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PERFORMANCE OF A THREE- STAGE AEROBIC RBC REACTOR IN DAIRY WASTE WATER TREATMENT

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ABSTRACT

Biological treatment using attached growth in a three- stage lab- scale rotating biological contactor (RBC) was implemented for wastewater from dairy industries. The wastewater contained high level of organic compounds due to cleaning and filling processes. Nutrients available in the wastewater enhanced the growth of microorganisms and allowed the biological treatment to be effective. The RBC consisted of 54 parallel discs rotating in reservoir and was arranged in three stages, i.e. 18 discs oriented in each stage. Effect of major operating physical variables such as hydraulic retention time (HRT), disc submergence and disc rotational speed were examined in COD removal. For duration of 5 days 96.4% BOD removal was achieved in batch experiment. BOD constant rate (k) and ultimate BOD were determined respectively, 0.8198 day-1 and 6349 mg/1 by Thomas graphical method. COD removal efficiency was increased from 85.3 to 97.4% while the HRT was increased from 8 to 32 h. The COD removal efficiency increased from 74.9 to 87.5% as the disc submergence was increased due to activation of second and third compartments. When the rotational speed was increased from 6 to 12 rpm, the COD removal efficiency was also increased from 62.7 to 93.7%.respectively. The stage COD removal efficiency was gradually decreased with an increase number of stage and about 88% of organic compounds were removed in the first stage of aerobic RBC, indicating that the single reactor may be sufficient in practical application.

I. INTRODUCTION

Biological treatment technologies are in favour of wastewater treatment from food industries since the wastewater is rich in nutrients. In attached growth processes, the microorganisms are responsible for the conversion of organic materials or nutrients are penetrated into the packing material [1]. Attached growth processes are operated as aerobic or anaerobic processes. Aerobic RBC processes as an efficient attached growth processes and has many advantages such as short Hydraulic Retention Time (HRT), high biomass concentration, high specific surface area, low energy consumption, operational simplicity, insensitivity to toxic substrate, less accumulation of sloughed bio-film and partial stir [2].

The complexity in the physical and hydrodynamic characteristics requires that the design of the RBC process should be based on fundamental information from pilot plant and field installations [3]. There are few variables

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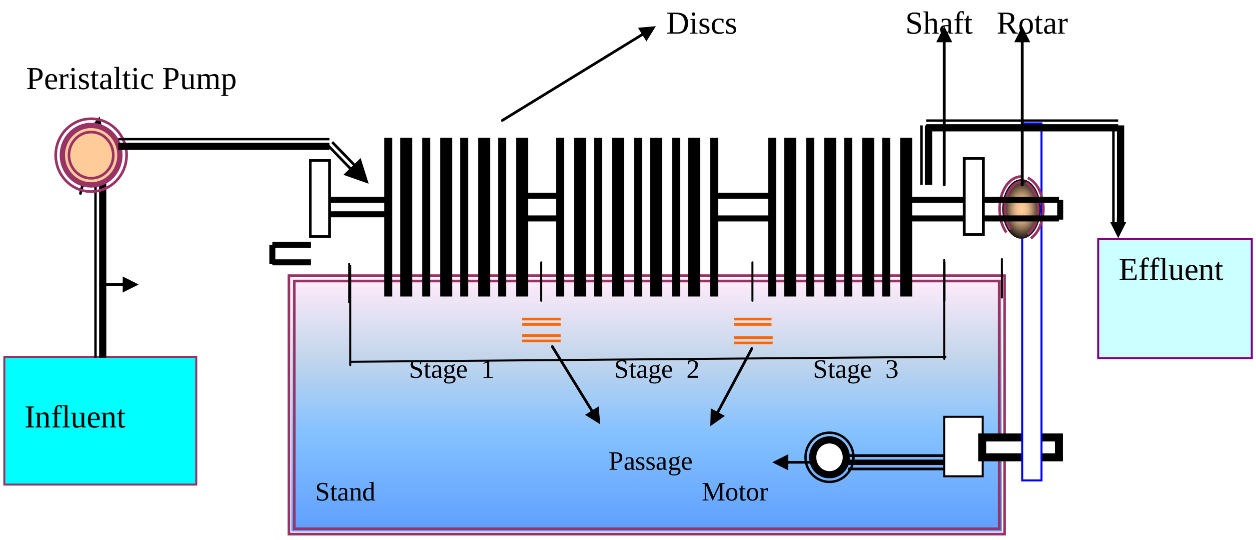
that effect on RBC's efficiency such as loading rate, rotational speed, hydraulic retention time, staging, and temperature and disc submergence [4]. The disc rotational speed is a parameter, which affects oxygen transfer in the biofilm [5]. RBC bioreactor has been effective to remove toxic organic compounds such as phenol, toluene and trichloroethylene [6-9]. Nutrient removal has been extensively studied in RBC reactor as an efficient treatment process [10-15].Performance of RBC bioreactor has been evaluated for poultry and palm oil mill efficient as high-strength wastewater [16-17].

