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Treatability study on seafood processing industrial wastewater using anaerobic contact filter and rotating biological contactor

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Abstract

There are around 50 seafood processing industries located in Tamilnadu and 10 industries near Chennai. All these industries are located near the seacoast and thereby discharging their effluents into the sea and thus polluting the coastal zone and sea. Apart from the major chemical and petro-chemical industries, these seafood processing units are the main sources of coastal and sea pollution. The difficulty in managing the problem in this industrial sector may be attributed to number of reasons.

Hence a simple and low-cost effluent treatment system which can be operated and maintained even by semi-skilled manpower seems to be a viable solution for this industrial sector in their environmental management. Hence it was proposed to study the treatability of seafood processing industrial wastewater using anaerobic contact filter and rotating biological contactor which can satisfy the needs. A laboratory scale effluent treatment system was fabricated and a detailed study of the biofilm in the RBC was made and reported.

INTRODUCTION

Treatment of industrial wastes to prevent environmental pollution and suitable alternatives to combat present day energy crisis are the important areas of discussions all over the world today. Traditionally the industry, in India as well as in other developing countries, has adhered to minimum cost of production philosophy overlooking social responsibility to environment. The industry naturally questions investment in effluent treatment and considers it as a non-productive activity. Hence there exists a need for identification and implementation of low cost effluent treatment schemes for better environmental management.

The environmental management for industrial sector is different not only among the large, medium and small-scale industries, but also different types of industries and production processes. In Tamilnadu, by the way of Common Effluent Treatment Plants, the pollution problems from cluster of tanneries and textile dyeing industries are being dealt with. But a different strategy is to be evolved for environmental management in seafood processing industries that are scattered over the seacoast and having the advantage of discharging their effluent into the sea unlike most other types of industries.

There are around 50 seafood processing industries located in Tamilnadu and 10 industries near Chennai. All these industries are located near the seacoast and thereby discharging their effluents into the sea and thus polluting the coastal zone and sea. Apart from the major chemical and petrochemical industries, these seafood processing industries are the main sources of coastal and sea pollution. The difficulty in managing the problem in this industrial sector may be attributed to the following reasons.

1. Mostly being small-scale industries, not willing to provide a high cost effluent treatment systems.
2. Lack of knowledge of low cost effluent treatment systems.
3. Non availability of adequate space to provide effluent treatment systems.

Hence a very simple and low cost effluent treatment system which can be operated and maintained even by less qualified people seems to be a viable solution for this industrial sector in their environmental management.

In shrimp processing, the shrimps after catchments are subjected to pre-processing of peeling where shell and head are peeled off. The stuff obtained after peeling off the head and shell portions are called as 'head less shell on'. After the head and shell portions are removed completely, the meat is washed with 10 PPM chlorinated ice water at a temperature $4^{o}C$ to $5^{o}C$ to minimise the microorganisms and pathogenic bacteria present in the meat. Then the washed meat is weighed and graded according to its size and colour. After grading, the meat is again washed with 5 PPM chlorinated water. Then glazing is done with 2-3 PPM chlorinated ice water at a temperature $0.5^{o}C$ to $2^{0}C$. Then the processed meat is freezed at a temperature $-40^{o}C$ for 90 minutes and stored in cold storage at a temperature $-18^{o}C$. After this, quality control inspection is done through organoleptic and bacteriological examinations. Then the processed shrimps are transported for shipment through precooled insulated container.

The quantity of water consumed for the shrimp processing is 10 m^3 per ton of the product. The quantity of the wastewater generated is 10 m^3 per ton of the shrimps processed. The water use areas are: washing of fishes with chlorinated water, ice making, cleaning of process equipment and wastewater from House keeping.

The characteristics of the effluent imply a higher B.O.D to C.O.D. ratio and hence for the treatment of the wastewater, biological treatment was preferred. Since an aerobic treatment system can not take as much organic load as present in the wastewater from the seafood processing industry, an anaerobic treatment system was preferred to reduce the organic loading to an extent, which is suitable for the subsequent aerobic polishing treatment. Hence an effluent treatment system consists of an anaerobic contact filter followed by a rotating biological contactor was preferred for this study.

