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Review on Process, Application and Performance of Rotating Biological Contactor (RBC)

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***Abstract*-** The rotating biological contactor is an attached growth biological treatment used in removal of biodegradable matter present in wastewater is popular due to its simplicity low energy requirement, low land requirement, stable in various shock loading and recirculation not required and low hydraulic retention time. This review paper focuses on various controlling parameter of RBC like organic loading, hydraulic retention time, speed of rotation, dissolve oxygen, staging, temperature, submergence etc. The paper also highlights on the performance studies of RBC for different types of wastewater.

***Index Terms*-** Rotating biological contactor, organic loading, speed of rotation, dissolves oxygen, staging and submergence.

I. INTRODUCTION

A rotating biological contactor is an aerobic and anaerobic fixed film biological treatment. This treatment is widely used as secondary treatment of industrial and domestic wastewater. In this system the disc portion is partly submerged in wastewater and partly exposed in atmosphere. The rotation of the system leads to continuous growth of microorganisms and the formation of biological slime layer on the surface of the discs known as biofilm is developed on the rotating disc. The constant rotation of the disc causes mixing of the liquid. During submergence organic matter is removed while during emersion aeration of the culture is accomplished. Oxygen is transferred to the thin film of liquid that remains attached to the discs when they rise above the liquid surface increasing its dissolved oxygen content. The Rotating Biological Contactor (RBC) was introduced, on the basis that the Dissolved Oxygen (DO) in the reactor did not have significance on treatment efficiency because adequate amount of oxygen could be supplied during the air exposure cycle required for metabolism of microorganism. (Kubsad et al, 2004).

In rotating disc shaft assembly is mounted into a tank with the shaft slightly above the surface of the liquid. Approximately 34-60 % of the disc surface is submerged in the waste and the remaining disc surface is exposed to the atmosphere. (Ahmady, 2005). The rotation of the discs also mixes the liquid keeping the detached biomass in suspension and maintaining a uniform dissolved oxygen concentration. Although the exact composition of the microbial population on a disc depends upon the type of wastewater being treated and the relative position of the disc in the reactor. A continuous sloughing off from the discs when the innermost microorganisms lose their ability to adhere to the rotating surface and sloughed biofilm have good settling characteristics. Sloughed biofilm and suspended solids are washed out of the contactor as the wastewater flows through the unit. They are later removed from the effluent during secondary clarification. (Kinner et al ,1983)

Rotating biological contactor requires low power because the only power required for rotation is needed in overcoming the drag friction of discs in the liquid. RBC has a better shock load, because of the short residence time and the shock does not kill the whole biomass and recovery is fairly rapid. RBC have more process stability with load variations since the microorganisms in a fixed film system are attached to a media, they cannot wash out with increasing flow rate. Also fixed film systems generally have a greater mass of microorganisms, making them better able to handle increasing organic load. Recycling of solids is not required as the microorganisms are not washed off. (Borghi et al, 1985). RBC requires low energy, short hydraulic retention time and low operating cost. It has excellent process control and is capable of handling a wide range of flows and organic concentration. (Pathan et al, 2011)

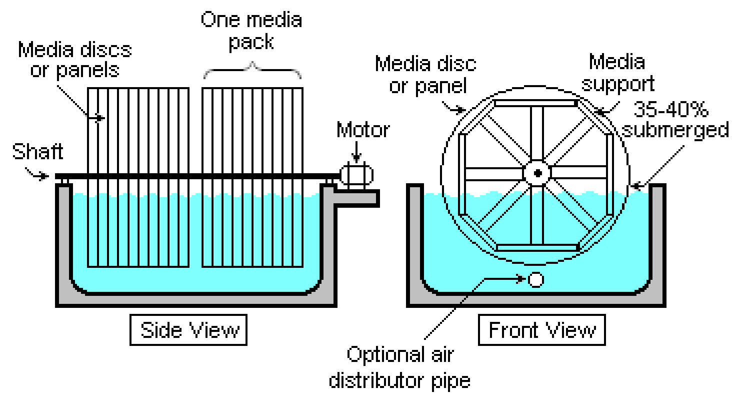

Fig 1: grapghical representation rotating biological contactor (http://en.wikipedia.org/wiki/Rotating_biological_contactor)

The RBC is used because of its advantages such as high specific surface area, high activated sludge concentration, better sludge settling, process stability, and low maintenance and power consumption.(Ghawi et al,2009). RBC is widely used for its simplicity of construction and operation, low energy consumption in comparison with other aerobic treatment processes, reliability in terms of stability to sudden hydraulic surges. The sludge from RBC has good settling ability. (Hansford et al,1978)

II. RBC CONTROLLING PARAMETERS

The major factors controlling rotating biological contactor systems design and their performance are organic loading, hydraulic loading, Biomass, rotational speed wastewater temperature, staging and others. The performance and the operational problems of each stage of an RBC system needs to evaluate and the design criteria should be effectively judged. The rotating biological contactor performance and design parameters are given in table 1.

