollutants with high percentages.

3.2.1. Total suspended solid (TSS)

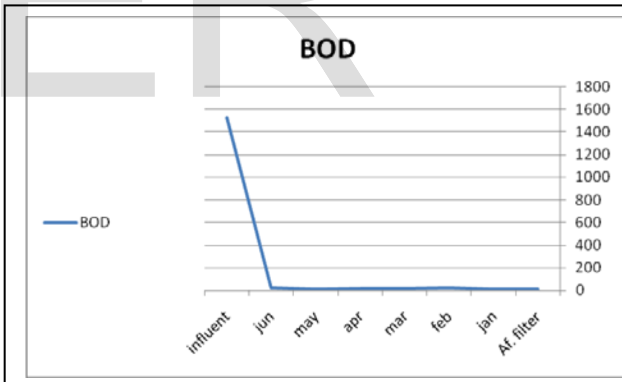
Total suspended solids (TSS) include all particles suspended in water which will not pass througha filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural and construction sites. Solids analyses are important in the control of biological and physical wastewater treatment processes and for assessing compliance with regulatory agency wastewater effluent limitations, (Emara et al., 2010). The concentration of total suspended solids recorded in Tables (1,2), and represented graphically in Figures (5) for influent and effluent of MBBR pilot plant shows the decrease in the concentration of TSS in influent and effluent of MBBR pilot plant and and after filter. The data show the efficiency removal was (98.3 %) of TSS concentration the after r pilot plant which the efficiency removal was (99.7%) after membrane filter.



Fig(5) TSS value

3.2.2. Biochemical oxygen demand.

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consumewhile decomposing organic matter under aerobic conditions. Biochemical oxygen demand is determined by incubating a sealed sample of water for five days and measuring the loss of oxygen from the beginning to the end of the test., (Kermani et al., 2009). The concentration of BOD recorded in Table (1,2) and represented graphically in Figure(6) for influent and effluent of MBBR pilot plant shows the decrease in the concentration of BOD5 in treated water. As indicated in tables (1,2), the efficiency removal was (98.6 %) of BOD5 and removal efficiency 99.6% after membrane filter.



Fig(6) BOD value

3.2.3. Chemical oxygen demand.

Chemical oxygen demand (COD) does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements take five days. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes, (Water Environment Federation 2002b). The concentration of

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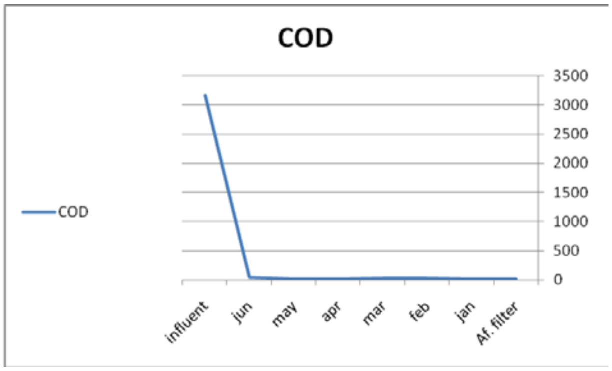
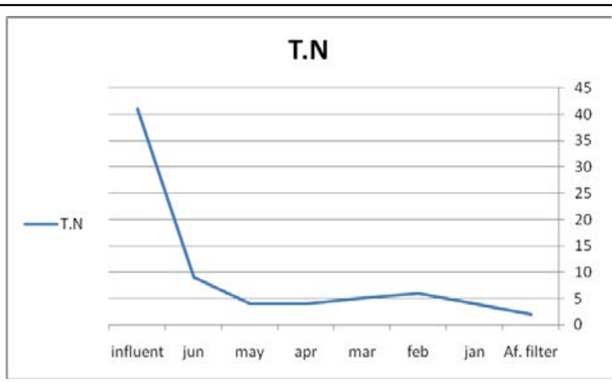
COD recorded in Table (1,2), and represented graphically in Figures(7) for influent and effluent of MBBR pilot plant shows the decrease in the concentration of COD in treated water . As indicated in tables (1,2), the efficiency removal was (99 %) of COD concentration and removal efficiency (99.7%) after membrane filter.



Fig(7) COD value

3.2.4Total nitrogen

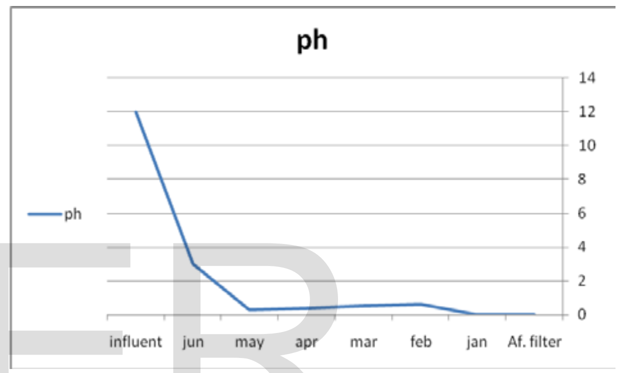
Total Nitrogen is the sum of nitrate (NO3),nitrite (NO), organic nitrogen and ammonia (all expressed as N. Organic nitrogen is decomposed to ammonia, which in turn on one hand is assimilated to bacterial cells, leading thus to net growth, on the other hand is oxidized to nitrite and nitrate. In a second step, nitrate is converted to gaseous nitrogen and is removed from the wastewater. Denitrification is known to proceed as conversion of nitrates to nitrites and subsequent conversion of nitrites to nitric oxide, nitrous oxide and nitrogen gas, (Water Environment Federation 2002b) Biological treatment process utilized to convert ammonia into nitrate using aerobic autotrophic bacteria(Hazen and Sawyer 2007). The concentration of TN recorded in Table (1,2), and represented graphically in Figures(8) for MBBR influent and effluent shows the decrease in the concentration of TN in treated water . As indicated in tables (1,2), the efficiency removal was (87 %) of TN concentration and removal efficiency (95.4 %) after membrane filter.



Fig(8) T.N value

3.2.5. Phosphate

Phosphorus (P) is commonly found in municipal and agricultural waste and wastewater, originating from the digestion of phosphorus-containing food sources. Soluble reactive phosphorus, typically in the form of orthophosphate (PO4+3), can be a nutrient for aquatic plants, such as algae, which can be either a health risk to aquatic life or an aesthetic nuisance to those living near or using the waterways. In the case of blue-green algae, toxic by-products can be produced, which create health issues if a lake or reservoir would be used as a source of drinking water(USEPA 2004).The concentration of TP recorded in table (1,2) and represented graohically in figure (10) for pilot plant influent and effluent shows the decreases of TP in treated water, as indicated in table (1,2) the efficiency removal was 91% and after filtration was 100% .



Fig(9) total phosphate value

4. Conclusions

From the studies it can be concluded that the food processing wastewater is easily amenable to
biological treatment. The results obtained show that used modified moving bed biofilm reactor (MBBR) containing carriers in the anaerobic, anoxic and aerobic zones of the bioreactor can remove pollutants with high degree of chemical oxygen demand, biochemical oxygen demand and suspended solids from the food processing wastewater with percentage almost 97% and after addition stage multimedia filter it would be almost 100%.

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