Dairy industries generate a large variety of wastewaters that are usually treated in a complex plant. Oil and fat contained in Dairy wastewaters are usually removed in conventional treatment plants with floatation devices. Effluents from process of cooking of tuna have been treated individually in an evaporation plant to obtain a concentrate waste with high protein content [18]. Treatability of fish canning wastewater with COD concentration of 6000 mg/1 was evaluated in a combined system composed of well-arranged three sequentially; anaerobic-anoxic-aerobic reactor. Ninety percent COD removal efficiency has been achieved [19]. An integrated system included physical pre-treatment unit, an anaerobic digestion and an activated sludge system was employed to treat effluents from a tuna-processing unit. =

In this combined units, 95% COD removal efficiency was achieved with Organic Loading Rate (OLR) of 1.2kg COD/mg day [20]. Anaerobic filter (AF) and a down stationary fixed film (DSFF) reactor were examined for treatment of tuna processing wastewater. COD removal efficiency of 75 to 70% has obtained in AF and DSFF respectively [21]. Other researches carried out on food and fish processing wastewater treatment are anaerobic pond, sequential band reactor (SBR), upflow anaerobic sludge bucket (USAB), fibre biofilm reactor and hybrid bio reactor [13,22-24]. In the present research work treatability of food processing wastewater as a medium strength industrial wastewater was investigated in a three-stage rotating biological contactor

Fig 1: Sketch of the Experimental Set-up of RBC Bioreactor.

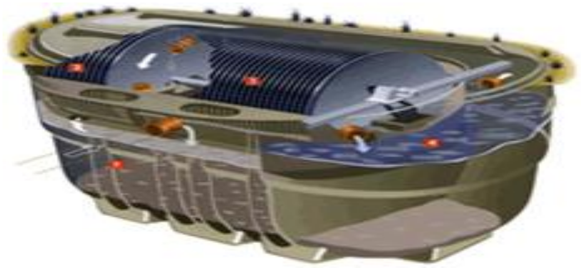


II.EXPERIMENTAL

A lab-scale three stage RBC was fabricated with a thick acrylic plastic transparent sheet. The schematic experimental setup is as shown in Fig.1. The RBC had total volume of 21.L and working volume 15.L. The dimensions of the RBC reactor were 80cm long, 40cm width and 30cm depth, which consisted of three stages.

Each stage was separated by fixed baffle plates with 6 discs in each compartment. Lightweight clear plastic discs with 35cm diameter were mounted on a galvanized hollow metal shaft (o.d. 2cm) and interspacing of 5mm. The available surface area for biofilm growth was about 10m2. The shaft passes through the centre of each disc and was mounted on bearing attached to each end of the wastewater container. The disc spacing along the length of the shaft was minimized while maintaining enough space for wastewater to circulate between discs. The shaft and attached discs were rotated by variable speed dry motor. Flow through discs was parallel to the shaft. The substrate feed rate was controlled by a variable speed peristaltic pump.

Experimental model sketch of RBC Reactor



The variables in the rotating biological contactors were hydraulic retention time, disc submergence level in the wastewater, rotation speeds, pH control, supplementary nutrients and volumetric flow rate of the wastewater. The influent was taken at volumetric flow rate of 30, 36, 45 and 60 1/day. The samples were taken for analysis for each volumetric flow rate after two times of corresponding retention time, based on steady state assumption

III. INOCULATION CONDITIONS

A sediment sample from aeration tank of dairy industrial wastewater plant was used to culture suitable biomass for process startup. A 5L batch culture in suspended growth was inoculated with a well grown sediment sample as seed culture. TSS content of seeding solution was 9500 mg/1. The nutrients were added into the culture to promote the microbial growth rate. The batch system was incubated at room temperature for 1 week and the microbial cell density was increased. During the batch process, one third of the fresh wastewater was daily mixed with the old acclimated culture, to make sure that the microbes have sufficient substrates to follow progressively growth rate. Fresh wastewater was fed into the RBC and the discs were rotated at 11rpm. The RBC system was operated and fed batch wise, this duration last for additional 2weeks. During batch operation, thin biofilm layer was gradually developed on the discs.

