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Rotating biological contactors : A critical review

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Abstract

The rotating biological contactor process offers the specific advantages of a biofilm system in treatment of wastewater for removal of soluble organic substances and nitrogen compounds. It is a unique adaptation of the moving-medium biofilm system which facilitates easy and effective oxygen transfer. Media in the form of several large flat or corrugated discs with biofilm attached to the surface is mounted on a common shaft partially submerged in the wastewater and rotated through contoured tanks in which wastewater flows on a continuous basis. The compactness of the system and its economical operation makes it a viable option specially suited for decentralized wastewater treatment technologies. The process optimization and adaptability under different environmental conditions and influent characteristics remain challenging tasks for the efficient use of this technology.

1. INTRODUCTION

In its simplest form, a rotating biological contactor (RBC) consists of parallel circular disks attached perpendicular to a horizontal shaft which passes through their centers.

The entire assembly is placed into a tank with the shaft slightly above the surface of the liquid so that the disks are approximately half immersed. Microorganisms grow on the surface of the disks and rotation of the shaft brings them into contact with the liquid allowing the digestion of the organic matter. Although microbial growth results from this substrate utilization, the rotation of the disks through the liquid provides a constant shear force which causes continual sloughing of the culture, thereby maintaining a more or less constant film thickness. The rotation of the disk also mixes the liquid which keeps the stripped biomass in suspension and allows it to be carried from the reactor by the effluent. Aeration of the culture is accomplished by two mechanisms. As a point on the disk rises above the liquid surface, a thin film of liquid remains attached to it and oxygen is transferred to that film as it passes through the air. In addition, a certain amount of air is entrained by the bulk of the liquid due to the turbulence caused by the rotation of the disks.

Performance of a RBC system is affected by the influent flow rate, rotational speed of the disks, variations in hydraulic and organic loading rates, and temperature.

The dissolved oxygen (DO) levels in RBC units are generally low, occasionally affecting their performance. The adverse effects of low DO levels can be overcome by supplemental aeration.

The rotation of the disks is achieved by electrical motors coupled to gear boxes or belt and pulley arrangements. Long-term operation of such systems is prone to mechanical failure, and RBC

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units may remain unoperational for extended periods of time, especially in developing countries. For these reasons a model RBC system was developed in which the RBC unit was rotated by the weight of the influent sewage and portion of the treated wastewater which was recirculated. Such a system would have the additional advantage of aerating the wastewater.

It is believed that the proposed system of rotating the biological contactor units by the weight of influent sewage and recirculated effluent is a viable alternative for the treatment of wastewater in small communities where sewage generation is not continuous. With the data available, the system can be operated at 2 rpm with an influent flow rate of 1 L/min. The corresponding recirculation rate is 7 L/min, and the hydraulic and BOD loading rates are 0.035 m3/d.m2 and 0.01 kg/d.m2, respectively. With the present system, BOD removals of up to 88% can be achieved with a single RBC unit. High dissolved oxygen concentrations occuring in the RBC unit enhance its performance, and power requirements are minimal.

2.Factors affecting performance of RBC system –

2.1 The rotational speed-

The rotational speed of the RBC media is a very important parameter that affects nutrient and oxygen mass transfer in the biofilm and consequently substrate removal. Usually an increase on the speed of rotation increases the dissolved oxygen concentration available to the microorganisms and as a result they are able to degrade the substrate at a higher rate. However, increasing the rotational speed leads to higher power consumption, which may not be economical for wastewater treatment applications(Ramsay et al. 2006). Besides, if the rotational speed gets too high, the microorganisms will be stripped off the media, deteriorating the effluent quality and lowering the biodegradation rate in the reactor.

2.2 Organic loading-

The organic loading of a RBC reactor must be accurately defined during planning and designing. The variation of the organic loading rate is generally accomplished by changing the inlet flow rate or the HRT, which also results in a change in the hydraulic loading (Najafpour et al. 2005). Available data show that, for a given system, as the applied organic loading rate increases, the substrate removal rate increases and removal efficiency decreases. Reduction in substrate removal efficiency may be an indication of limitation in dissolved oxygen.

2.3 Hydraulic loading-

The performance of RBCs has historically been correlated with hydraulic loading. Increasing the flow rate through the bioreactor reduces the liquid retention time in the system and results in a reduction in removal efficiency. In defined conditions increasing hydraulic loading also leads to an increase of attached biomass on RBC media surface (Alemzadehand Vossoughi 2001)

2.4 Hydraulic retention time-

Studies with RBC systems have revealed that longer contact times improve the diffusion of the substrate into the biofilm and its consequent removal of the influent (Hanhan et al. 2005; Najafpour et al. 2006).This trend is also verified with toxic and heavy metals Substrates (Costley and Wallis 2000; Majumder andGupta 2007; Sirianuntapiboon and Chuamkaew2007).

