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Performance of Rotating Biological Contactor in Wastewater Treatment – A Review

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Abstract- The management of the medium and small scale industries feel burden to treat waste if the cost involvement is high. Hence there is a board scope for cheaper and compact unit processes or ideal solutions for such issues. Rotating biological contactor is most popular due to its simplicity, low energy less land requirement. The rotating biological contactors are fixed film moving bed aerobic treatment processes, which able to sustain shock loadings. Unlike activated sludge processes (ASP), trickling filter etc. Rotating biological contactor does not require recirculation of secondary sludge and also hydraulic retention time is low. This review paper focuses on works done by various investigators at different operating parameters using various kinds of industrial wastewater.

Index Terms— bio film, organic loading, rotating biological contactor, submergence, wastewater

1 Introduction

Due to global civilization and industrialization, there is a great demand for the water. A small fraction of the same is utilized and rest is being generated as wastewater. The disposal of such wastewater into water courses creates an adverse impact on the human health, flora and fauna. Hence the safe disposal of such wastewater either on land or water bodies is the most challenging task before the engineers [1]. Pollution can be reduced by changing processing method in the industry and/or by waste treatment plants. Various kinds of industries include food processing, pharmaceuticals, leather tanning and finishing, breweries and distilleries, textile, pulp and papers, plastics and resins, dairies, electroplating, chemical, oil refinery, nuclear power plant, thermal power plant etc. The constituents of wastewater includes physical properties such as colour, temperature, odors, solids; the chemical constituents are surfactants, proteins, fats, oil, grease, Phenols, heavy metals, pH, BOD, COD, chlorides, pesticides, volatile organic compounds etc. biological constitutions namely animals, plants, protests, archaebacteria, etc. and the radioactive constitutions namely alpha, beta emitters. Based on the constituents present in the wastewater, they are classified into low, medium and highly concentrated.

Earlier the wastewater treatment objectives were removal of suspended and floatable material, treatment to biodegradable organics and elimination of pathogens. The wastewater normally treated with primary, secondary and advance treatment methods. The primary treatment includes equalization, neutralization, screening, grit removal, primary sedimentation, etc and the secondary treatment processes includes the biological and/or chemical treatment processes. The advanced treatment method namely denitrification, phosphorous removal, carbon adsorption, ion exchange, electrodialysis, reverse osmosis, polishing pond, etc and the biological treatment process such as activated sludge process, trickling filter, oxidation ditch, aerated lagoon, stabilization pond, rotating biological contactor etc [2].

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The first rotating biological contactor (RBC) was installed in West Germany in 1960, later it was introduced in the United States and Canada. A rotating biological contactor is an aerobic fixed film moving bed biological treatment [3]. The mechanisms of the biological rotating contactor are (i) oxygen absorption at the liquid film flowing over the disc's surface during the air exposure cycle (ii) direct oxygen transfer at the air-reactor liquid interface, with this diffusion being the result of the turbulence created by the rotating discs and (iii) direct oxygen absorption by the microorganisms during the air exposure of the discs [4]. However, the organic loading can provide an attractive alternative by combining the effect of hydraulic loading and organic concentration in one parameter [5]. The systems are more effective and the end products formed are non toxic. The schematic diagram of a 2 stage RBC is shown in Fig.1.

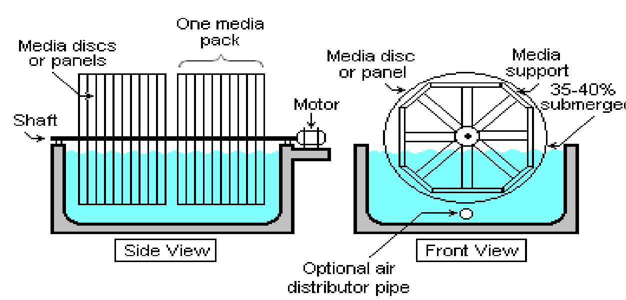

Fig 1: A two stage biological rotating contactor

(Source:http://en.wikipedia.org/wiki/Roatating)

In this review paper, the importance for the treatment of wastewater and the investigations carried out by various investigators using RBC to treat different kinds of industrial wastewater are discussed

2. LITERATURE REVIEW

The removal of COD from dairy industry effluent using three stage batch mode rotating biological contactor (RBC) was investigated by Nitin et al., (2013) In each stage, 6 disks of 17.8 cm dia and 5mm thick are developed with 1 cm spacing between them. The experiments were conducted by varying initial COD concentration (1000 – 1250 mg/L) and HRT (4 – 48 hrs). The investigator achieved 93% COD removal at optimum COD loading rate of 1100 mg/l, HRT 6 hrs at rotating speed of 35 rpm with 30% submergence [6].