A. Organic Loading and Hydraulic Loading Rate

Organic loading rate is very important and major element in designing RBC. The efficiency of RBC depends mainly on organic loading rate rather than on the organic concentration or flow rate. Substrate utilization rate (organic removal rate) increases with increasing the Organic Loading Rate (OLR) to such limit which after it, increasing the load has no or very limited impact on the removal rate. There is a strong correlation between the organic loading at influent and the concentration of the Total Suspended Solids (TSS) present in the rotating biological contactor. (Ahmady, 2005).Effect of organic loading rate was studied and was evaluated, firstly organic loading was kept constant of Chemical Oxygen Demand (COD) 6.2 g/l and Hydraulic Retention Time (HRT) was reduced from 48 to 24 hours ,which showed that removal efficiency decreased as HRT reduced. Secondly they varied from 18.44 to 36.89 g/m^{2}day the COD removal efficiency decreased from 97.4 to 85.4 %. Reduction of COD removal capacity was due to limitation in oxygen mass transfer and disc surface area for attached microorganism. (Najafpour et al ,2006).The attached-growth process like in RBC seems to be more stable than the suspended-growth process like Activated sludge, when the wastewater has considerable fluctuations in flow rate and organic loading. (Najafpour et al ,2005).Increasing hydraulic loading decreases organic concentration removal efficiency in wastewater. Hydraulic loading rate, flow rate and organic loading altogether act in the substrate removal rate and efficiency. (Ghawi et al,2009)

B. Biomass

Biomass present on disc media plays important role in removing the organic and inorganic substrate present in wastewater, which they used it for their metabolism and treating wastewater. Microorganisms present in the wastewater adhere to the disc surfaces within 1 to 4 weeks and form a slime layer biofilm ranging from 1 to 4 mm in thickness. The biofilm after reaching a critical thickness, microorganisms in deep are unable to receive nutrient and oxygen, they are no longer able to stick to disc and slough off. (Yargholi et al, 2011). Large surface area allows a large, continuous and stable biomass population to develop on disc. (Schultz , 2005).The thickness of biofilm is not uniform since sloughing process occurs randomly. Sloughed biofilm and suspended solids are washed out of the contactor as the wastewater which is later removed in settling tank or at secondary clarification. (Kinner et al ,1983).The Biomass contains different types of microorganisms, initially brown colour organism is considered as healthy biomass whereas white and grey biofilm are regarded as unhealthy ones.(Pathan et al,2011).This newly develop RBC treatment can retain large amount of biomass, therefore it has the capacity to treat high strength of organic loading and hydraulic shocks. (Najafpour et al ,2006).When OLR of COD 11g/m^{2}day was loaded to RBC the biofilm thickness was measured in first and second stage which was found to be 2.4 and 1.7 respectively. Also there was average thickness increased from 2.8 to 3.5mm when OLR was increased from COD 23to 47 g/m^{2}day (Twafik et al ,2006)

C. Speed

The speed of rotation helps in transfer of oxygen and nutrient required for growth of microorganism present in the biofilm. The film thickness and the dissolved oxygen can be controlled by adjusting the rotational speed of the discs. (Borghi et al,1985). For any specific loading, increases the disc rotational speed improved the removal efficiency but eventually, the removal efficiency remained constant even though rotational speed was increased. (Brazil, 2005).The Soluble Chemical Oxygen Demand (SCOD) removal was increased from 62.7 to 93.7% when rotation speed was increased from 3 to 11 rpm due to increase in dissolve oxygen (Najafpour et al ,2006).In study of colour removal revealed that efficiency increased with increasing rotational speed. At low rotational speeds of 10 and 20 rpm, colour removal efficiencies were around 33% and 35%, respectively. TOC removal efficiencies for 10 rpm and 20 rpm were 65% and 72% respectively. These results indicated that aeration was not sufficient for decolourization and TOC removal, at low rotational speeds such as 10 rpm and 20 rpm. At higher rotational speeds of 30 and 40 rpm, decolourization and TOC removal efficiencies were approximately 75% and 80%, respectively. (Kapdan et al,2001).A change in the disc rotational speed does not always result in a major change in its treating capacity but, affects the power requirement. Thus to obtain high power economy the RBC should be operated at minimum rotating speed. (Fujie et al ,1982)