IV. ANALYTICAL METHODS

The source of dairy wastewater was from nearby dairy industry. The wastewater samples were characterized and the data are given in Table.1 with following parameters total suspended solids (TSS), total kjeldahi nitrogen (TKN), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and sludge volume index (SVI) were determined based on the standard methods for the examination of water and wastewater [25]. The pH was monitored by pH meter model (Systolic, India). For COD, a colorimetric method with closed reflux method was developed. Spectrophotometer (UV-VIS Spectrophotometer (ECIL,

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India), at 600nm was used to measure the absorbance of COD samples. While for total kjeldahi nitrogen (TKN), a semi-micro kjeldahi method was used Kjeldahl Assembly (Kjel Plus, India), COD digesters and BOD incubator. The dissolved oxygen concentration in wastewater was monitored by a DO probe.

Turbidity was also measured by turbidity meter mode Turbo 530 IR, WTW (Germany) based on nephelometric method and the results of the measurements was reported as nephelometric turbidity units (NTU). BOD and all other routine tests were also followed the standard methods [25]. The dry weight of the attached biofilm per unit wetted surface area of disc [X] was evaluated by drying the removable section at disc before and after biofilm attachment at a temperature of 80C for 24h. The difference between the measurements was divided by the wetted surface area of the disc equaled [X].

Table 1: Characteristics of dairy wastewater

Parameters	***Concentration***
pH	*6.3-8.0*
TCOD (mg/1)	*1600-1840*
SCOD (mg/1)	*800-960*
TSS (mg/1)	*320*
BOD (mg/1)	*650*
TKN (mg/1)	*350*
NH3 – N (mg/1)	*120*
Turbidity (NTU)	*230*

V. RESULTS & DISCUSSIONS

One of the newly developed techniques for the treatment of dairy wastewater is continuous treatment by the attached growth microbial film on a biological contactor (RBC). Since the process retains very high biomass, therefore it has the capacity to treat high strength of influent also can tolerate high organic and hydraulic shocks. ***Fig.2*** shows the BOD of dairy wastewater in batch experiment. The BOD was significantly reduced and the BOD removal in 5 days was 96.4%. The DO level at early stage was 8.0 mg/l, and then at 5 days the DO dropped to 4.3 mg/1. The DO level remained about constant, for duration of more than 5 days.

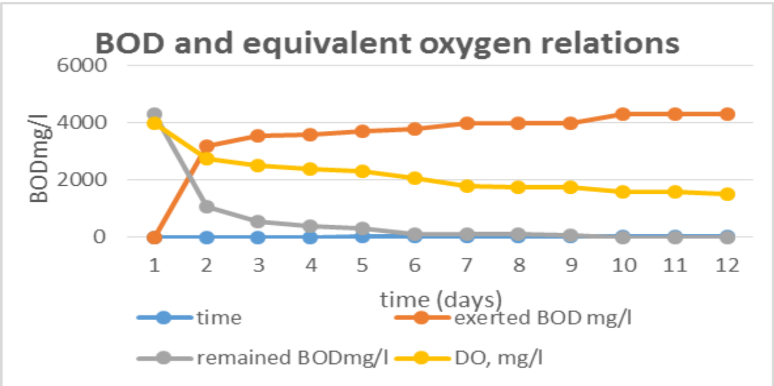

Fig: 2:- **BOD and equivalent oxygen relations**

Thomas graphical method was applied to determine BOD create constant (k) and ultimate BOD (Lo), the Thomas relationship is given by the following equation [26];

The linear model based on Thomas graphical method is shown in ***Fig.3.*** The obtained data were suitably fit with the projected model. The value of BOD rate constant (k) and ultimate BOD (L0) were 0.8198 day-1 and 6349 mg/l, respectively.