S.Syed Enayathali and Nehru Kumar (2012) used two stages RBC to treat grey water. The experiments were conducted at different influent COD (248, 294, 347, 395 and 480 mg/L) and rotational speeds (3, 4.5, & 6 rpm). The authors stated that maximum 95.7% removal of COD at 3 rpm as against 95.04% and 94.96% at 4.5 and 6 rpm respectively. The authors also reported that maximum removal of COD was achieved at 3 rpm with the blade rotational speed in laboratory scale RBC. The speed of the blades could be still lower in the full-fledged field level RBC and removes more COD. The effluent of the RBC can be used for irrigation and gardening without any risk [7].

The winery wastewater was treated using RBC for the reduction of COD by Lida et al. (2003) It was mentioned that extensive bio film developed on the RBC discs and contained a number of yeast and bacterial species that displayed a dynamic population shift during the evaluation period. The investigators attained 43% COD reduction with a retention time of 1 hour. Also the authors reported that one of the yeast isolates MEA5 was able to reduce COD from synthetic wastewater by 95% and 46% within 24 hours under aerated and non-aerated conditions respectively [8].

Kossay.K and Al-ahmady (2005) investigated the influence of organic loading on the functioning of RBC and comparing with other processes such as ASP and oxidation ponds. RBC reactor comprises of four stages and the experiments were conducted under wide range of operating conditions. i.e. contactors immersion range 34-60%, rotational speed 1.5-30rpm, detention time 0.3-6.85 hours, organic loading 0.1-360 g/m2.d, hydraulic loading up to 1250 l/m2.d. COD removal (40-85% of the organic loading applied) was noticed in the first stage of the reactor. The authors reported that to get an effluent with BOD ≤25mg/l and COD ≤ 60mg/l, the system must be operated on organic loading of approximately 22g BOD/m2.d and 65g COD /m2.d respectively. Also stated for nitrification, the RBC systems should be designed to work on loading rate not more than 10g COD/m2.d and the reactors should be designed for hydraulic loading 40 l/m2.d or less [9].

The oxygen transfer coefficient using modified RBC was studied by Radwan and Ramanujam (1995). Based on their earlier experimental studies with modified RBC at different rotating speeds, the authors established objectives (i) to estimate the physical and biological oxygen transfer coefficient with and without bio mass (ii) to evaluate the enhancement of oxygen transfer that results from the biomass and (iii) to estimate the thickness of the liquid film. The earlier studies were conducted using the laboratory scale model with discs modified by attaching porous nechlon sheets to increase the bio film area. The details of the model are number of stages-2, diameter of disc-30cm, number of discs-16, submergence of discs-40%, surface area per stage -1.17m2. The experiments were conducted using synthetic waste (500mg/l of COD) at 5 different rotating speeds (6, 12, 18, 24 and 30rpm). It was reported that oxygen transfer (KLa) increases with increasing the rotating speed and comparatively at 18 rpm, the rate of oxygen transfer was found to be quite high. The enhancement of oxygen transfer due to biomass was found decreased from 4.35 to 2.5 as the rotating speed increased from 6 to 30 rpm [10].

Jan Sima et.al.(2012) performed the experiments with laboratory scale RBC using white rot fungus isolated from the forest for the removal of textile dye (Remazol brilliant blue R) from the textile wastewater. The reactors consist of 12 discs of 13cm diameter and 1cm thick with total inner volume 7x10-3m3. The residence time distributions of the liquid phase in the reactor were measures to obtain hydrodynamic characteristics. The decolorization experiments with rotating disc conductors (RDC) using immobilized irpex lacteus mycelium and operated in the continuous flow through mode proved that these reactors are capable to decolorize anthraquinone textile dyes for long time periods with a high efficiency (≥92%) [11].

