Effect of Flow Rate and Disc Area Increment on the Efficiency of Rotating Biological Contactor for Treating Greywater

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ABSTRACT

The performance of greywater treatment through RBC (Rotating Biological Contactor) is related to many factors including rotational speed of disc, surface area of the media, thickness of biological film; quality and flow rate of influent. The plastic media provides surface for biological slime. The slime is rotated alternatively into the settled wastewater and then into atmosphere to provide aerobic conditions for the microorganisms. In this study the performance of RBC is investigated at different flow rates and disk areas of media by introducing additional discs on the shaft of RBC. Initially efficiency of the RBC was observed on six flow rates at the disc area of 9.78m^2. Furthermore optimized three flow rates were used to augment the disk area. The efficiency of RBC system was improved significantly at disk area of 11.76m^2 and flow rate of 20 L/h. Under these conditions the removal of BOD_5 (Biochemical Oxygen Demand) COD (Chemical Oxygen Demand) and TSS (Total Suspended Solid) was observed 83, 57 and 90% respectively.

Key Words: **Greywater, Rotating Biological Contactor, Disc Area, Flow Rate, Treatment.**

1. INTRODUCTION

Water scarcity is a global issue and not confined to the arid areas only. The haphazard urbanization, industrialization, agriculture, population growth and elevated standard of living have marked the gradual depletion of water resources. Studies reveal that reclaimed wastewater may be reused for non-potable uses and could find significant applications in the regions of water scarcity [1]. It will contribute in reducing the stress on available fresh water resources. Although wastewater in general and industrial wastewater in particular have been a potential source for recycling but they need extensive treatment. Greywater is the urban wastewater originating from the bathroom and kitchen excluding toilet waste. The water from kitchen contains food residues, high amount of oil, fat and dish washing chemicals that is way it is considered as dark greywater. It needs relatively more treatment before reuse. Literature reveals that some researchers have excluded kitchen wastewater from the other greywater streams [2-3]. The domestic greywater production is more than its consumption (if used for toilet flushing only), it is advisable to reuse only light greywater and resultantly reduce cost of the treatment

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and possible adverse effects [4]. The light greywater contains soaps, shampoos, body care products, hairs, body fats and traces of urine; and its sources are bathroom and washbasin [5-6]. Light greywater has particular advantages as it is a large source with low organic contents [1]. Treated greywater can support the water requirement in buildings/residences [7]. The generation of greywater volume and quality vary and depend upon many factors, including the life style of the inhabitants, living standard, population structure i.e. age and gender,water supply pattern, degree of water abundance, water charges and climatic conditions of the area. About 100-150 l/c/d (liter/capita/day) is the water demand in industrialized countries, of which 60-70% is transformed into greywater while most of the rest is used for flushing toilet and discharged as blackwater [4]. Greywater treatment does not aim at providing water of drinking quality. It may be used to meet the non-potable applications by applying no to high treatment. Depending upon the level of treatment and quality of effluent, greywater can be applied for crops, landscape irrigation, toilet flushing, cooling, groundwater recharge, vehicle washing, firefighting, laundry, ornamental lakes, streams, dust control, street washing and snow melting [8-9].

Numerous studies have been carried out on treated greywater to be reused in hotels [10], sports complexes [11] and multi-story buildings [12]. Greywater may pose health risks, undesirable aesthetics and environmental effects, if not handled properly [13-16]. For this reason efficient and reliable treatment system is required, which should provide proper conveyance and storage of treated greywater. This will reduce the offensive odor and color of greywater [17].

Many researchers conducted their research on treatment with different technologies, which based on the system of physical, chemical, biological and combination of these processes. A wide range of biological treatment process have been reported for greywater recycling [18-20], which include SBR (Sequencing Batch Reactor) [21], UASB (Upflow Anaerobic Sludge Blanket) [22], CW (Constructed Wetland) [23-24],], MBR (Membrane Bioreactor) [25-26] and RBC [27-31]. RBC is a secondary biological treatment process for domestic and biodegradable industrial wastewater. In RBC a rotating shaft is surrounded by plastic discs. The biological slime (a thin film) grows on the disc media as it rotates in to and out of the wastewater. During this movement aerobic decomposition of organic matters takes place by the microorganisms [31].

