

# Physico-Chemical and Biological Treatment of Olive Mill Wastewater by Rotating Biological Contactor (RBC) Reactors

*Alemzadeh, Iran\*<sup>+</sup>; Nazemi, Alireza*

*BBRC, Department of Chemical and Petroleum Engineering, Sharif University of Technology,  
P.O. Box 11365-6891 Tehran, I.R. IRAN*

**ABSTRACT:** *The removal performance of total poly phenols and orthodiphenols (o-diphenols) content in olive mill waste (OMW) was investigated with a three stages cross flow laboratory scale rotating biological contactor (RBC) in the present study. Due to high COD and other pollutant in the original OMW, physico-chemical treatment was effected for COD and other pollutant reduction prior to biological treatment of OMW by the RBC system. Inoculation of RBC was effected by sludge from olive oil factory. In biological treatment, effect of operating parameters such as hydraulic loading (HL) and influent COD were examined. The study of the physico-chemical treatment before biological treatment of OMW showed, that about 9.1% of total poly phenols, 3.2% of o-diphenols and 12% of COD were removed by physical treatment. The effect of chemical treatment by different coagulants, alum, bentonite and zeolite at different pH and concentrations showed that bentonite at pH 6.5 and 15g/l resulted in the best removal efficiency of 20% for poly phenols and o-diphenols. The experimental results in RBC system show that at low HL, significant removal efficiency was observed for poly phenols and o-diphenols, at the first stage, but with increasing HL, other stages took part in removal efficiency. Also, decreasing COD from 5000 to 2500 at different HL caused an increase in poly phenols and o-diphenols removal efficiency.*

**KEY WORDS:** *OMW, RBC, Total poly phenols, Biological treatment, COD, O- diphenols.*

## INTRODUCTION

Olive mill wastewater (OMW) is formed from the water content of the fruit and water used in washing and processing the olives, also the soft tissues from olive pulp and a very stable oil emulsion. The composition of OMW widely depends on the type of process involved in obtaining the oil [1-4].

Phenolic compounds in olive fruit have a great impact on the nutritional qualities of the fruit. The phenolic compounds found in virgin olive oil originate in the fruit from the beginning of the growth. OMW has been treated by different methods. Anaerobic digestion of unmodified OMW have been concerned with problems such as