D. Dissolved Oxygen (DO)

In partly submerged RBC the biomass on disc receives oxygen air -liquid interface during rotation of disc. The oxygen transfer rate is known to limit the performance of RBC's in aerobic wastewater treatment. An increase in the rotational speed from 18 to 42 rpm resulted in an increase in the dissolved oxygen concentration in the bulk liquid such that oxygen saturation increased from 37 to 99%. The rate of decolouration tended to be higher at higher rotational speeds when the dissolved oxygen concentration was at saturation. (Ramsay et al, 2006).In initial stage dissolved oxygen level generally reduces and slowly recovered in successive stages. There is direct correlation between DO and organic loading, higher the loading there is sharp decreased in DO. (Ahmady,2005). During treatment of food canning wastewater the BOD reduction was observed to be 96.4% at the end of 5th days. Initial DO level was 8.0 mg/l, then on 5th days the DO dropped to 4.3mg/l and remained constant for 5 days. If dissolved oxygen in reactor is not sufficient which affects treatment efficiency, after few days bad odour and detachment of biomass is observed (Najafpour et al.2006).At high disc rotation speed , oxygen absorption by the liquid film was more and at low speed this insufficient aeration occurred. Aeration through the liquid film is the main mechanism for biochemical oxygen transfer at rotational speeds investigated to be 3–25 rpm. (Kubsad et al,2004)

Table 1: Showing details of various experimental data and their performance

Type of reactor	Type of Disc material	Media dimension	Disc Submergence	RPM	Type of Wastewater	HRT	Inlet organic loading /substrate concentration	Mode of Working	Other data/ staging	Performance	Reference
Lab scale	Polymethyl acrylate with polyester colth mounted	diameter 18 cm	30 ,35 and 45 %	50 ,75 and 100	Phenolic Wastewater	36,28 and 24 hours for respective RPM	Phenol 40 to 220 mg/L	Batch	Single	Phenol removal efficiency was 99% for phenol loading of up to 40 to 180 mg/L . At higher rotational speed, the dissolved oxygen concentration in the fluid was increased from 4 to 6.9 mg/L also the increasing rotational speed decreased HRT.As submergence increased it HRT reduces	(Pradeep et al, 2011)
Lab scale	textured plastic sheet	-	40%	1.7	Grey water	1/2 ,1 and 1 1/2 hour.	COD 146 mg/L	Batch	Single	Percentage removal of BOD_5 and COD being 53 and 60% respectively at 1 1/2 hour HRT. Removal efficiency increases with increasing HRT.	(Pathan,2011)
Lab scale	polystyrene wedge attached to disc	diameter 35 cm	40%	10	Heavy Metal prepared in Laboratory	84 days	Heavy metal concentration of 5 to 83 mg/L	Batch	Single	The high metal sorption capacities recorded, particularly for copper, indicate that the biofilm of a RBC could be used as a tool to remove and recover metals from wastewaters.	(Costley et al,2001)
Pilot Plant	-	-	40%	-	Domestic Grey water	12 Hours	Three BOD Concentration of 72 mg/L,119 mg/L and 182 mg/L	Continuous	Single	The treatment efficiency of the RBC system based on BOD removal is ranged between about 93.0 to 96.0 %, and based on TSS removal is ranged between about 84.0 to 95.0 % for all concentrations of influent grey water	(Kader et al,2011)
Pilot Plant	polyurethane	diameter 23 cm	40%	6	Winery effluent	1Hour	COD 3828 mg/L	Continuous	Two	On average, the RBC reduced the influent COD of the winery effluent by 23% (from 3 828 mg/l to 2 910 mg/l) and increased the pH by 0.95 units (from 5.77 to 6.13) at an average retention time of 1h.	(Coetzee et al,2004)