Too short a HRT will result in low removal rates,. Too short a HRT will result in low removal rates, whereas too long a HRT will not be economically feasible. In order for a biological system to compete successfully with conventional physicochemical methods of treatment, the shortest possible HRT associated with the most efficient removal rates is required (Costley and Wallis 2000).

2.5Wastewater characteristics-

The influent substances and its concentration levels may play a significant role in the operation of RBCs. For example, the flux into the biofilm may be smaller for large and slowly biodegradable compounds. The presence of particulate organic matter can reduce the flux of soluble substrate since the particulate matter occupies space within the biofilm, which decreases the rate of biodegradation (Grady et al. 1999).

2.6 Dissolved oxygen levels-

In an aerobic RBC system the biofilm is allowed to form on the medium, which is partly submerged in the wastewater and partly exposed to the air. The rotation alternately exposes this biofilm to atmospheric oxygen and wastewater. Oxygen transfers from the air to the RBC unit in three ways: by oxygen absorption at the liquid film over the biofilm surface when the biofilm is in the air; by direct oxygen transfer at the air-water interface; and by direct oxygen absorption by the microorganisms during their exposures (Grady 1982). Dissolved oxygen is very important in carbonaceous oxidation and nitrification being the most important design factor for aerobic RBCs. During operation oxygen levels must be properly controlled and to prevent from becoming a limiting factor, initial stages should have at least 2 mg DO/l (Grady 1982). If the rotating motion does not supply sufficient oxygen, a supplemental aeration system should be installed(Surampalli and Bauman 1997; Rodgers and Zhan 2003). Usually this promotes remarkable performance of the RBC, with an established thinner and active aerobic biomass, allowing considerable cost savings in design and construction of RBC units.

2.7 Temperature-

Temperature is one of the most important factors that affect the rate of biological processes and over the first-stage of an overloaded RBC, shifting the load to the next stage and progressively taking over the system (Mba et al. 1999). RBC units properly designed and supplemented with essential nutrients consistently produce the best effluents and maintain biofilm on the media with better adhesion characteristics, especially when treating industrial wastewater.

2.8 RBC medium submergence-

The percentage of RBC medium submergence depends on several factors, namely the operation type, microorganisms and characteristics of the effluent to be treated. Typically in aerobic processes of municipal wastewater treatment the submergence is about 40%, although in nutrients removal it can attain 60%. However, due to the diversity of industrial wastewater there is no reference value for disc submergence. Increased submergence was developed to reduce shaft and bearing loads and to improve equipment reliability (Tchobanoglous and Burton 1991). Submerged biological contactors (SBCs), as are called, operate at 70–90% submergence providing the advantages of larger medium volume available and fewer SBC units required (Schwingle et al. 2005). Submergence in excess of 50% will decrease the rate of oxygen transfer in the system, thereby if the SBC is used to treat wastewater aerobically, additional air drive units to provide oxygen and rotation must be used (Rodgers and Zhan 2003).

CONCLUSION:

RBCs enable high DO concentrations in the bulk liquid due to diffusive transfer of oxygen from air into the exposed liquid film surface. Therefore, requirement of external aeration in the reactor compartment can be avoided. The adoption of the new boundary layer concept reveals that average DO levels in the liquid film usually remains higher than in the bulk liquid.

Under variations of nutrient and hydraulic loading rates in influent, RBCs can sustain such fluctuations within a tolerable range and perform efficiently. Although this is valid for most biofilm systems, RBCs may provide an economical advantage. The tolerable limit for such performance depends upon system configuration and temperature which can be determined from simulations.

The RBC stages under high nutrient loading rates show a non-uniform biomass distribution with heterotrophs dominating the surface layers where soluble organic substrate concentration remains high. The nitrifying species with a slower growth rate than heterotrophs become dominant once the heterotrophs start to dwindle. The latter stages of RBC show a more homogenous biofilm matrix than the first stage.

Temperature increase shows an improvement in the overall removal efficiency.

Denitrification is only partial in RBC systems and occurs predominantly in the initial stages of the RBC where high heterotrophic population and anoxic ambience is readily available.

Flow recirculation reveals little improvement in the overall removal efficiency of the RBC system.

Increasing submergence ratio in the first stage increases denitrification. However, changing the submergence affects the removal efficiency of other nutrients and a submergence level of 40-42% is optimum for all stages and shows best results.

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BIBILIOGRAPHY

1.A. Tawfik, H Temmink: Sewage treatment in a RBC system. Journal of water, air and soil pollution 175, PP 275 -289, 2006.