---

*To whom correspondence should be addressed.*

*+ E-mail: alemzadeh@sharif.edu*

*1021-9986/06/4/47*

*7/\$/2.70*

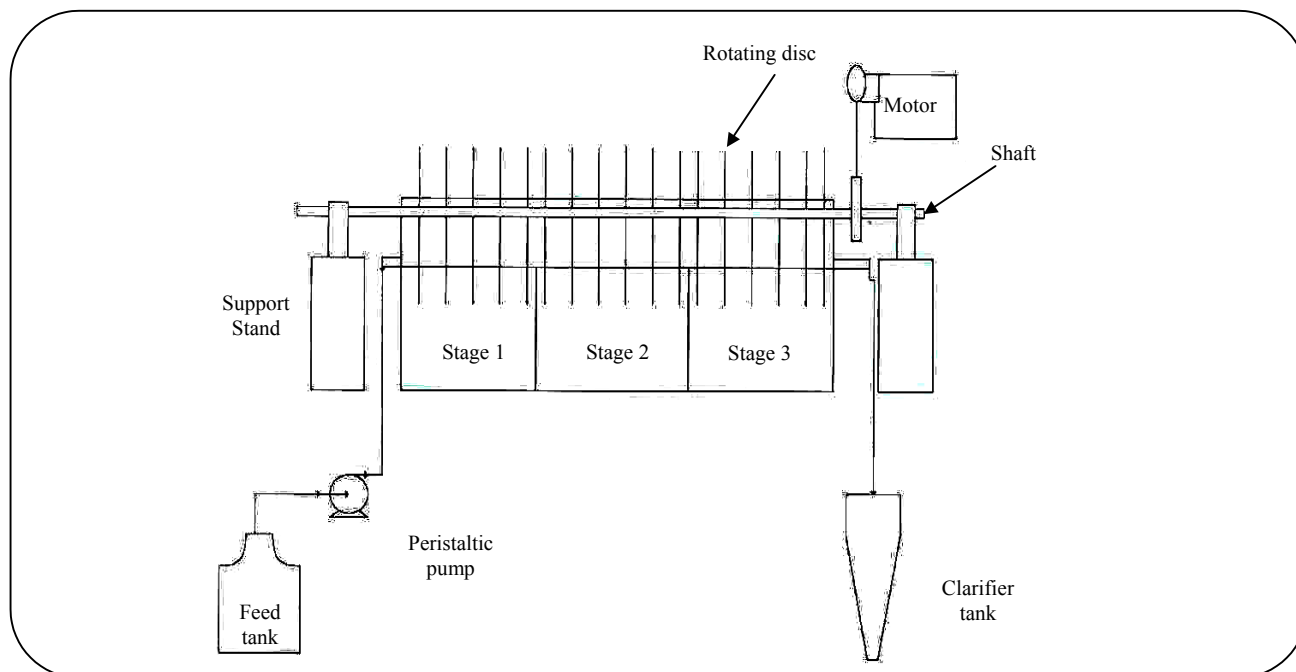


Fig. 1: Diagram of RBC system.

high toxicity and low biodegradability and acidification of the reactor [5,6]. Although diluting the waste, could partly solve these inconvenience, but other pre-treatment were necessary. Pre-treatment of OMW with *Geotrichum candidum* to partially remove the phenolic compounds, decreased the toxicity of methanogenic bacteria, and increased COD removal and rate of anaerobic process [7].

Anaerobic digestion of OMW previously fermented aerobically with *Aspergillus terreus* to remove inhibitors before anaerobic digestion was investigated by others [2]. Difficulties in anaerobic digestion were mainly connected with the presence of recalcitrant or inhibiting substances, essentially poly phenols and lipid. Pretreatment of OMW by previously aerobic fermentation with *Aspergillus niger* [2] and *Geotrichum candidum* [7] could reduce residence time required for anaerobic process. Selective pre-removal of inhibitors such as lipids and poly phenols through lime or lime/bentonite addition followed by phase separation before anaerobic digestion as a chemo-physical treatment has been studied [8].

Attached growth processes of microorganisms operates as aerobic or anaerobic processes. Aerobic RBC process as an efficient attached biofilm system has many advantages such as short hydraulic retention time, high biomass concentration, high specific surface area, low

energy consumption, operational simplicity and insensitivity to toxic substrate [9]. RBC bioreactors consist of the equipments such as, tank in which the discs are rotating, motor and feed tank with peristaltic pump. There are few variables that affect RBC efficiency such as loading rate, rotational speed, hydraulic retention time, staging, temperature, pH and discs submergence [9]. RBC system has been utilized in removing toxic organic compounds such as phenol, toluene and trichloroethylene [10-13]. Nutrient removal has also been extensively studied in RBC reactors as an efficient treatment process [14-17]; besides, RBC system has been evaluated for poultry effluent for its high strength quality wastewater [18].

In this context, RBC treatment was effected, after pretreatment of OMW by physico-chemical methods before biological remediation.

## MATERIALS AND METHODS

The bench-scale RBC model is shown in Fig.1, with three equal stages each comprising 24 discs contributing an approximate total surface area of 1.5 m<sup>2</sup> per stage. The discs were made of 3mm thick plexi-glass material and were mounted on a 15mm rigid stainless steel shaft at a spacing of 15mm. The tank in which the discs were

rotated was fabricated of 5mm thick plexi-glass with a total liquid volume of 7.5 l. The rotational direction of discs was cross to the direction of wastewater flow, so this investigation was effected in a cross flow system with rotation of 15rpm [10] and retention time of 15-52 hrs.

Inoculation of RBC was effected by sludge from olive oil factory and microbial acclimation was done up to 224ppm of poly phenols and 73ppm of o-diphenols. The utilized OMW was collected from olive oil factory, Sefidroud in Gilan, Iran.

The composition of OMW is according to table 1. The first series of pretreatment tests was carried out using only physical methods such as centrifugation, filtration and flotation. Centrifugation was effected with centrifuge model Chrisa 11ks at 3000rpm for 15min and 5°C to decrease the solid particles without any inconvenient problems. The supernatant was separated and filtered by cotton tissue. Flotation was studied in a 3 liter reservoir for 2 hours. Chemical treatment was effected by jar test with three coagulating compounds, alum, bentonite and zeolite. pH was adjusted by using lime.

#### **Inoculation**

Pre-treated OMW was inoculated with sludge from an OMW pool after appropriate dilution and neutralization.