RBC can be operated aerobically as well as anaerobically [32] depending upon the type of influent and level of treatment required. Many researchers have treated wastewater by applying RBC technology under various operating conditions. Chesner, et. al. [33] have concluded that dissolved oxygen concentrations and organic removals depend on size and rotational speed of discs. Friedman, et. al. [34] have also worked on the effect of disc rotational speed on performance of RBC. He treated synthetic wastewater at 'eight stage' RBC under sixteen different combinations of rotational speed of RBC, influent concentration and hydraulic flow rates. He determined that neither hydraulic loading nor organic loading factor alone was a sufficient design parameter but another parameter like rotation per minutes of discs had shown significant effect on the treatment efficiency of RBC. Friedler, et. al. [27] applied two stage RBC pilot scale system for the treatment of light greywater and determined that RBC was producing good quality effluent having BOD_5 and turbidity of 2.3mg/l and 0.6 NTU (Nephelometric Turbidity Unit) respectively. The overall removal efficiency was up to 96% in BOD_5, 98% in turbidity and 64% in COD. The stability of pilot plant was demonstrated in BOD_5 and COD removal, producing effluent of steady concentration. Tawfik, et. al. [35] investigated effect of disc material on the pollutants removal efficiency of RBC. He compared the efficiency of RBCs made from polyurethane and polystyrene material for treating UASB treated effluent at the same operational conditions and concluded that both reactors achieved almost similar removal efficiency of COD. However, during the comparison of different disc materials he did not treat greywater.

Since RBC is working on the principle of bio-absorption [36] and the growth of biofilm is the function of many factors including organic loading, hydraulic retention time, flow rate, rotational speed, surface area and roughness of the disc. The slime layer accumulates on the discs and takes one to four weeks to form. The thickness ranges from fraction of millimeter to 2mm depending upon the concentration of the substrate [37]. In this study a continuous flow type RBC system was developed at laboratory scale to analyze the effects of varying flow rates and disc area increments on its performance.

2. MATERIALS AND METHOD

2.1 Development of Continuous Flow Type RBC System and Greywater Collection

A single stage continuous flow type RBC system was designed and developed at laboratory scale. The holding capacity of RBC system was 50 liters and was fabricated from organic glass. The discs were textured plastic and having the surface area of 9.78m^2.

The ratio of tankage to the disc area was kept 0.0051m^3/m^2. The rotating discs were submerged up to 40% in the greywater. An electric motor equipped with gear box was mounted on the shaft to control the rotations of the disks at the rate of 2rpm. The laboratory scale continuous flow type RBC system was setup and its schematic diagram and picture are shown in Figs. 1-2.

A hall of residence at NCEAC (National Center of Excellence in Analytical Chemistry), University of Sindh, Jamshoro, Pakistan was selected for collection of greywater. The existing plumbing work was retrofitted to separate the greywater from the black water. The greywater collection tank (equalization tank) was constructed outside the building. The collection tank was provided with discharge pipe at the bottom and overflow pipe at the top with 6 inch free board. The strainer was followed by equalization tank in order to avoid floating particles like hairs, threads of fabric etc. From the equalization tank greywater was lifted through pump to OT (Overhead Tank) and same was discharged to RBC at various flow rates. The effluent was then collected in sedimentation tank or SST (Secondary Settling Tank). RBC system was operated continuously by varying the operating conditions.

2.2 Flow Rate Optimization

In order to optimization the flow rate, the RBC system was operated at six flow rates (F-1 to F-6). The values of flow rates and corresponding hydraulic loading rates are given in Table 1.

Samples of influent and samples of effluent were collected from the outlet of OT and SST respectively and analyzed for BOD_5, COD and TSS. Maximum removal of pollutants was observed at operating conditions F-4, F-5 and F-6 having flow rates of 25, 20 and 17 L/h respectively.

2.3 Flow Rate and Disc Area Optimization

For further investigation, the RBC system was operated at aforesaid three flow rates and six disc areas. The aim of this study was to determine the effects of flow rates and disc area increment on the efficiency of RBC unit for treating light greywater. Thus, the RBC unit was operated under eighteen operational conditions FD (Flow Rate Disc Area) as shown in Table 2. The disc area was increased from 5-30% in six steps by addition of 2 discs in the existing discs (the base line disc area was 9.78m^2).