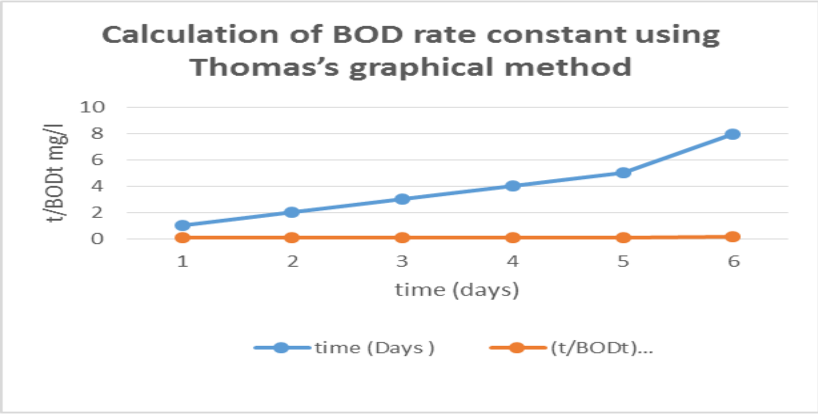

Fig:3:¬-Calculation of BOD rate constant using Thomas's graphical method

Effect of OLR on RBC performance was evaluated by HRT stepwise decreasing from 48-24 hrs. with a constant influent COD of 6200 mg/l. The experimental run was started with HRT of 48h which was equivalent of OLR of 18.44 to 36.89 g/m2 day.

Fig.4 shows variation of COD removal efficiency and COD removal rate versus OLR at steady state condition. As OLR was increased from 18.44 to 36.89 g/m2day, COD removal efficiency was decreased from 97.4 to 85.4%. The rate of COD removal was increased from 3 -5.3 g/day. Reduction in COD removal efficiency was an indication of insufficient elimination capacity because of limitation in oxygen mass transfer and disc surface area for attached microorganisms. The COD removal of 85.9% at HRT of 24 hrs.proved that suspended microorganisms had significant contribution in degradation of organic matters.

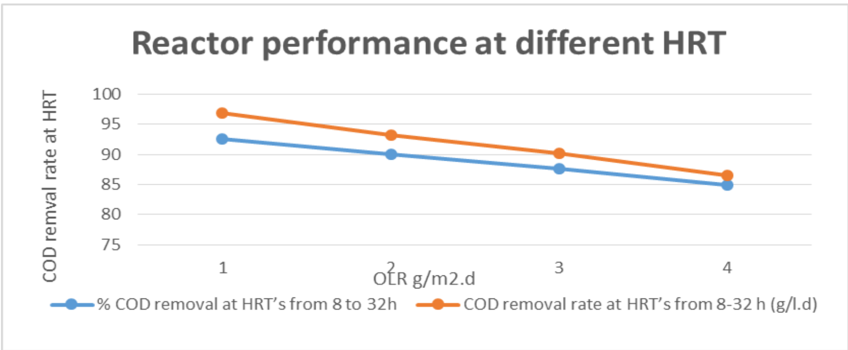

Fig: 4**:- Reactor performance at different HRT**

Fig.5 presents the effluent TSS and sludge volume index with respect to HRT. The effluent TSS was 290 mg/l at HRT of 48h while SVI was 224 ml/g. As HRT was decreased to 40h, TSS was increased to 1080 mg/l with a SVI of 49 ml/g. The SVI remained less than 60 ml/g at lower retention times. Due to high organic loading at

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HRT's of shorter than 40h, the biofilm formation rate was high (especially in first stage). The high TSS content of effluent with low sludge had good setting property. The turbidity of settled treated wastewater with various HRT was measured. The retention time in the setting tank was set 1h, the minimum turbidity was 46 NTU for HRT of 4