#### **Acclimation**

Microbial acclimation was effected in two sections, at the first run, molasses, ammonium phosphate and urea at COD 5000 in 31 days were evaluated. In the second run, the amount of molasses was reduced and OMW, after physico-chemical treatment, was added and acclimation was continued to 49 days, and the system was adapted to about 300 ppm of OMW poly phenols and o-diphenols.

#### **Analytical methods**

RBC samples were collected from the head - end of the first stage and from the tail end of all the three-stages through the respective sampling ports placed in each stage of the reactor. The samples were filtered through the 0.45µm millipore filter paper.

In each experiment, COD was measured by COD meter model Velp Scientifica Eco-16[19], total poly phenols and o-diphenols contents were determined. Extraction of phenolic compound at pH 2 with ethyl acetate in the

**Table 1: The composition of utilized OMW.**

COD	61633mg/l
Poly phenols	1221 ppm
O-diphenol	371 ppm
N-NH <sub>3</sub>	43 ppm
Soluble P	234 ppm
Lipids	17 mg/l
pH	5.41

same volumetric ratio, dehydration by sodium sulfate for 30 min. and evaporation of residual ethyl acetate by rotary evaporator [8]. Total phenolic compounds were determined by Folin-Ciocalteu's reagent and photometrically by spectrophotometer model at 725 nm according to reference [8].

For measuring o-diphenols, 10 ml of OMW sample was mixed with 2ml 5% sodium molybdate in 50% ethanol and measuring the absorption at 370 nm by photometer model Spectronic 21D [6].

## **RESULTS AND DISCUSSION**

The results of COD, total poly phenol and o-diphenols before and after physical treatment of crude OMW, centrifugation, filtration and flotation respectively are presented in tables 2 ,3.

The results of table 2 presents that physical treatment resulted in the reduction (%) of COD, total poly phenols and o-diphenols by as much as 12, 9.1 and 3.2%, respectively.

Table 3 is the results of physical treatment of OMW by flotation which shows that COD removal is two times the results obtained for centrifugation and filtration.

Coagulation and chemical treatment of OMW was effected using three different coagulants: bentonite, zeolite and alum and the results are presented in tables 4 and 5.

Chemical treatment of OMW was effected using three different coagulants: bentonite, zeolite and alum which the results are presented in tables 4 and 5. The data show that bentonite at 15 g/l, pH = 6.5 shows the highest percentage of COD removal compared to other coagulants.

## **BIOLOGICAL TREATMENT**

Biological treatment was effected in RBC system fed from OMW wastes after physico-chemical treatment and dilution with two initial COD, 2500 and 5000 mg/l and

**Table 2: Chemical analysis before and after physical treatment (centrifugation and filtration) of OMW.**

Run	COD(mg/l)	Poly phenol(ppm)	O-diphenol (ppm)
Before physical treatment	61633	1221	371
After physical treatment	54236	1109	359
%Removal	12	9.1	3.2

**Table 3: Chemical analysis of OMW before and after flotation.**

Run	COD(mg/l)	Poly phenol(ppm)	O-diphenol(ppm)
Before flotation	54236	1109	359
After flotation	39871	1087	352
% Removal	23.3	1.08	1.9

**Table 4: Effect of bentonite(B) and zeolite(Z) concentrations and pH on coagulating process.**

Conc. (ppm)	COD removal %		Polyphenol removal %		Orthodiphenol removal %	
	pH=6.5	pH=8	pH=6.5	pH=8	pH=6.5	pH=8
5 g/l	25.4	22.4	5.8	8.2	7.3	8.8
B 10 g/l	26.9	22.3	6.9	9.2	7.4	9.5
15 g/l	29.7	26.2	10.1	10.5	10.2	10.9
5 g/l	7.2	9.4	4.2	4.8	1.1	0.5
Z 10 g/l	13.2	12.1	6.9	5.7	3.0	2.1
15 g/l	13.4	16.7	8.4	9.1	3.1	2.5

**Table 5: Effect of alum concentration and pH on coagulating process.**

Conc. (ppm)	COD removal %		Polyphenol removal %		Orthodiphenol removal %	
	pH=5.41	pH=7	pH=5.41	pH=7	pH=5.41	pH=7
100	6.3	8.1	2.5	1.4	2.1	2.4
300	11.5	13.2	2.3	1.9	2.8	3.0
500	14.2	18.3	3.1	2.7	2.8	3.9

different hydraulic loadings. The effect of input hydraulic loading(HL), on total poly phenol, o-diphenols and COD removal at different stages under two initial COD 2500 and 5000 mg/l are presented in Figs. 2-7. Comparing Figures show that percent removal of total poly phenols and o-diphenols are higher than COD removal, which could suggest that poly phenols and o-diphenols removal are easier for the attached micro-organisms on the surface biofilm at RBC reactor.