This anaerobic treatment represents the controlled applications of the process, which occurs under natural conditions when organic matter decays anaerobically, brought by mixed cultures of certain facultative and anaerobic bacteria.

Rotating biological contactor consists of a series of flat or corrugated discs of 2-3 m in diameter mounted on a horizontal shaft and driven mechanically so that the discs rotate at right angles to the flow of settled wastewater. As the discs rotate, an aerobic biological film builds up on the discs in the same way as it develops with the film medium in a percolating filter. Thus degradation occurs with the film alternatively adsorbing organic nutrients from the wastewater and then obtaining oxygen from the atmosphere for oxidation.

EXPERIMENTAL SET-UP

A Laboratory scale effluent treatment system consisting of an anaerobic contact filter and a rotating biological contactor was fabricated. The anaerobic contact filter was made-up of PVC pipe, 0.15 m diameter and 1.49 m height with Plastic globules of size 20 mm diameter as filter media. These plastic globules were specially ordered and procured from a plastic parts manufacturing industry at Madurai, Tamil Nadu. The filter was operated in the down flow mode. Coarse stones of size 20mm were filled as a supporting media to a height of 15 cm, on which the plastic globules were filled for a height of 94 cm. To avoid any floatation of the plastic balls, granite stones for a height of 10 cm were filled over the plastic media. A liquid column of 15 cm above the packed media was kept for the separation of liquid and gas phases and for providing suspended growth zone. Design parameters of the anaerobic contact filter are given in Table 1.

Table 1. Design parameters of the anaerobic contract filter.

Sl. No.	Description	Values
1.	Internal Diameter of the Filter	0.15m
2.	Height of the Filter	1.49m
3.	Particle size of the Filter Medium	2mm
4.	Filter Bed Height	0.94m
5.	Volume of the Filter Bed	$0.0263m^3$
6.	Volume of the Media	$0.0210m^3$
7.	Porosity	0.44

The biodiscs of the RBC were made up of asbestos. The total numbers of discs were 14, with a diameter of 0.28 m each. The spacing between each disc was 0.042 m. The RBC was made-up of M.S. with a rectangular cross section of capacity to hold an effluent volume of 0.067 m3. Provisions were made for the inlet and outlet of the wastewater. The discs were placed with a submergence of 40% in the wastewater. The total surface area of the discs was 1.724 m2. The dimensions of the RBC are given in Table 2.

Table 2. Design parameters of the rotating biological contactor.

Sl. No.	Description	Values
1.	Number of discs	14
2.	Diameter of the disc	0.28m
3.	Spacing between the discs	0.02m
4.	% submergence of the discs	40
5.	Surface area of the discs	$1.742m^2$
6.	Rotational speeds	5,9 and 14.

The treatment units were arranged in such a way that the wastewater first passes through the anaerobic contact filter and the effluent passes through the rotating biological contactor. This set-up was made to give an anaerobic treatment to the seafood processing wastewater followed by the aerobic polishing treatment to bring down the parameter to disposal standards.

In order to develop the required Biomass over the media of the treatment units, cowdung slurry was initially fed into the ACF and RBC separately. Cowdung was collected and slurry was prepared using water. The filtered cowdung slurry was fed into the units along with additional nutrients such as glucose and peptone. Urea was also added as and when required as the source of nitrogen to the microorganisms. The feeding slurry was continued for about 15 days till a sufficient amount of biomass was developed on the media.

The wastewater collected from a seafood processing industry was then introduced along with the cowdung slurry and nutrients into the treatment units. The portion of the wastewater is slowly increased and after 10 days, 100% wastewater was fed into the system, to attain the stabilisation of the units.