Biodegradation of phenol in a batch flow single stage laboratory scale RBC was examined by Pradeep.et.al (2011) at ambient room temperature between 27 and 320C. During their studies the impact of various processes variables such as concentration of phenol, rotational speed and percentage of submergence of discs was examined. The reactor was prepared with 6 discs each of 8 cm diameter, 3 mm thick and total surface of the discs was 745cm3. The working volume was 10L and disc submergence 40%. The authors reported that the phenol removal was 99% when its concentration between 40 and 180mg/l. The removal efficiency is decreased when phenol concentration increased beyond 200mg/l. Also reported that to achieve 99% removal of phenol at different submergence of discs i.e. 40%, 35% and 30%, HRTs required were i.e. 24, 28 and 32 hours respectively. [12].

A three stage laboratory scale RBC was fabricated by Ebrahimi et al (2008) with 8mm thick acrylic sheets, which comprised of 16 discs in each stage with 32cm diameter and interspacing the discs at 8mm. After extension, the total surface area of the discs was 8.57m2 and the submergence 33%. The working volume of the reactors was 65.6L and the discs were rotated 4rpm. The investigators were able to remove 96% COD at HRT of 36 hours [13].

Gimavaes et al., (2003) examined the decolonization of sugar refinery effluent using laboratory scale RBC in a long term repeated batch operation. The decolourization medium composition was optimized using polyurethane foam (PUF) - immobilized fungus. A three stage RBC reactor was prepared from a polymethyl-methacrylate cylinder, 25 cm in length and 18 cm diameter. Each stage comprised of three discs each of 14cm diameter. A 2.5mm thick PUF was fixed as both sides of the discs and rotated at 4rpm with 40% discs submergence. The working volume of the reactor was 7.5L. The experiments were conducted at room temperature of 38^{o}c. The authors noticed that wastewater had a color. Addition of glucose was obligatory and the minimum glucose concentration was found to be 5g/l. The RBC containing P.chryrosoporium immobilized on PUF discs was operated with optimized decolourization medium, in continuous mode with a retention time of 3 days. By simply reversing the feed inlet of the reactor after17 days of operation, it was possible to double the active fungal lifetime. During the course of operation the color, total phenols and chemical oxygen demand (COD) were reduced by 55, 63 and 48% respectively. The experimental results revealed that the possibility of sugar refinery effluent to treat continuously in a RBC. The active fungal like tissue can be increased by simply increasing the feed inlet of reactor. The reactor not only removed the color of the effluent by 55% but also reduced total phenol and COD by 63% and 48% respectively [14].

Prashant Kadu, et al (2013) used three stage laboratory scale RBC to treat the municipal sewage. The experiment set up was prepared with acrylic sheet, PVC pipe (shaft) of diameter 20mm having 60cm length and different sizes of discs used. Based on the experiments, authors reported that amount of overall oxygen transfer varies with surface area of the discs & rotating speed. The authors also reported a BOD reduction from 131.72mg/l to 58.39mg/l, COD from 268.82mg/l to 132.81mg/l and TSS removal upto 80% in the first stage [1].

50 liters volume laboratory scale RBC was employed to treat maize processing waste water to evaluate the reduction of COD by Pedroza-Islas and Duran (1989). The operating conditions were COD - 6400mg/l, retention time - 2.5 days, hydraulic loading rate - 20 L /day, discs submergence - 36%, rotating discs speed - 16rpm and ratio of maize processing wastewater with tap water was 1:3. The investigators were able to achieve 84.6% COD removal [15].

The application of treated wastewater for irrigation was studied by Bahman and Nasin (2011). The authors used RBC with packing bed as a pilot system to monitor its performance in the treatment of municipal wastewater to be used for irrigation to enrich the soil properties. The reactor comprises of three stages with 18 litres effective volume and had 20 cm diameter bed with 3.36 m2. The influent wastewater characteristics were DO – 0 mg/l, pH 7.8-7.1, total nitrogen 53mg/l, TSS 180-120 mg/l, BOD 225 mg/l. The reactor was containing three steel rotating cylinders each 20 cm length and diameter. The cylinders were packed with polypropylene ball bearings and ratio of surface to volume of RBC was 3 times more than common RBC and rotating speed 16rpm. The authors mentioned in their paper that 96.8% BOD elimination rate in 0.025m3/m2.d water load declined to 77.7% in 0.1 m3/m2.d water load. The dissolved oxygen has been increased to maximum at the outlet after passing through all the three stages [16].

