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RBC or porous pots for textile wastes treatment

F.O. Otieno and J.S. Kilani

ABSTRACT

Textile industries in Kenya have mushroomed over the last few years with the result that there has been an increase in the amount of wastewater produced. This wastewater has previously not been adequately treated prior to discharge to receiving waters with the result that these streams are highly polluted.

Textile processing uses bleaches and dyes in large quantities and these create problems in the form of difficult effluents which are discharged from the works.

This paper reports the results of investigations on the treatment of high strength textile wastewaters by rotating biological contactors (RBC's) and Porous Pots. The effects of loading rate and disk media composition on organic removal rate were examined. The results show that comparatively, RBCs can treat high strength textile wastewaters better than porous pots. The resulting effluent organic content was adequate for discharge into either marine or freshwater receiving waters without fear of polluting these sources. Mean COD, BOD_5, TOC removals of 80%, 71% and 60% respectively for the RBC and 69%, 60% and 50% respectively for the Porous Pot using a hydraulic loading rate of 0.08 m^3/m^2 day. At higher loading rates up to 0.30 m^3/m^2.day, the organic removal efficiency was reduced.

INTRODUCTION

The processing of textiles uses bleaches and dyes in large quantities and these create problems in the form of difficult effluents which are dicharged from the works. This study compared the treatment of high strength textile wastewaters using Rotating biological contactors (RBC's) and Porous Pots.

RBCs consist of a series of closely spaced vertical discs mounted on a horizontal driven shaft which is supported by bearings and is slowly rotated by power driven equipment. The rotating shaft alternatively dips the disc surfaces into the waste material and then into the air. Waste material continuously flows parallel to the disc. The waste level is slightly less than half the disc diameter. Intimate contact between the waste material and disc surface is provided by contoured tank bottoms. Porous Pots consist of cylindrical vertical columns with porous membrane inside. Inside them is attached a diffuser with oxygen supply to keep the entire aerobic.

RBC's have several advantages namely the retention time is very short, they are relatively cheap, consume low power, are cheap to maintain and are dependable, and due to large captive biomass production in terms of hyrdaulic overload, the biomass is not washed out of the system.

DEVELOPMENT OF RBCs

The first recorded use of the rotating biological contactors was by Weigand (1900) in Germany. His model was made from wooden cylinders although it was never adopted for operational use. Further investigations of this process as filter substitutes were made by Imhoff (1926), Doman (1929) and Back (1934). However, the units suffered from clogging. Of these researchers, Doman discs that acted as a contact media performed with discouraging results.

Later on, Hartmann (1964) and Hartmann (1967) with the advent of expanded polystyrene as a support medium undertook experiments using rotating units with a plastic disc. The Imhoff rotating disc package was further redeveloped in England by Simpson (1971), the product being marketed in 1972 with the trade name "Bio-disc." Welch (1968) experimented on RBC systems utilizing synthetic sewage waste. The system consisted of two RBC stages with immediate and final setting. The synthetic sewage concentration had a COD and hydraulic loading of between 500 - 4000 mg/l and 1.6kg/m^3d - 32kg/m^3d respectively. The resulting effluent from the first stage setting tank was followed by gravity to a second RBC unit which was identical to first stage to allow for comparison of staging and determination of the effects of any organism or bi-product created by the first unit that may have seriously affected the second stage unit. The reduction in COD was found to be in the range 60-80% for both stages depending on the organic loading rate.

Pescod and Nair (1972) investigated retention time on RBC treating a substrate of diluted nightsoil supernatant. They concluded that retention time had little effect on COD removal. However, such a result could have been due to the low organic loading rate of $8g/m^2d$ which was used. The performance of an RBC in the treatment of domestic wastewater in the U.S.A. was reported by Antonie et al(1974). His results demonstrated that the RBC was capable of achieving high degree of BOD and suspended solids removal. It was also reported to have exhibited stable operation under fluctuating hydraulic and organic loading.