EXPERIMENTAL RUNS

It was decided to have three rotational speeds 5,9 and 14 rpm. As per literature, it was recommended to have a loading rate of as low as 0.837 kg COD/m3 day for treating wastewater from food processing industry for an anaerobic contact filter when an aerobic treatment is followed. In this study, the organic loading rate was assumed as 1 kg/COD/m3 day for the anaerobic contact filter that corresponds to the hydraulic flow rare of 0.014 m3/day. Hence, it was decided to have three hydraulic flow rates 0.010 m3/day, 0.015 m3/day and 0.020 m3/day for the anaerobic contact filter that corresponds to the organic loading rates of 0.7 kg COD/m3/day, 1.04 kg COD/m3/day, and 1.39 kg COD/m3/day respectively. The organic loading rates for the RBC depended upon the percentage of organic load removed in the ACF.

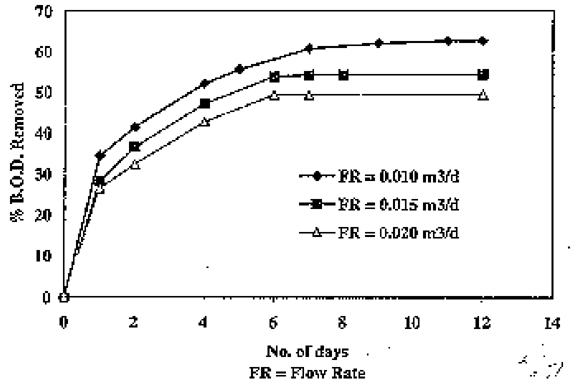
The first run of the study was conducted with hydraulic flow rate of 0.010 m3/day to anaerobic contact filter followed by the rotating biological contactor at 9 rpm. The treated wastewater was analysed for the parameters pH, Total dissolved solids, BOD and COD regularly until the system reached the steady state condition, reaching the asymptotic values.

The second run was with the hydraulic flow rate of 0.015 m3/day for the system with the same rotational speed of 9 rpm for the RBC. The parameter pH, Total dissolved solids, BOD and COD were analysed regularly. The Dissolved Oxygen in the RBC was also analysed then and there. After the steady state condition was reached, the third run was started with the hydraulic flow rate of 0.020 m3/day with the same rotational speed of 9 rpm for RBC.

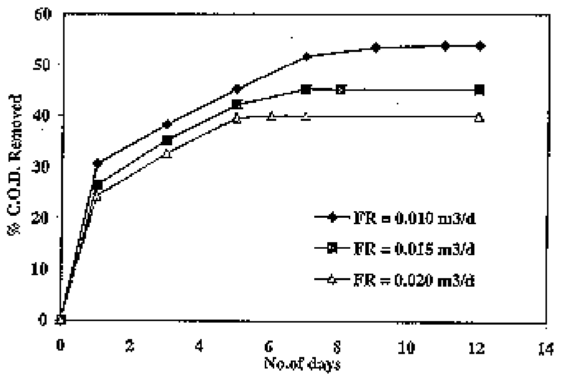
Then, the rotational speed of the RBC was changed to 5 rpm and then to 14 rpm and the procedure was repeated for the hydraulic flow rates of 0.010 m3/day, 0.015 m3/day and 0.020 m3/day for each rotational speed. The pH and Dissolved Oxygen level in the reactor were checked periodically for every run to note any change in the reactor due to the microbial activities. Sufficient numbers of days were allowed in between the runs when the experimental parameters were changed for attaining the flow equalisation.

The biofilm formed on the surface of the biodisc were scraped carefully for microbial examination. Simple smearing was done and observed under the microscope with low power objective for identifying the presence of higher species like protozoa, algae etc. Then the sample was observed under high power objective for identifying the presence of bacterias etc. and reported.

The samples of wastewater collected from the seafood processing industry were suitably diluted and filled in a series of BOD bottles and the same were incubated at 27°c along with blanks. BOD exerted on the 1st, 2nd, 3rd, 4th, 5th, 6th, and 7th days were determined. Using the above BOD data above, the deoxygenation constant (k1) and the ultimate BOD of the wastewater from the seafood processing industry were determined using Thomas slope method.



B.O.D. Removal Efficiencies by A.C.F.



C.O.D. Removal Efficiencies by A.C.F.

Figure 1. Performance of the anaerobic contact filter on the removal of organics.