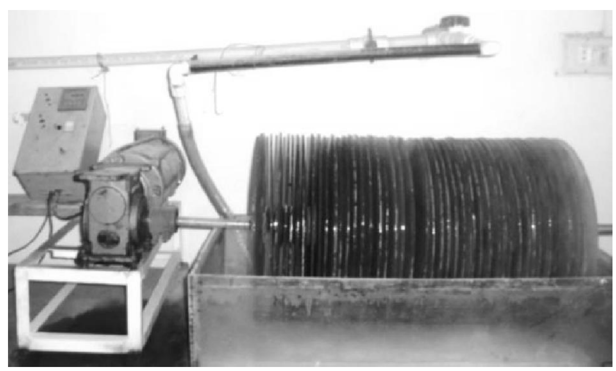

FIG.2. ROTATING BIOLOGICAL CONTACTOR

TABLE 1. PERFORMANCE OF RBC SYSTEM AT VARIOUS FLOW RATES

Operating Conditions	Flow Rate (Lh^{-1})	Hydraulic Loading Rate ($m^3m^{-2}d^{-1}$)	BOD_5 (%)	COD (%)	TSS (%)
F-1	100	0.245	31	29	38
F-2	50	0.123	35	30	46
F-3	33	0.082	36	35	52
F-4	25	0.061	40	35	58
F-5	20	0.049	48	38	78
F-6	17	0.041	59	40	81

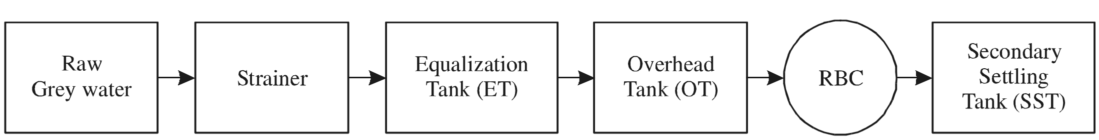

FIG. 1. SCHEMATIC DIAGRAM OF RBC SYSTEM

2.4 Sampling and Analysis

The raw greywater samples were collected from the outlet of OT and treated greywater samples were collected from the SST. The samples were transported to laboratory and analyzed either immediately or stored at 4°C for a maximum period of 48 hours, depending on the parameter to be analyzed. The samples were analyzed in triplicate for BOD_5, COD and TSS. Each test was performed in accordance with the Standard Methods; APHA [38].

3. RESULTS AND DISCUSSION

The average BOD_5, COD and TSS concentration of influent was observed as 35±11, 136±38 mg/l and 39±19 mg/l (Not given in the table) which showed that the greywater was light and diluted. Similar values have been reported in the literature [26] for the greywater from the showers of sports club where mean values of BOD_5 and COD were observed as 59±13, and 109 ± 33 mg/l respectively.

The performance of RBC was investigated at various flow rates through the removal of BOD_5, COD and TSS by analyzing influent and effluent samples as shown in Table 1. Fig. 3 shows the removal of BOD_5, COD and TSS at disc area of 9.78m^2 and flow rates 100, 50, 33, 25, 20 and 17 L/h. The removal percentages of BOD_5, COD and TSS were observed in the range of 31-59, 29-40 and 38-81% respectively. The system was found to be not very efficient at high flow rates, however, as the flow rated were decreased significant removal efficiency was obtained as shown in Table 1. The BOD_5 removal was observed as 40, 48 and 59% at the flow rates of 25, 20 and 17 L/h respectively. Similarly COD and TSS removal were 35, 38, 40, 58, 78 and 81% respectively for the same three flow rates as shown in Fig. 3.

To investigate further, the combined effect of the variation in flow rate and disc area was studied. For this the RBC system was operated at six disc areas and under each incremental disc area the system was operated on three flow rates of 25, 20 and 17 L/h, as shown in Table 2.

Raw and treated greywater samples were collected and analyzed. Fig. 4 shows the removal of BOD_5 in the range of 56-83% for the disc area increase of 5-30%. The disc area of RBC at 10% increment was 10.74m^2