The effect of ambient temperature on RBC efficiency as a biological ecosystem was investigated by Presner et al (1976). They observed that slime developed more and grew thicker on heated discs than on unheated ones. There was greater accumulation of sludge on the unheated discs after about 7 days. They reported a maximum COD removal at the optimal metabolic rate of 30°C and fell with further temperature increases. In the thermophilic range, the best removal was achieved at temperature of 55°C. This work was carried out using synthetic waste of COD 200mg/l and they achieved a low removal of 64% at a high organic loading rate.

More recently, secondary biological treatment by RBC's was evaluated, Patrick and Lehman (1983). It was reported that the maximum slime growth developed at an optimum peripheral velocity of 0.27 to 1.5m/s with hydraulic loading of $0.09/m^3/m^2d$ and a final effluent of 25 mg/l BOD and 300mg/l ss giving a total removal efficiency of 88% and 87%.

Development of the RBC in the Treatment of Industrial and High Strength Wastes.

Industrial wastes are not consistent and vary considerably both in strength and biodegradability. Therefore, while most domestic wastes have a BOD_5 below 450mg/l, that of industrial wastewaters may range from 50-100,000 mg/l and even more. Researchers have therefore concluded that aerobic treatment is more advisable in the treatment of industrial wastes at the RBC stage.

Pescod and Norton (1983) investigated the treatment of a strong organic wastewater (COD 4000-5000 mg/l) with a combination of anaerobic and aerobic packed cage RBC. They report that the optimum efficiency under aerobic conditions occurred at a loading rate of 50kg BOD_5 m^2-d. They further reported that anaerobic RBC systems also proved to be resistant to severe shock loading, an aspect which is important in the treatment of highly variable strength wastewaters. The investigation also revealed that a series of aerobic and anaerobic or combined together would provide the most economic design for RBCs in the treatment of industrial wastewaters.

Kanji et al (1986) investigated the oxidation of ferrous iron (Fe^{2+}) by acidophilic iron-oxidizing bacteria using a laboratory scale RBC. The iron Fe^{2+} concentration was adjusted to 500 mg/l with low pH (1-3) and temperature(10-40°C). They achieved a good effluent with low iron concentrations and removal efficiency of 50-75%.

The RBC have demonstrated the potential of achieving high degree removal for BOD, COD and suspended solids as per the literature. It has exhibited stable operation under fluctuating hydraulic and organic loading conditions and variation in temperature. The high density sludge solids generated by the processes indicate significant potential, saving in overall treatment plant construction and operating costs. These factors along with low power consumption and low maintenance costs make the RBC an attractive option for application to a variety of wastewaters.

The design and operational parameters were investigated by several researchers as a result of finding means of increasing active biomass maintenance in the reactor through attachment to solid surfaces.

Organic and hydraulic loading parameters have been used as influencing parameters in the performance of RBCs, with most literature pointing close correlation in carbonaceous substrate removal as a factor of assessing the performance of RBCs. Other parameters reported are retention time, rotational speed, submergence and pH.

Pescod and Nair (1972) investigated the performance of RBC based on retention time and reduced it to as low as 2.5 hrs without adversely affecting the treatment efficiency. Infact, Welch (1968) suggested that if the disc slime was dispersed in the tank liquor, the mixed liquor volatile suspended solids (MLSS) would be about 17000 mg/l. Pretorius (1971 considered the active slime and estimated it to be 37,000 mg/ . From these results, it is evident that microbial biomass inside RBC reduces the application of retention time as an important factor in the design process of RBCs.

The relationship between disc speed and oxygen transfer coefficient has also been investigated. As would be expected, Bitanja (1975) indicated that an increase of disc rotational speed increased the oxygen transfer to the bulk liquid, with an optimal rotational speed of 3-4 revolutions per minute.

The other parameter which increases removal efficiency in the design of RBCs is staging. Proper staging to simulate flug flow operation which allows a succession of morphological and biochemically specialised stages according to changes in the substrate quality is desired.

Depths of immersion have also got a bearing on the efficiency of RBCs. Optimal values range from one to two thirds the diameter with most systems having 40-50% areal immersion. Lumbers (1980) indicated that 57% depth of immersion achieved optimum performance. He also studied the relationship between depth of immersion to rotational speed.