RESULTS AND DISCUSSION

The results obtained from the various experiments are discussed as follows. For a hydraulic flow rate of 0.010 m3/day for the system and a rotational speed of 9 RPM for the RBC, a steady state was reached on the 12th day. At the outlet of the ACF, the maximum BOD removal percentage was 62.50 and that of COD was 53.91. At the final outlet of the RBC, the maximum BOD removal percentage was 97.75 and that of COD was 86.96. The pH was in the range of 6.84 - 7.22. For the hydraulic flow rate of 0.015 m3/day for the system and the same rotational speed of 9 RPM for the RBC, a steady state was reached on the 8th day. At the outlet of the ACF, the maximum BOD removal percentage was 54.13 and that of COD was 45.22. At the final outlet of the RBC, the maximum BOD removal percentage was 87.88 and that of COD was 79.13. The pH was in the range of 7.14 - 7.31. For the hydraulic flow rate of 0.020 m3/day for the system and the same rotational speed of 9 RPM for the RBC, a steady state was reached on the 7th day. At the outlet of the ACF, the maximum BOD removal percentage was 49.25 and that of COD was 40.00. At the final outlet of the RBC, the maximum BOD removal percentage was 79.50 and that of COD was 70.43. The pH was in the range of 7.25 - 7.34.

For the hydraulic flow rate of 0.010 m3/day for the system and a rotational speed of 5 RPM for the RBC, a steady state was reached on the 9th day. At the final outlet of the RBC, the maximum BOD removal percentage was 87.75 and that of COD was 79.13. For the hydraulic flow rate of 0.015 m3/day for the system and the same rotational speed of 5 RPM for the RBC, a steady state was reached on the 7th day. At the final outlet of the RBC, the maximum BOD removal percentage was 77.75 and that of COD was 70.26. For the hydraulic flow rate of 0.020 m3/day for the system and the same rotational speed of 5 RPM for the RBC, a steady state was reached on the 7th day. At the final outlet of the RBC, the maximum BOD removal percentage was 74.50 and that of COD was 67.30.

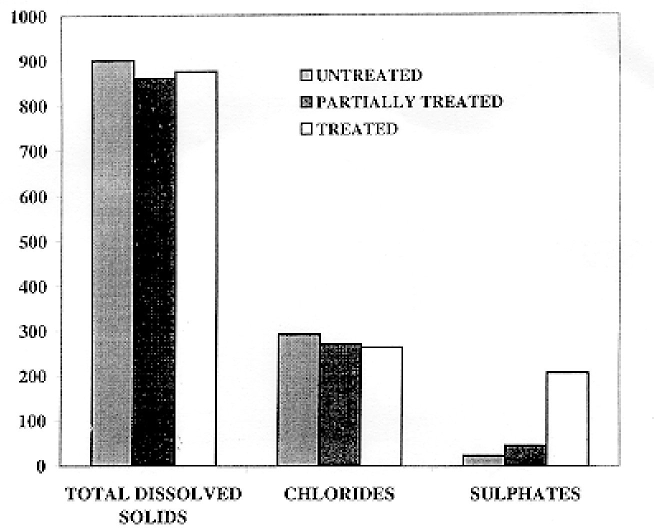


Figure 2. Concentrations of parameters at different levels of treatment.

When the rotational speed of the RBC was increased to 14 RPM, for the hydraulic flow rate of 0.010 m3/day into the system, the steady state was achieved on the 6th day. At the final outlet of the system, the maximum percentage of BOD removal was found to be 98.75 and that of COD was 90.43. With the same rotational speed of 14 RPM for the RBC, for the hydraulic flow rate of 0.015 m3/day into the system, the steady state was achieved on the 4th day. At the final outlet of the system, the maximum percentage of BOD removal was found to be 91.00 and that of COD was 83.48. With the same rotational speed of 14 RPM for the RBC, for the hydraulic flow rate of 0.020 m3/day into the system, the steady state was achieved on the 4th day. At the final outlet of the system, the maximum percentage of BOD removal was found to be 89.00 and that of COD was 80.00.