Figs. 2, 4 and 6 are the results of poly phenols, o-diphenols and COD removal under different HL with initial COD of 2500 mg/l, and Figs. 3,5 and 7 are the

results obtained for initial COD for 5000 mg/l.

Figs. 2-7 illustrate the effect of initial COD of 2500 and 5000 on the poly phenols, o-diphenols and COD removal by different hydraulic loading. According to these Figures, poly phenols and o-diphenols removal were affected by the input HL, as could be seen poly phenols removal(%) decrease along with increasing HL. The highest percent removal took place in the first and second stages at low HL and the third stage had lower influence in the treatment. Increasing HL showed that the second and the third stages had considerable influence on contaminants removal%.

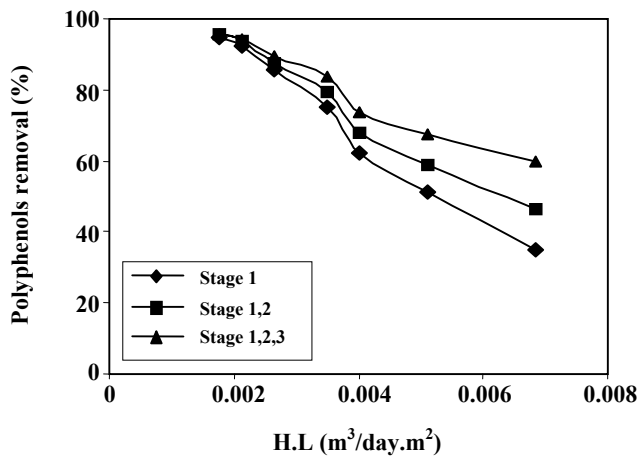


Fig. 2: Effect of H.L. on Poly phenols percent removal at influent COD 2500. poly-phenol was measured according to Ref.[8].

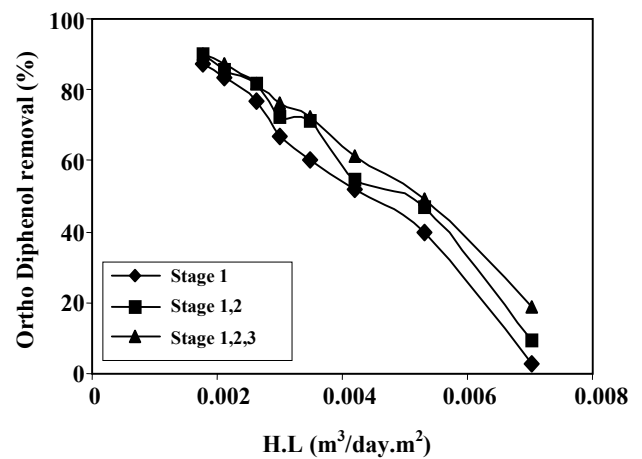


Fig. 5: Effect of H.L. on O- diphenols removal (%) at influent COD 5000. o-diphenol was determined from Ref.[6].

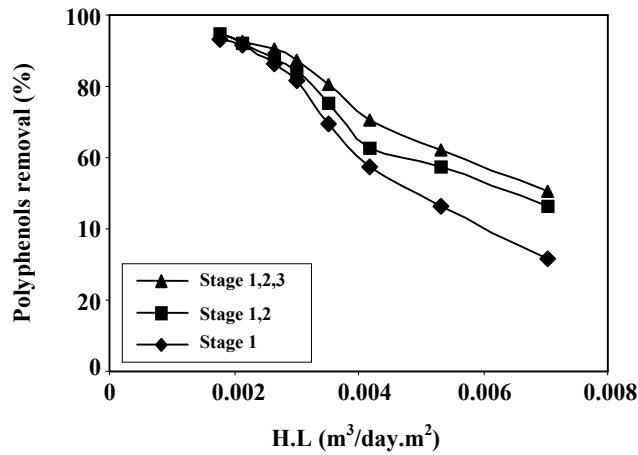


Fig. 3: Effect of H.L. on Poly phenols percent removal at influent COD 5000. Poly phenol removal was effected according to Ref.[8].

