

Industrial Food Processing Wastewater Treatment by Anaerobic/Anoxic/Aerobic Configuration in Moving Bed Biofilm Reactor (MBBR).

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Abstract: Industrial wastewater is one of the important pollution sources in the pollution of the water environment. 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. In this study, experiments have been conducted to evaluate the pollution in industrial food wastewater and treated by using new technique, 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) and total phosphorus and other parameters. The results indicated that the quality of wastewater is very high concentrated with pollutants. The pilot plant was designed to perform treatment with high efficiency removal so we constructed modified MBBR process.

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Keywords: Industrial food processing wastewater, moving bed biofilm reactor (MBBR), biological nutrient removal

1. Introduction

Industrial wastewater is one of the important pollution sources in the pollution of the water environment. During the last century a huge amount of industrial wastewater was discharged into rivers, lakes and coastal areas. This resulted in serious pollution problems in the water environment and caused negative effects to the eco-system and humans life. (Emara et al., 2014) 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 and may contain toxic pollutants. The best strategy for toxic industrial wastewater is in general to segregate at the source and sometimes by applying onsite treatment within the production lines with recycling of treated effluent (Emara et al., 2014) .

As example of industrial wastewater Food processing industry. Food processing industry wastewater poses pollution problems due to its high

COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand). Moreover the characteristics of wastewater depict wide variation due to the variation in the type of products manufactured (Trapani et al.,2010) .

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. (Gugała et ea.,2015).

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. 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). Biological processes are a cost-effective and environmentally sound alternative to the chemical treatment of wastewater (Mulkerriens 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., 1999). 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., 1994). Biofilm reactors are especially useful when slow growing organisms like nitrifiers have to be kept in a wastewater treatment process. Both nitrification and denitrification have been individually successful in the biofilm reactor (Wang et al., 2006). 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. The movement inside a reactor can be caused by aeration in an aerobic reactor and by a mechanical stirrer in an anaerobic or anoxic reactor. Researchers have proven that MBBR possesses 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 (WWTPs) to overcome the eutrophication problem in receiving waters (Chen et al., 2008).

2. Material and Methods

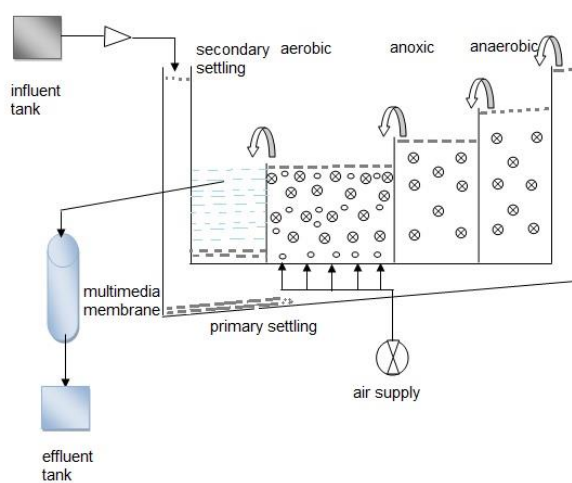
2.1 Potatoes and snacks industry wastewater

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 equalization tank located on site before being discharged to the municipal sewer. The wastewater was used in this study was collected from the equalization tank for 6 months. A laboratory-scale pilot plant comprising of modified MBBR pre-treatment and multimedia filter post-treatment was utilized for the treatment.

2.2. Experimental setup of 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. The pilot plant was fed with industrial wastewater from an influent tank outlet to the primary settler treatment then to the first chamber anaerobic zone, the dimensions of the anaerobic chamber was 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 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 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 was 400L. 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 5 μ m, the permeate was extracted through the membrane to collect into the effluent tank.



Hybrid moving bed biofilm reactor-- membrane bioreactor pilot plant

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 day for 6 months. Temperature and PH were measured with METTLER PH meter model (TOLEDO), TDS was measured with JENWAY conductivity meter model (4510), COD,TN and TP with DR2000, BOD5, TSS all measured in accordance with standard method (APHA 2005)

3. Results

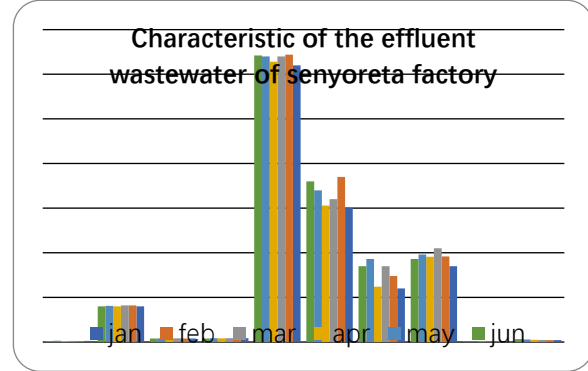
3.1.Potatoes and snacks industry wastewater characteristic