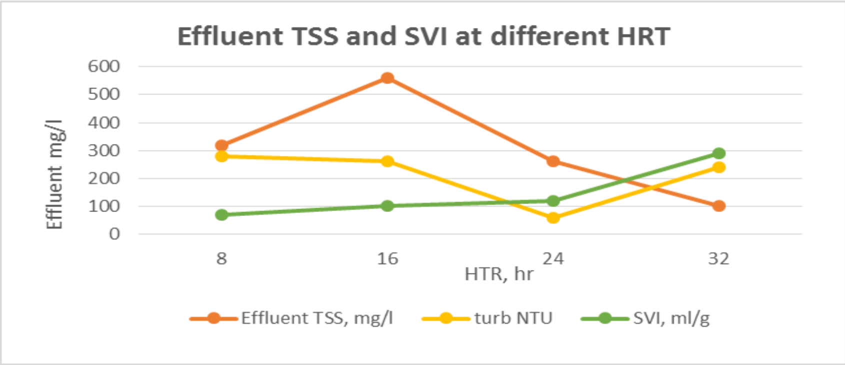

***Fig: 5:-* Effluent TSS and SVI at different HRT**

Fig.6 illustrates the performance of each stage in COD removal. First compartment of the RBC was the most efficient stage. A result of 73.4% and 88.8% removal efficiency was achieved at HRT of 24 and 48 h, respectively. Very lower efficiencies were achieved in the second and third stages. High exerted BOD within 1 day of batch experiment confirmed the high degradation rate occurred in the first stage.

Organic loading rates in the second stage were 3.54, 8.19, 14.7, 24.93 g/m2 day, while OLR for the first stage were 55.33, 66.39, 82.99, 110.66 g/m2 day, respectively. Differences in colour and thickness of the biofilm were clear indications for high performance of the first stage. Biofilm is the first stage was thicker and creamy colour. Biofilm in second and third compartments were brownish and thin. The results denoted that these stages act as secondary treatment units where only 15% of the overall system efficiency was developed to the last two stages.

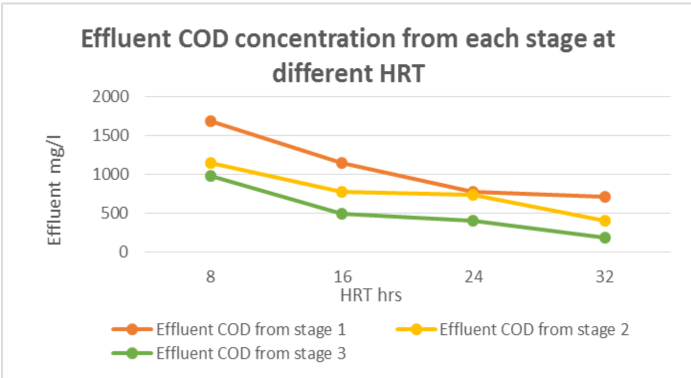

***Fig: 6:-* Effluent COD concentration from each stage at different HRT**

Table: 7 show the effect of food to microorganism ratio (F/M) at various HRT on elimination capacity (EC). Basically, elimination capacity in biological treatment systems is inversely related to F/M which increases with decrease in HRT. In this experiments, maximum elimination capacity, 13.28 g COD r l-1 day-1, was achieved at HRT of 48 h of while food to microorganism ration was minimum (0.22 day-1). Elimination capacity at retention times of 40 and 32 h showed almost same, 12.23 and 12.55 g COD r l-1 day-1, respectively. A drastically decrease in EC was observed while F/M increased to 0.42 day-1 (corresponds to HRT of 24h).

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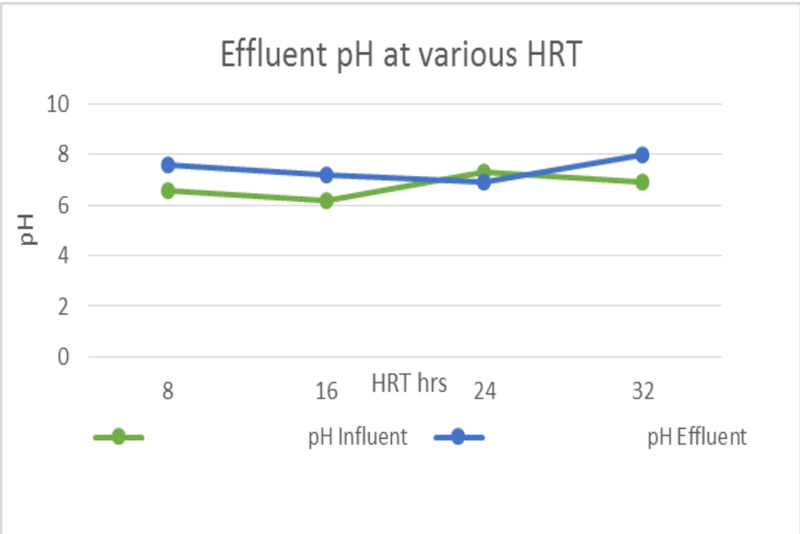
Table 7:- Elimination capacity as a function of F/M

HRT, hrs	F/M ratio l/d	Elimination capacity, g COD r/l.d
48	0.22	13.42
40	0.25	12.26
32	0.28	12.54
24	0.42	9.55

Fig. 8 demonstrates the effluent pH at various HRT. The pH remained in the range of 6.6 – 7.3 throughout the experiments. They were no significant changes in pH of the effluent. Attached biofilm on the discs for each HRT was measured. At steady state condition, the remained VSS was 650-700 g at various HRT. In compare to activated sludge (AS) system [3], the MLVSScontent of the RBC reactor was three times higher than AS [3000-5000 mg/l] and with more stability, lower energy requirements and also no necessity of sludge recycling.