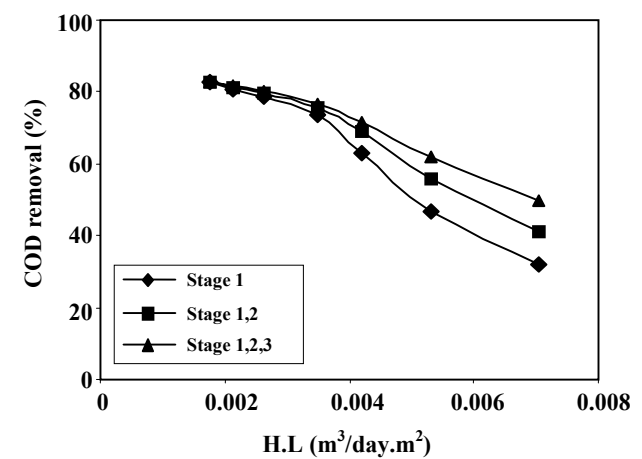


Fig. 6: Effect of hydraulic loading on COD removal (%) at influent COD 2500 mg/l, COD was determined according to Ref.[19].

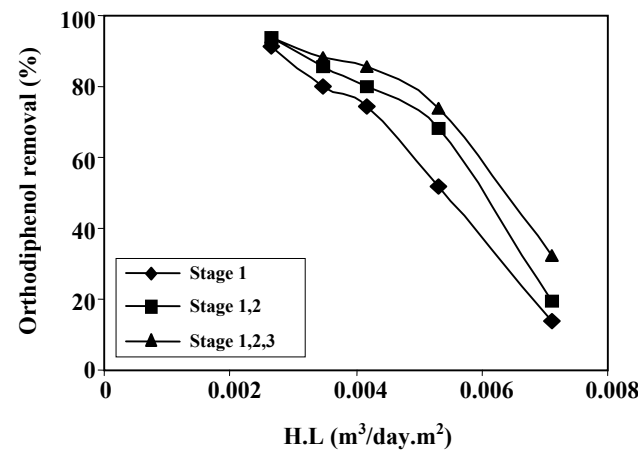


Fig. 4: Effect of H.L on O-diphenols removal (%) at influent COD 2500. O-diphenol was measured according to Ref[6].

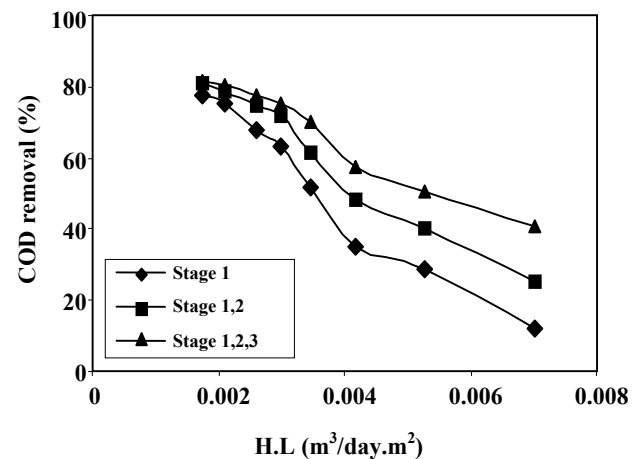


Fig. 7: Effect of hydraulic loading on COD removal (%) at influent COD 5000. COD was determined from Ref.[19].

## CONCLUSIONS

Crude olive mill wastewater (OMW) was collected from olive oil factory, Sephidroud in Gilan. Physical treatments such as centrifugation, filtration and flotation were effected to reduce solids and lipids content in the waste. Centrifugation and filtration resulted in 12% removal of COD and flotation resulted in 23% removal of COD. Chemical treatment by different coagulants as bentonite, zeolite, and alum after physical treatment resulted showed that bentonite at 15 g/l and pH 6.5 causes the highest percentage of COD removal. After appropriate dilution and neutralization by lime, inoculation and acclimation were performed, respectively. The RBC system with 24 discs was utilized for biological treatment of OMW, including poly phenols, o-diphenols and other organic components, which is defined as COD. Initial COD of 2500 and 5000 mg/l were fed to the system. Effect of increase in hydraulic loading caused a decrease in treatment efficiency. The main role of treatment was affected by the first stage at low HL. Increasing HL presents that second and third stages take more important role in contaminants percent removal. Increase in COD loading, resulted in overall decrease in removal efficiency.