EXPERIMENTAL WORK

The scope of this work was to investigate the possibility of treating high strength textile wastes using RBCs and Porous pots and to compare the efficiencies of the two systems. Simple modes of RBC and Porous pots were set up in the laboratory. The RBC had a single compartment with an inlet and outlet at opposite ends and parallel plastic bio-rings. The cages were driven by two infinitely single speed electric motors and the waste was fed by means of peristaltic pumps. Actual textile waste initially diluted to suitable concentrations for acclimatization purposes was used as feed.

The RBCs and Porous pots runs were based on weekly periods at each loading in order to allow the reactors time to reach a steady state as observed during the acclimatization period. Among the dependent variables which were measured in the series runs were COD, BOD_5 and TOC at constant depth of immersion of 40% rotational speed of 2 rpm, and temperature 20-24°C. The average retention time was 4 hrs for all the loadings as applied. The results were noted when a quasi-steady state had been reached which was considered to have been reached when not more than 5% variability occurred on three consecutive samples of COD.

RESULTS, DISCUSSIONS AND CONCLUSIONS

Table 1 gives the characteristics of the textile waste as used in this study. Textile processing uses bleaches and dyes in large quantities and these create problems in the form of difficult effluents which are discharged from the factories.

Table 1: Characteristics of the Textile Wastewater.

pH	7.5 - 9.00
Alkalinity	600 - 1200 mg/l
COD	800 - 10,000 mg/l
BOD_5	200 - 8,000 mg/l
IVA	200 - 600 mg/l
TOC	240 - 9,000 mg/l
NH_3-N	9.0 - 60 mg/l
Organic-N	10.0 - 80 mg/l
TKN	19 - 140 mg/l
PO_4-P	1.0 - 10 mg/l
SS	50 - 1000 mg/l
TS	1700 - 10,000 mg/l
Colour	

Table 2 gives the COD, BOD_5 and TOC removal efficiencies at different OLRs and as observed during the present study for both RBC and the porous pots. Clearly, at higher OLR (due to precipitation by the calcium magnesium ions) and higher retention times, the removal efficiency for COD, BOD_5 and TOC is far much better for the RBC compared to that for the Porous pot. This was expected given the many advantages RBCs have over porous pots. Furthermore, porous pots presented numerous problems especially clogging of the filter and non growth of satisfactory film. COD removal efficiencies ranged from 70% to 95% for RBC and from 60-80% for porous pots.

The BOD_5 removal efficiency also followed a similar pattern but with a much lower removal at identical loadings to COD. BOD_5 had its best removal efficiency at a slightly lower loading rate. The results presented in this study clearly lend credence to further work to assist in solving numerous problems currently facing most textile industries in Kenya.

Table 2: Performance of RBC's and Porous Pots in the Treatment of Textile Wastewater.

RUN	INFLUENT QUALITY			HRT
NO.	COD	BOD$_5$	TOC	Hrs
1	200	100	120	3.0
2	600	320	420	4.0
3	800	480	620	4.5
4	1000	500	680	5.0
5	1200	580	900	5.5
6	1800	690	930	6.0
7	3000	1500	18.0	6.5
8	6000	3800	3600	7.0

EFFLUENT QUALITY mg/1			REMOVAL EFFICIENCY %		
COD	BOD$_5$	TOC	COD	BOD$_5$	TOC
60	40	58	70	60	52
(78)	(45)	(65)	(61.0)	(55)	(46)
174	112	189	71.0	65	55
(234)	(141)	(223)	(61.0)	(56)	(47)
224	168	279	72.0	65	55
(304)	(202)	(335)	(62.0)	(58)	(46)
240	150	286	76.0	70	58
(340)	(205)	(360)	(66.0)	(59)	(47)
240	157	351	80.0	73	61
(336)	(238)	(459)	(72.0)	(59)	(49)
306	145	363	83.0	79	61
(486)	(255)	(446)	(73.0)	(63)	(52)
300	330	540	90.0	78	70
(720)	(525)	(810)	(76.0)	(65)	(55)
300	760	1044	95.0	80	71
(1200)	(1292)	(1584)	(80.0)	(66)	(56)

Figures in brackets refer to Porous pots.

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