The sludge age and sludge residence time (SRT) is the averagevalue of time for the sludge spends in the aeration basin. The SRT is completely analogous to HRT, which is the average residence time of a drop of water in the aeration basin. Solid residence time was calculated based on measured amounts of volatile attached and suspended solids in the RBC. At retention times of 24,32,40,48 h, SRT's of 7.6, 12.8, 65.9, 74.4 days was obtained, respectively. Results are shown that HRT decreased, SRT also was decreased and washed out sludge increased. There was no logic relationship between HRT/SRT and influent COD to determine washout factor so as to degradation rate in each stage was different for any influent COD concentration.



<u>Fig: 8:- Effluent pH at various HRT</u>

Fig.9 illustrates a consistent trend for DO concentration is the first and third stages with different concentrations with respect to HRT. The differences between DO in the first and third stages were resulted from difference on Do consumption rate or COD removal rate which has been discussed earlier. Low amount of Do in the first stage was good sign of balance between DO consumption and aeration rate.

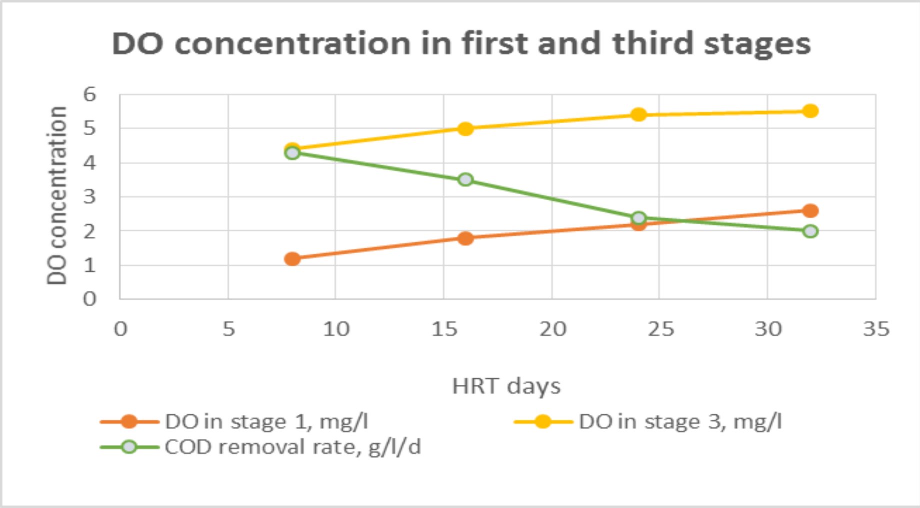


***Fig: 9*:- DO concentration in first and third stages**

RBC reactor has been basically designed for the attached microbial growth. One of the major physical variables which affected the reactor performance was available contactor surface area. Fig.10 shows the effect of submergence level of COD removal efficiency at HRT of 40h and rotational speed of 11rpm. In this experiment, three submergence levels 36, 31.4, 23.7% were examined. As the disc submergence from 36 to 31.4% was decreased, TCOD and SCOD removal efficiency were also decreased from 87.5 and 93.7 to 74.9 and 89.5% respectively.

At submergence level of 23.7%, the removal efficiency was increased due to activation of second and third compartments. Also rate of COD removal at different submergence level confirmed effluent COD trend. As a result, maximum efficiency can stage, lower disc submergence was employed to activate next stages.