Received : 16<sup>th</sup> October 2005 ; Accepted : 20<sup>th</sup> February 2006

## REFERENCES

- [1] Borja, R., Garrido, S. E., Martinez, L. Ramos-Cormenzana, A., Kinetic study of anaerobic digestion of olive mill wastewater previously fermented with *Aspergillus*, *Process Biochemistry*, **28**, 397 (1993).
- [2] Martin, A. Borja, R. Garcia, I. and Fiestas, J. A., Kinetics of methane production from olive mill wastewater, *Process Biochemistry*, **26**, 101 (1991).
- [3] Ragazzi, E. and Veronesse, G., Recherche sulle fenolissi-dasie sul contenuto in o-difenoli delle olive, *Ann.Chim.*, **57**, 1456 (1967).
- [4] Sorlini, C., Andreoni, V., Ferrari, A. and Ranalli, G., The influence of some phenolic acids present in oil mill waters on microbic groups for the methanogenesis, Proceedings of International Symposium on Olive by Products Valorization, Sevilla, Spain pp. 81-88 (1986).
- [5] Boari, G., Brunetti, A. Passion, R. and Rozzi, A., Anaerobic digestion of olive mill wastewaters, *Agricultural Wastes*, **10**, 161 (1984).
- [6] Borja, R., Martin, A., Maestro, R., Alba, J. and Fiestas, J. A., Enhancement of the anaerobic digestion of olive mill wastewater by removal of phenolic inhibitors, *Process Biochemistry*, **27**, 231 (1992).
- [7] Beccari, M., Majone, M., Riccardi, C., Savarese, F. and Torrisi, L., Integrated treatment of olive oil mill effluent: effect of chemical and physical pretreatment on anaerobic treatability, *Wat. Sci.Tech.*, **40**, 347 (1999).
- [8] Box, J.D., Investigation of the folin-ciocalteau phenol reagent for the determination of polyphenolic substances in natural waters, *Water Res.*, **17**, 511 (1983).
- [9] Palma, L.D., Merli, C., Paris, M. and Petrucci, E., A steady state model for evaluation of disc rotational speed influence on RBC kinetics: model presentation, *Biosource Technol.*, **86**, 193 (2003).
- [10] Alemzadeh, I. and Vossoughi, M., Biodegradation of toluene by an attached biofilm in a rotating biological contactor, *Process Biochem.*, **36**, 707 (2001).
- [11] Alemzadeh, I., Vossoughi, F. and Houshmandi, M., Phenol biodegradation by rotating biological contactor, *Biochem. Eng.*, **11**, 19 (2002).
- [12] Brar, S. K. and Gupta, S. K., Biodegradation of trichloroethylene in a rotating biological contactor, *Water Res.*, **34**, 4207 (2000).
- [13] Torkian, A., Alinejad, K. and Hashemian, S.J., Post-treatment of upflow anaerobic sludge blanket-treated industrial wastewater by rotating biological contactor, *Water Env. Res.*, **75**, 232 (2003). Neu, K.E., Achievement of biological nutrient removal in full-scale rotating biological contactor wastewater treatment plant, *Water Sci. Tech.*, **26**, 1115 (1992).
- [14] Neu, K. E., Achievement of biological nutrient removal in full-scale rotating biological contactor wastewater treatment plant, *Water Sci. Tech.*, **26**, 1115 (1992).
- [15] Su, J. L. and Ouyang, C. F., Advanced biological enhanced nutrient removal processes by the addition of rotating biological contactor, *Wat. Sci. Tech.*, **35**, 153 (1997).

- [16] Gupta, A.B. and Gupta, S.K., Simultaneous carbon and nitrogen removal from high strength domestic wastewater in an aerobic RBC biofilm, *Water Res.*, **35**, 1714 (2000).
- [17] Raper, W.G.C. and Green, j.M., Simple process for nutrient removal from food processing effluent, *Water Sci. Tech.*, **43**, 123 (2001).
- [18] Najafpour, G. D., Naidu, P. N. and Kamaruddin, A.H., Rotating biological contactor for biological treatment of poultry processing plant wastewater using *Saccharomyces cerevisiae*, *AJChE.*, **2**, 1 (2002).
- [19] APHA Standard methods for the examination of water and wastewater, 20<sup>th</sup> Ed., American Public Health Association, Washington D.C. (1998).