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 industrial wastewater

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

Table (1)



Fig(3)

Table 2 represents the results after treatment with four stages: anaerobic, anoxic, aerobic and filtration, for 6 months from January to June 2016 to evaluate the treatment .The best hydraulic retention time is: 1 hour in anaerobic, 1hr in anoxic, 4hr in aerobic = 6 hr

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

Table (2)

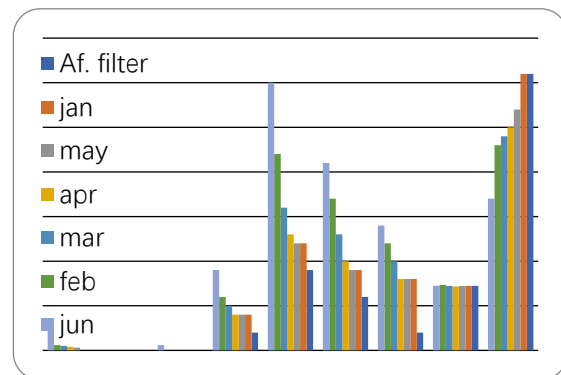


Fig (4)

3.2.1. Total suspended solid (TSS):

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 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.

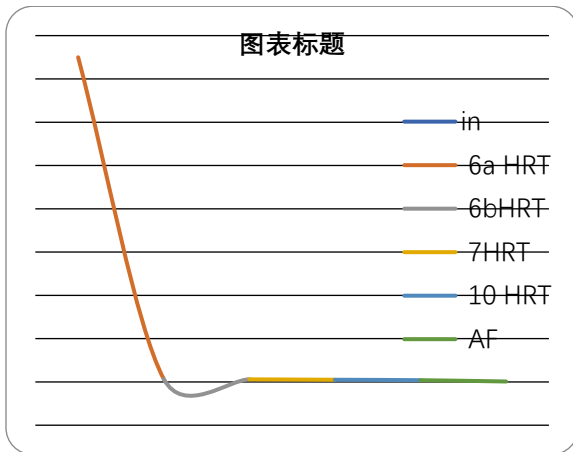
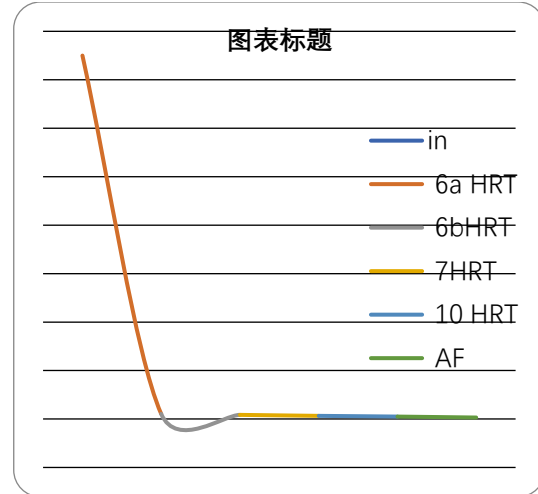


Fig (5) TSS values

3.2.2. Biochemical oxygen demand.

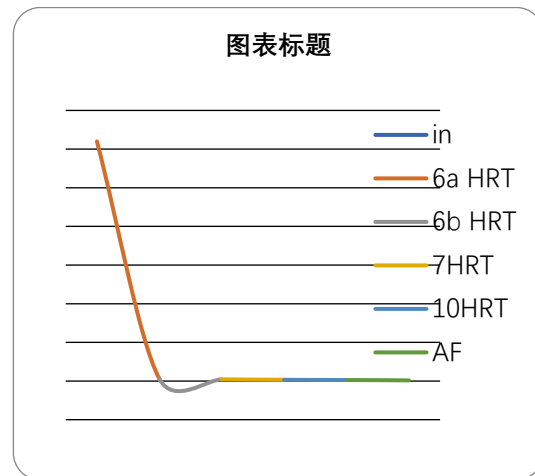
The amount of organic matter that can be biologically oxidized under controlled conditions. A measure of the amount of food available to the microorganisms in a particular waste. It is measured by the amount of dissolved oxygen used up during a specific time period (5 days at 20°C in the dark), (Kermani et al., 2009).The BOD for industrial waste is normally in the range of 1000 to 3000 mg/L. 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 eff . As indicated in tables (1,2), the efficiency removal was (98.6 %) of BOD5 and removal efficiency 99.6% after membrane filter.