Type of reactor	Type of Disc material	Media dimension	Disc Submergence	RPM	Type of Wastewater	HRT	Inlet organic loading /substrate concentration	Mode of Working	Other data/ staging	Performance	Reference
Lab scale	Plexiglas	diameter 7 cm	35%	8	Municipal wastewater	22.5 hour	COD 32 to 182 mg/L	Continuous	Single	The removal efficiency achieved in terms of COD, BOD Total suspended solids and total nitrogen was 82%,86%63% and 54% and efficiency increased when it is followed by settling which was for COD and TSS up to 94% and 97%.respectively	(Hiras et al,2003)
Lab scale	Polyurethane foam pasted on plastic disc	diameter 18 cm	40%	4	Sugar refinery	3 days	-	Continuous	Single	The result showed that RBC can treat sugar refinery effluent .It not only treat and remove colour by 55%,but also reduce total phenol and COD by 63% and 48 % respectively	(Guimaraes et al,2005)
Lab scale	plastic Disc	diameter 35 cm		10	Palm Oil mill effluent	5 day	COD 16000 mg/L	Batch	Single	The untreated POME was fed with the volumetric flow rates of 1.1, 2.3, 3.6, 4.8 and 6 l/h. About 88% COD was removed with the lowest flow rate of 1.1 l/h of POME. When the flow rate was increased to 3.6 l/h the reduction of COD decreased to 57%.	(Najafpour et al ,2005)
Lab scale	polyurethane foam attached to disc	diameter 25 cm	42.50%	10	Petroleum refinery	7.6, 3.8, 2.53 and 1.89 h, respectively, in each successive stage.	2.3 -5.3,4.7-10.7,9.5-18.8 and 12.7-25.1 $g/m^2.d$ for respective hydraulic loading 0.01, 0.02, 0,03 and 0.04 $m^3/m^2.d$	Batch	Four	COD removal rate was 87.5% , 84.9% , 81.5% and 80.2% for respective loading of inlet COD 2.3 -5.3,4.7-10.7,9.5-18.8 and 12.7-25.1 $g/m^2.d$	(Tyagi et al ,1992)
Lab scale	Acrylic	diameter 32 cm	33	4	Dairy Wastewater	16 ,24 & 36 hour	COD (45 -72 g/L)	Continuous	Three	COD removal rate was 80% , 83% and 92% was achieved at 16 ,24 and 36 HRT	(Ebrahimi et al ,2008)
Lab scale	Lightweight clear plastic sheet	diameter 35 cm	36,31.4 and 23.7%	3 to 11	Food canning	24 ,32,40 and 48 hour	55.33,66.39,89.99 and 110.66 g/m^2	Batch	Three	COD removal was increased 85.3 to 97.4% when HRT was increased from 24 to 48 hour. Also the COD removal at first stage was 88% of organic compound which indicates that single stage RBC may be sufficient in practical application.	(Najafpour et al ,2006)

E. Staging

Various studies on staging of RBC till now have revealed that it has improved the treatment efficiency. During experimentation of smaller multiple stages RBC in series achieve greater constituent reduction than a single stage of the same total media and hydraulic volume. This series configuration facilitates microorganism population to segregate as they acclimate to the different conditions within the treatment basin. This results in better carbon reduction and nitrification (Brazil, 2005).When microorganisms are grown in stages then different types will flourish in varying degree to remove various substrate concentration from stage to stage.(Borghi et al,1985).Difference of biomass thickness and colour indicated that there is high removal efficiency was achieved in first stage .The biofilm in first stage was thick and creamy colour and in second and third compartment were brownish and thin which only support 15% of removal efficiency. (Najafpour et al ,2006).Decrease in the amount of attached biomass on the successive stages was found in the control RBC during studies . (Janczukowicz et al ,1992)

F. Temperature

The temperature is the main factor which directly affects and controls the rate of biological process. (Borghi et al,1985). Temperature is another important factor affecting the limiting viscosity of RBC sludge and limiting viscosity decreased by increasing the temperature. (Jdayil et al ,2009).During experimentation the author observed that in the range of 15–36 ◦C, the bioreactor was more active in comparison with the responses at lower temperature than 15 ◦C and higher than 36 ◦C. (Alemzadeh et al,2002)

G. Disc Submergence

Disc submergence along with other factor affects the biological process. Generally, partially submerged RBC's are used for nitrification and fully submerged for denitrification. (Teixeira et al,2001).The experiment was carried out with three submergence level from 23.7,31.4 and 36%.As disc submergence was increased from 31.4 to 36 % the removal efficiency of Total Chemical Oxygen Demand (TCOD) and Soluble Chemical Oxygen Demand (SCOD) improved and result obtained were 74.9 to 87.5 % and 89.5% to and 93.75% respectively. (Najafpour et al ,2006). For aerobic RBC Submergence more than 50% is not practically possible as the bearings holding the shaft will be immersed in wastewater and can get deteriorated affecting the working of shaft.(Pradeep et al ,2010).Various performance of disc submergence are shown in table 1.

III. CONCLUSION

Rotating biological contactor is very effectively used for treatment of wastewater of very high organic loading. Mostly now a days the RBC is used for aerobic treatment process for removal of organic concentration, also anaerobic RBC are used for Dinitrification process .As various controlling parameters like organic loading , hydraulic retention time, speed of rotation, dissolve oxygen ,staging, temperature, submergence etc prose limitation on performance of reactor. Nevertheless improvement and studies should also be done on biofilm characteristic, cost of actual treatment unit on site and its structure during operation, various operational problems, supporting disc media etc. Several modification in structure of RBC are still needed concern regarding changing rotational speed to acquire desired dissolve oxygen for maximum removal efficiency of varying organic loading, disc submergence ,step feeding during multiple staging to improve RBC's performance.

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