Rotational speed was another physical process variable, which was investigated in this study. The rotational speed effect on reactor performance on SCOD removal, effluent pH and turbidity are illustrated in table 2. Two disc rotational speeds [3 and 11 rpm] were examined. The SCOD removal was decreased from 96.3 to 62.7% when the rotational speed decreased from 11 to 3 rpm. The SCOD removal from 62.7 to 93.7% was that dissolved oxygen [DO] was dropped to the lower value even below 0.1 mg/1 when the rotational speed decreased to 3 rpm. It indicated that rate of aeration was not as necessarily enough to treat few days bad odour was spread out due to oxygen depletion. In spite of low removal efficiency, no film detachment process occurred. SVI was nearly 0 to 3 rpm that was denoted non-settle ability of outlet suspended solid. The bio-film was in gel form and brownish at rotational speed of 3 rpm.

VI.CONCLUSIONS

The three-stage lab-scale rotating biological contactor obtained a successful result in dairy industry wastewater treatment. A 93.7% COD removal efficiency was achieved at HRT of 40 h. The stage COD removal efficiency decreased with an increase of number of stages and about 88% organic compounds were removed in the first stage of aerobic RBC system was concluded as an effective process for treating high-strength organic wastewater under operating conditions of 11 rpm and 36%

submergence level. One important point declared in this study was at submergence level of 23.7% removal efficiency was increased due to activation of second and third compartments.

REFERENCES

[1.] American Public Health Association; American Water Works Association; Water Environment Federation (1985) Standard Methods for the Examination of Water and Wastewater, 16th ed.; Washington, D.C.

[2.] APHA, AWWA, WEF. Standard methods for the examination of water and wastewater, 19Ed. Washington, DC, 1995.

[3.] Ayers RS, Westcott DW. FAO irrigation and drainage. In: Water Quality for Agriculture, Food and Agriculture. Rome, Italy: Organization of the United Nations, 1985 Paper 29 Rev. 1.

[4.] A.W.A. De Man, P.C. Grin, R.E. Roersma, K.C.F. Grolle, G. Lettinga, Anaerobic treatment of municipal wastewater at low temperatures. Anaerobic treatment. A grown-up technology, in: Conference papers (Aquatech 86), Amsterdam, 1986, pp. 451–466.

[5.] A.C. Van Haandel, G. Lettinga, Anaerobic Sewage Treatment. A Practical Guide for Regions With Hot Climate, Wiley, Chichester, England, 1994, 226 p.

[6.] Banerjee, G. (1997) Hydraulics of Bench-Scale Rotating Biological Contactor. Water Res., 31, 2500-2510.

[7.] Banerjee, G., Treatment of phenolic wastewater in RBC reactor, Water Res.33 (1997), 705-714.

[8.] Bintanja, H.M., Vandererve, J.J.V.M., Boelhouwer, C., 1975. Oxygen Transfer in a rotating discs treatment plant. Water Res.9, 1147-1153.

[9.] P, Hartmann L. Activity of biomass in RBC system treating pulp industrial wastewater. J Environ Eng 1992; 118(5): 744–50.

[10.] Casey TJ. Unit Treatment Processes in Water and Wastewater Engineering. Chichester: John Wiley, 1997. p. 187–88.

[11.] Cooper AB. Activities of benthic nitrifiers in streams and their role in oxygen consumption.

[12.] Microbial Ecol 1984; 10:317–34.

[13.] Cooper P., Day M. and Thomas V. (1994) Process option for phosphorous and nitrogen removal from wastewater RWEM 8, 84±91.

[14.] Chang AC, Page AL, Asano T, Hespanhol I. Developing human health-related chemical guidelines for reclaimed wastewater irrigation. Water Sci Tech 1996; 33(10–11): 463–72.

[15.] Davis ML, Cornwell DF. Environmental engineering. New York: McGraw-Hill; 1998. p. 289–98.

[16.] Droste RL. Theory and practice of water and wastewater treatment. New York: John Wiley; 1997. p. 578–612.

[17.] Evans, F. L. (1985) Consideration of First-Stage Organic Overloading in Rotating Biological Contactor Design. J. —Water Pollut. Control Fed., 57, 1094.

[18.] Eckenfelder Jr. WW. Industrial water pollution controls third ed. New York: McGraw-Hill; 2000. p. 388–93.

[19.] Fang, H. H. P.; Li, Y. Y.; Chui, H. K. (1995) UASB Treatment of Wastewater with Concentrated Mixed VFA. J. Environ. Eng. (Reston, Va.), 121, 153.

[20.] Elvers KT, Lemming K, Moore CP, Lappin-Scott Bacterial—fungal biofilms in flowing water photo—processing tanks. J Appl Microbial 1998; 84:607–18.