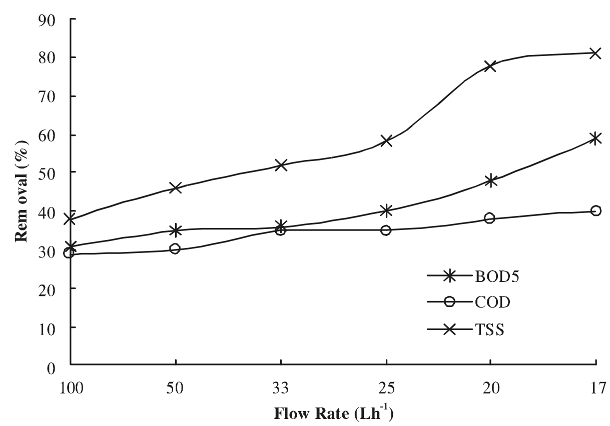

FIG. 2. REMOVAL PERCENTAGE OF BOD_5, COD, AND TSS AT SIX FLOW RATES

TABLE 2. PERFORMANCE OF RBC SYSTEM AT VARIOUS FLOW RATES AND DISC AREAS

Operating Conditions	Flow Rate (Lh^{-1})	Disc Area Increment (%)	Disc Area (m^2)	BOD_5 (%)	COD (%)	TSS (%)
FD-1	25	5	10.27	56	39	65
FD-2	20	5	10.27	56	42	81
FD-3	17	5	10.27	64	42	81
FD-4	25	10	10.74	59	43	71
FD-5	20	10	10.74	62	48	81
FD-6	17	10	10.74	69	48	88
FD-7	25	15	11.25	79	50	71
FD-8	20	15	11.25	80	56	89
FD-9	17	15	11.25	83	59	90
FD-10	25	20	11.76	80	54	73
FD-11	20	20	11.76	83	57	90
FD-12	17	20	11.76	83	59	95
FD-13	25	25	12.27	81	54	73
FD-14	20	25	12.27	83	56	90
FD-15	17	25	12.27	83	60	95
FD-16	25	30	12.78	81	54	71
FD-17	20	30	12.78	83	56	91
FD-18	17	30	12.78	83	60	95

and the removal was observed up to 69%. The removal of BOD_5 at the operating conditions of FD-1 to FD-6 was insignificant which may be due to transport of excess suspended solids in the SST which may cause increase in biomass in the effluent and resulting contributes more contents of BOD_5 in the effluent. On other hand the removal of BOD_5 enhanced and remained almost constant from operating condition FD-7 and onwards. The flow rate of 20 L/h and disc area of 11.76m^2 showed BOD_5 removal efficiency of 83% (at the hydraulic loading rate of 0.041m^3/m^2-d) as shown in Table 2. It was the maximum removal of BOD_5 observed in this study. Further decrease in BOD5 was not observed beyond operating condition FD-11 as shown in Table 2 and Fig. 4.

As presented in Fig. 5 the COD removal is significantly low at initial increments of disc area of 5-10% and the flow rates of 25 and 20 L/h. A considerable increase in percent removal of COD was observed as 60% at operating condition FD-15 (flow rate 17 L/h and disc area 12.27m^2). Similarly further decrease of COD was not observed after operating condition FD-15 as shown in Table 2 and Fig. 5. However, COD removal is less as compared to removal of BOD_5. It may be due to presence of slowly biodegradable organic compounds in the influent [27].

Fig. 6 reveals that TSS removal is 89% at the increment of disc area as 15%, flow rate of 20 L/h i.e. operating condition FD-8. This may be due to large surface area which encourages a bulky, continuous and stable biomass to develop on the discs [39] which help in removal of suspended solids from the wastewater through the sticky conditions on the disc. Further by increasing the disc area up to 30% the removal was reached up to 91% at the flow rate of 20 L/h as shown in Fig. 6, which is very little increase in removal of TSS as compared to 89% removal. However, the maximum removal of TSS up to 95% is observed at FD-12 i.e. at the flow rate of 17 L/h and disc area of 11.76m^2.

The results are compared with the literature. Almost similar results of TSS removal (from 84-95%) for different concentrations of greywater by RBC are reported by Abdel-Kader, [40]. In a separate study performed by Friedler, et. al. [41] two greywater treatment systems RBC and MBR were investigated. The results of BOD_5 and COD removal were relatively higher than the current study. The BOD_5 removal in both systems was more than 96% whereas COD removal was almost 70%. The reasons for enhanced removal efficiency may be due to different system design components. The RBC system reported by friedler, et. al. [41] is comprised (in comparison to single basin of present study) of two basins in series followed by a sedimentation basin.