2.Akunna J.C., Jefferies C: Performance of family size sequencing batch reactor and RBC units treating sewage at various operating conditions. Journal of water science and technology 41, PP 97 – 104, 2000.

3. Alemzadeh I, Vossoughi M (2001) Biodegradation of toluene by an attached biofilm in a rotating biological contactor. Process Biochem 36:707–711.

4.Ayoub G M, Saikaly P.: The combined effect of step feed and recycling on RBC performance Journal of water Resources 38, PP 3009 – 3016, 2004.

5. Evans L.F.: Consideration of first stage organic overloading in RBC design. Journal of water pollution control 57,

1094 – 1098, 1985.

6.Grady CPL Jr (1982) Modelling of biological fixed films–A state of the art review. In: Wu YC, Smith ED, Miller RD, Patken (eds) Proceedings of the 1st international conference on fixed-film biological processes, April 20–23. University of Pittsburgh, Ohio, USA, pp 344–403.

7.Grady CPL Jr, Daigger GT, Lim HC (1999) Rotating biological contactor in Biological wastewater treatment.

8.Hansfor G.S., Andrews J.F.; A steady – state model for rotating biological disc reactor. Journal of water resources, 12, PP 855 – 868, 1978.

9.I.Esen and R.A.Ashraf: Rotary Biological contactor operation with water action. Journal of environment International, vol. 18, PP 403 – 408 , 1992

10.I.Vinage, P. Rudolf: Biological waste gas treatment with modified RBC.in a continuosly operated RBC reactor. Journal of applied microbiology and biotechnology 10, 2010.

11.M. Dolores Coello, M.R. Rodriquez: Use of microbial activity measurements for monitoring RBC biofilms. Environment monitory assessment 2010.

12.Majumdar P S, Gupta S K : Removal of Chlorophenols in sequential anaerobic – aerobic reactors. Journal of Bioresources technology 98, PP 118 -129, 2007.

13.Matrin cereceda, S. Serrano: Biofilm communities and operational monitoring of a RBC system. Journal of water, air and soil pollution 126, PP 193 -206, 2001.

14.Mba D, Bannister RH, Findlay GE (1999) Mechanical redesign of the rotating biological contactor. Water Res 33:3679– 3688.

15.Najafpour G, Yieng HA, Younesi H, Zinatizadeh A (2005) Effect of organic loading on performance of rotating biological contactors using palm oil mill effluents. Process Biochem 40:2879–2884.

16. P. Rudolf, P. Pudiger: Rotating biological contactors. In kennes C. Veiga M C, Bioreactors for waste gas treatment. Kluwer academic, Dordrecht PP 201 – 204, 2001.

17.P. Saikaly, G. M. Ayoub: Ammonia nitrogen removal in step feed RBC. Journal of water, air and soil pollution 150, PP 177 – 191, 2003.

18.P. Teixeira, R. Oliveira: Denitrification in a closed rotating biological contactor. Biotechnology letters 22, 1789 – 1792, 2000.

19.Patwardhan A.W.: RBC – A review. Indian Engg. Chem. Res. 42, 2035 – 2051, 2003.

20.Ramsay J, Shin M, Wong S, Goode C (2006) Amaranth decoloration by Trametes versicolor in a rotating biological contacting reactor. J Ind Microbiol Biotechnol 33: 791–795.

21.Rao Y. Surampalli, E.R. Baumann: Role of supplemental aeration in improving overloaded first stage RBC performance: Journal of water, air and soil pollution 98, PP 1 – 15, 1997.

22.Rodgers M, Zhan XM (2003) Moving-medium biofilmreactors. Rev Environ Sci Biotechnol 2:213–224.

23.S. Cortez, P. Teixeira: RBC – A review on main factors affecting performance. Journal of Environment Science and biotechnology 7 PP 155 - 172, 2008.

24.S. Sirianuntapiboon: Treatment of wastewater by packed cage RBC system. Journal of Biresource technology 97, 1735 -1744, 2006.

25.S. Srikattanaporn: Efficiency of RBC system for treatment of waste water containing surfactants. Water quality and research journal, Canada 38, PP 737 -752, 2003.

26.S. Tandee : Application of packed cage RBC system for treatment of high nitrogen containing wastewater. Thammasat international journal of science and technology 5 (5), 28 – 39, 2000.

27.S.C. Costley, F.M. Wallis: Effect of flow rate on heavy metal accumulation by RBC biofilms. Journal of industrial microbiology and biotechnology, 24, PP 244 -250, 2000.

28.Tchobanoglous G, Burton FL (1991) Wastewater engineering: treatment, disposal and reuse. Metcalf & Eddy, 3rd ed. McGraw-Hill International Editions, New York.