Fig(6) BOD5 value

3.2.3. Chemical oxygen demand.

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. 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 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 eff . 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

3.2.4 Total nitrogen

Nitrogen appears in wastewater as ammonia, nitrite, nitrate and organic nitrogen. 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) Ammonia (NH_3^+) is a colorless gas with a strong pungent odor. It is easily liquefied and solidified and is very soluble in water. Ammonia will react with water to form a weak base. High concentrations of ammonia are toxic to humans and animals that is why sanitation engineers and government are working closely in removing ammonia from wastewater. Untreated volumes of ammonia in wastewater can disperse on the air, and affect those who have inhaled the chemical. This can also bring serious illnesses and skin disorders due to physical contact or consumption of ammonia. Biological treatment process utilized to convert ammonia into nitrate using aerobic autotrophic bacteria. The biological infiltration uses two types of bacteria: the bacteria that oxidize ammonia to nitrite (nitrosomonas) and the bacteria that oxidise nitrite to nitrate (nitrobacter). Both types of autotrophic bacteria need proper biomass, right environment, and sufficient air to treat biochemical oxygen demand. Nitrification requires ample amount of oxygen to carry out the process (Hazen and Sawyer 2007). The concentration of TN recorded in Table (1,2), and represented graphically in Figures(8) for MBBR inf and eff shows the decrease in the concentration of TN in eff . As indicated in tables (1,2), the efficiency removal was (90 %) of TN concentration and removal efficiency (95.4 %) after membrane filter.

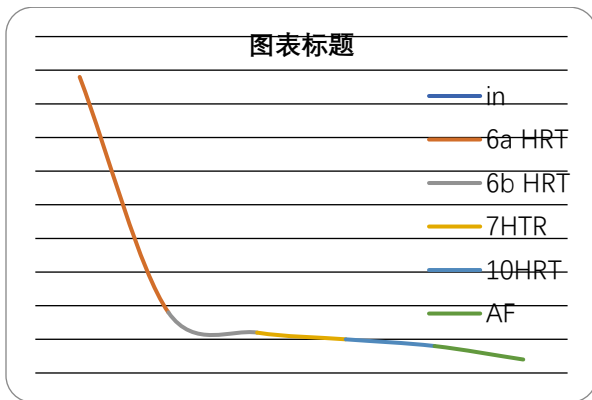


Fig (8) Total Nitrogen value

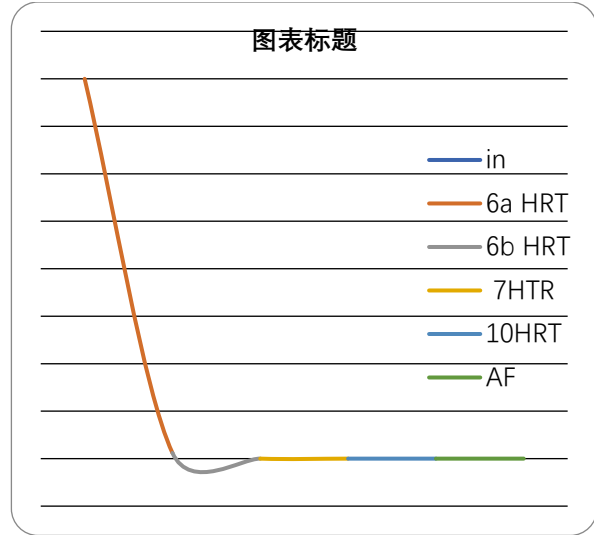
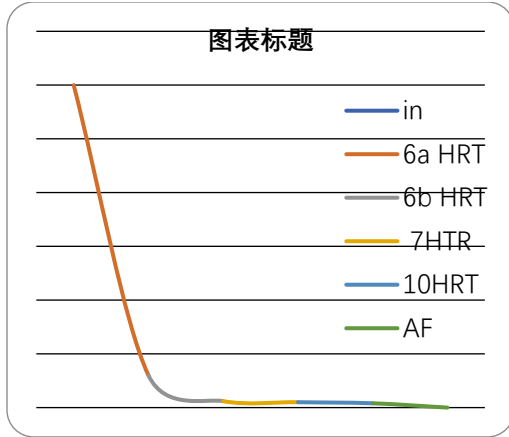


Fig (9) Ammonia values

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 (PO_4^{+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. The usual forms of phosphorous found in aqueous solutions include:

- Orthophosphates: available for biological metabolism without further breakdown
- Polyphosphates: molecules with 2 or more phosphorous atoms, oxygen and in some cases hydrogen atoms combine in a complex molecule. Usually polyphosphates undergo hydrolysis and revert to the orthophosphate forms. This process is usually quite slow (USEPA 2004).The concentration of TP recorded in Table (1,2), and represented graphically in Figures(10) for MBBR inf and eff shows the decrease in the concentration of TP in eff . As indicated in tables (1,2), the efficiency removal was (97%) of TP concentration and removal efficiency (100 %) after membrane filter.



Fig(10) phosphate value

4. Conclusions

The results presented in this study demonstrate that the modified moving bed biofilm reactor (MBBR) containing carriers in the anaerobic, anoxic and aerobic zones of the bioreactor -pilot plant can removed pollutants in Industrial food processing wastewater with percentage almost 100% .

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