[21.] Friedman, A. A.; Robbins, L. E.; Woods, R. C. (1979) Effect of Disc Rotational Speed on Biological Contactor Efficiency.J. —Water Pollut. Control Fed. 51, 2678-2690.

[22.] Figueroa L. A. and Silverstein J. (1992) The effect of particulate organic matter on biofilm nitrification. Wat Environ. Res. 64, 728±733.

[23.] F. El-Gohary, F.A. Naser, Cost-effective pre-treatment of wastewater, Wat. Sci. Tech. 39 (5) (1999) 97–103.

[24.] 21.Gantzer CJ, Kollig HP, Rittman BE, Lewis DL. Predicting the rate of trace-organic compound removal by natural biofilm. Water Res 1988; 22(2): 191–200.

[25.] Gantzer CJ, Rittman BE, Herricks EE. Effect of long-term water velocity changes on streambed biofilm activity.Water Res 1991; 251:15–20.

[26.] Gupta AB, Gupta SK. Simultaneous carbon and nitrogen removal in a mixed culture aerobic RBC biofilm. Water Res 1999; 33(2): 555–61.

[27.] Halling-Sørensen B, Jørgensen SE. The Removal of Nitrogen Compounds FromWastewater.Amsterdam: Elsevier Science Publishers BV, 1993.

[28.] Hsu C-L, Leu H-G, Tseng H-T, Ouyang CF. Prediction of the conversion rate for nitrogenous compounds in a shallow channel, 6th IAWQ Asia-Pacific Regional Conference Asian Water quality. Korea, 1997. pp. 1058–63

[29.] Kim B.J., Molf.A.H. 1982. The Scale up and limitations of physical oxygen transfer in rotating biological contactors. Water Sci. Technol. 14, 569-579.

[30.] Rotating biological Contactors. Water Sci. Technol. 26, 545–553.

[31.] Klees R. and Silverstein J. (1992) Improved biological nitrification using recirculation in rotating biological contactors. Water Sci. Technol. 26, 545±553.

[32.] Kugaprasatham S., Nagaoka H. and Ohgaki S. (1991) Eject of short-term and long-term changes in hydraulic conditions on nitrifying bio.lm. Water Sci. Technol. 23, 1487–1494.

[33.] 1999:48.

[34.] Oga T, Suthersan S, Ganczarezyk JJ. Some properties of aerobic biofilms. Environ Technol 1991; 12:431–40.

[35.] Organic matter removal in combined anaerobic–aerobic fixed-film bioreactors R. Del Pozo, V. Died* Water Research 37 (2003) 3561–3568

[36.] Paolini, A. E. (1986) Effect of Biomass on Oxygen Transfer on RBC System. J. —Water Pollut.

Control Fed. 58, 306.

[37.] Purification of rotating biological contactor (RBC) treated domestic wastewater for reuse in irrigation by biofilm channel Chen-Lung Hsu, C.F. Ouyang *, H.T. WengChungli, 32054, Taiwan, ROC: 2000

[38.] Report of Water Resources Bureau, Taiwan, 1996.

[39.] Saggy, M.; Kott, Y. (1990) Efficiency of RBC in Removing Pathogenic Bacteria from Domestic Sewage.Water Res., 24, 1125.

[40.] SIMULTANEOUS CARBON AND NITROGEN REMOVAL IN A MIXED CULTURE AEROBIC RBC BIOFILM A. B. GUPTA and S. K. GUPTA* Wat. Res. Vol. 33, No. 2, pp. 555±561, 1999

[41.] Strom, P. F.; Chung, J. C. (1985) The Rotating Biological Contactor for Wastewater Treatment. In Advances in Biotechnological Processes 5; Mizrahi, A., Wezel, A. L. V., Eds. Alan R. Liss, Inc.: New York.

[42.] Shyu G-S, Chang T-K, Hsu Y-P. Study of irrigation water quality standard. J Chin AgriEng

[43.] 1995; 42(4):1–12.

[44.] Tawfik, A.; Klapwijk, B.; el-Gohary, F.; Lettinga, G. (2002) Treatment of Anaerobically Pre-Treated Domestic Sewage by a Rotating Biological Contactor.Water Res., 36, 147.

A. Tawfik, The biorotor system for post-treatment of anaerobically treated domestic sewage. Ph.D. thesis, Wageningen University & Research Center, Sub-department of Environmental Technology, 2002.

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