Wojciech and Ewa (1992) investigated the influent of the raw wastewater dosing system on technological parameters of the rotating biological discs. Synthetic wastes were used throughout their studies to feed the two reactors arranged in series. Each reactor divided into four stages and in one reactor the influent of equal flow rate (i.e.33/33/33 RBC) fed into first, second and third stages. In second reactor, the raw waste flowed to the first stage (2/3rd of total flow and to the second stage (1/3rd of flow rate). In both the reactors, the number of discs/stage – 6 numbers, each disc diameter - 0.8m, submergence - 40%, total surface area /unit - 24m2, rotational speed - 1.75rpm, the average influent COD concentration - 510mg/l and the hydraulic loading rate - 0.054m3/m2.d. The authors reported that in the reactor one (i.e.33/33/33 RBC) increase in COD was noticed and caused by step feeding of raw waste at different stages. Based on the experiments the authors also concluded better COD removal could be obtained by feeding the waste to the first and second stages. The adding raw wastes to the third stage decreased process efficiency [17].

Vijay Kubsad et al. (2004) modified the model developed by Kim and Molof to examine the oxygen transfer from air to water. The model was comprised consist of three stages, each stage carried 14 discs having a diameter 0.23m with the discs submergence of 35% in trough and rotated at 5.3 rpm. The volume of the liquid in the absence of biomass was 24L. Various models available were evaluated with the experimental data obtained by the investigators. It was reported the data was well fitted into the modified Kim and Molof model (the regression co-efficient 0.95) which was much higher than other available models [18].

Waskarh V.G et al (2012) studied the work conducted by various investigators on the application of RBC in the removal of bio degradable matter from the waste water. The authors reviewed nearly 34 references and presented details of various experimental results and their performance in a tabular form. The authors concluded that the RBCs can be effectively used for treatment of wastewater having very high organic loading. Also suggested the need to conduct studies on bio-film characteristics, on-site treatment cost, operational problems etc [3].

Diaas EI Mohayerie et al. (2012) the authors constructed a new form of rotating biological contactor (sRBC) used self-rotating discs system consists of feeding tank (2x2x6m) channel size 3m length and 0.5 wide, upstream and downstream (0.5x0.5X0.6m) the cross section of the channel was trapezoidal shape with 0.4 m width and a depth of 0.12m for the downstream weir with the conditions like influent and effluent discharge was same using the pump arrangement, four reactors constructed and each reactor discs 5 mm in thickness and different diameter, number of disc and spacing between disc. Each reactor were constructed contain acrylic curvature rips interconnected between discs. Each rip has 1 mm in thickness and 270 mm in length. Based on the experiments the authors concluded that self rotating biological contactor (sRBC) oxygen transfer model established. It is a function of parameters affecting oxygen transfer and can be used as practical tool in computing oxygen transfer co-efficient for self-RBC discs. Self RBC is applicable in the form of rotating biological contactors in free rotation [4].

3. Conclusion

RBC having enabled high DO attentiveness in the bulk liquids due to diffusive transfer of oxygen from air into the exposed liquid film surface, the requirement of external aeration in the reactor compartment can be avoided. The adoptions of the new boundary layer concept expose that average DO levels in the liquid film usually remains higher than in the bulk liquid. Under variation of nutrient and hydraulic loading rates in various kinds of wastewater influents, RBCs can sustain such fluctuations within a tolerable range and perform efficiently. Although this is valid for most bio film systems, RBCs may provide an economical advantage. The tolerable limit for such performance depends upon system configurations 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 heterotrophy become dominant once the heterotrophs start to dwindle. The latter stages of RBC show a more homogenous bio film 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 optimum submergence was found approximately 40-42% for all stages to achieve better results.

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