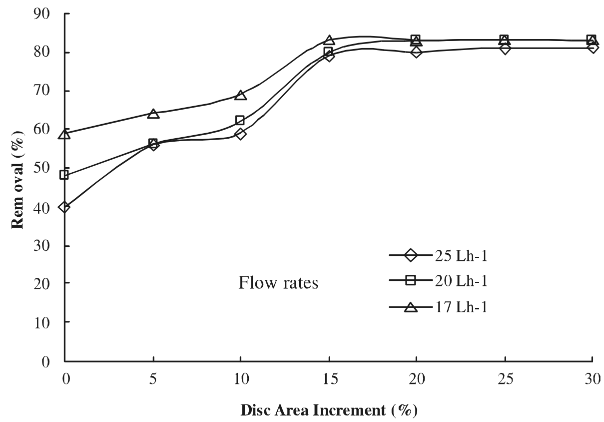

FIG. 4. REMOVAL PERCENT OF BOD_5 AT THREE FLOW RATES

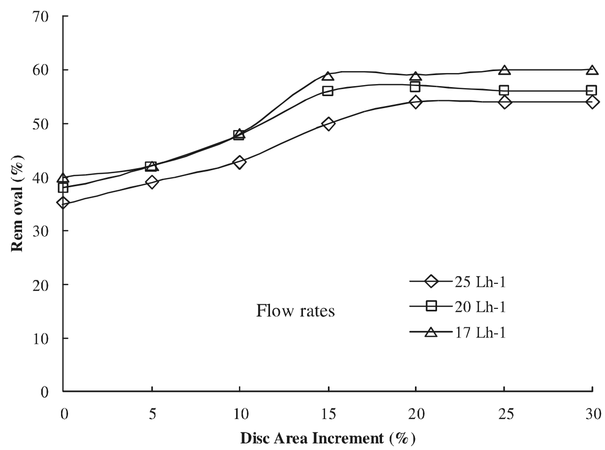

FIG. 5. REMOVAL PERCENT OF COD AT THREE FLOW RATES

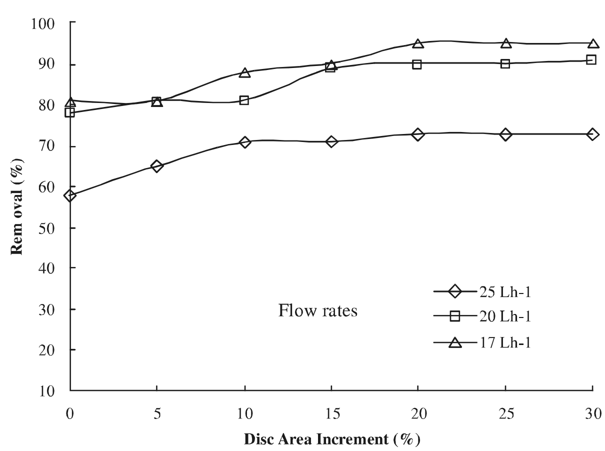

FIG.6. REMOVAL PERCENT OF TSS AT THREE FLOW RATES

As the discs are increased, the load on the shaft will also rise and resultantly more power will be consumed in the treatment process of RBC. The consumption of more power will not be cost effective option for long run. The maximum removal of TSS up to 95% is observed at FD-12 i.e. at the flow rate of 17 L/h and disc area of 11.76m^2. The flow rate is very low and ultimately treated water production will be less and process would not be cost effective. Therefore, considering the real facts and application of greywater, operating condition FD-11 is suitable, where disc area increment is 20% (11.76m^2) and flow rate is 20 L/h .

4. CONCLUSIONS

This study demonstrates the performance of RBC in treating greywater of low strength. Initially the simulator was operated at six flow rates, ranging from 100-17 L/h. The considerable removal efficiency in BOD_5, COD and TSS was observed in the last three flow rates of 25, 20 and 17 L/h. The removal percentages of BOD_5, COD and TSS were observed in the range of 31-59, 29-40 and 38-81% respectively. Later on the RBC system was operated at six disc area increments at aforementioned three flow rates (Flow Rate - Disc Area increment conditions i.e. FD-1 to FD-18). BOD_5 removal was observed in the range of 56-83%. The maximum removal of BOD_5 was observed at operating condition FD-11 (i.e. 20 L/h flow rate and 11.76m^2 disc area). The maximum removal of COD was observed as 60% at FD-15 (i.e. at disc area increment of 25% and flow rate of 17 L/h. COD removal is less as compared to BOD_5 which indicates presence of slowly biodegradable organic matters in the effluent. The TSS removal of 95% is observed at operating conditions: FD -12, FD -15 and FD -18.

After analyzing overall results, the maximum removal efficiency was obtained on high disc area increment (30%) or on the less flow rate (17lh^{-1}). The increase in disc area ultimately increases load on the shaft and therefore requires more power input. The consumption of more power will not be cost effective approach and also the low flow rate will produce relatively less effluent. These facts favors the optimum operating conditions of disc area increment of 20% (11.76m^2) and flow rate of 20 L/h to achieve the removal of BOD_5, COD and TSS at 83, 57 and 90% respectively.

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