The dissolved oxygen level in the RBC reactor was found to be in the range of 3.7 - 4.5 mg/l during the experiments. The performance of the anaerobic contact filter on the removal of organics is shown in fig. 1. The concentrations of the other parameters such as total dissolved solids, chlorides and sulphates at different levels of treatment are shown in the fig.2. The effect of the hydraulic flow rates on BOD removal of the system is shown in fig. 3 and that of COD is shown in the fig. 4. The effect of the rotational speed of the RBC on the BOD removal of the system is shown in the fig. 5 and that of COD is shown in the fig. 6.

During the microscopic examination of the bio film scraped from the discs of the RBC, mixed population of eukaryotic zooplankton like parameceum and bacteria belonging to actinomycetes in more numbers were observed. There were no algae, filamentous protozoa, yeast observed in the biofilm. Bacteria like diplococci, coccibacilli and few filamentous bacterias were seen. No mycelial or filamentous fungi were present. No clostridium and endosporeforming rods were present.

The BOD data was obtained for the seafood processing industrial wastewater from the first day to the seventh day. Thomas slope method was followed to determine the deoxygenation constant and the ultimate first stage BOD and the same were estimated as 0.22 / day and 1020 mg/l respectively. A typical seafood processing industry, processing one T/day of shrimps, generates about 10 m^3/day of wastewater with a BOD of 800 mg/l was considered for this study. Considering the results obtained corresponding to the hydraulic flow rate of 0.010 m^3/day and 14 RPM, where about 89 % of BOD and 80 % of COD removal were achieved and thereby bringing down the effluent BOD of 800 mg/l and COD of 230 mg/l which are well within the tolerance limits prescribed for the sea disposal of industrial effluent.

With the corresponding hydraulic loading rates and organic loading rates, the design dimensions of the ACF and RBC were arrived at. The required volume of the media for ACF works out to be 8.3 m^3. Hence a filter of 2.3 m diameter and 3m height including 0.5 m water stagnation and a 0.5 m free space in the ACF. The effective volume of the ACF will be 10.38 m^3 (2.3 m diameter and 2.5 m height) and the detention time of the ACF will be 25 hours.

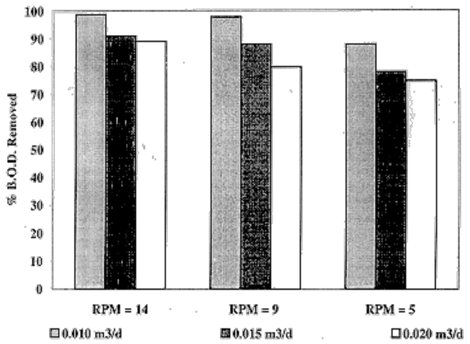


Figure 3. Effect of flow rate on B.O.D. removed in the system.

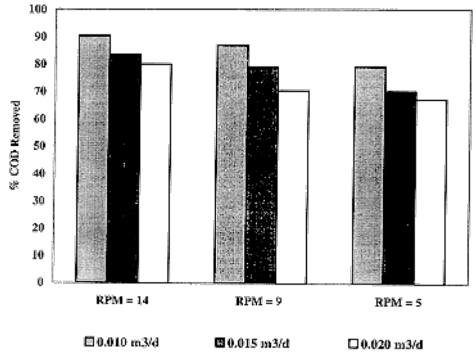


Figure 4. Effect of flow rate on C.O.D. removed in the system.

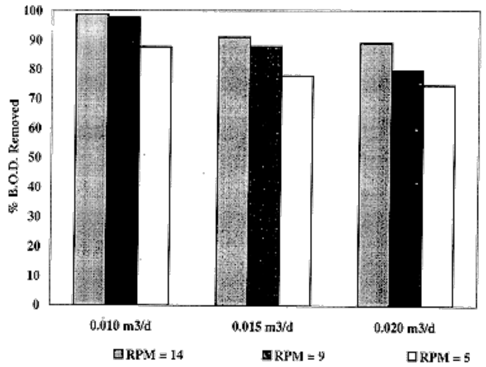


Figure 5. Effect of RPM on B.O.D. removed in the system.

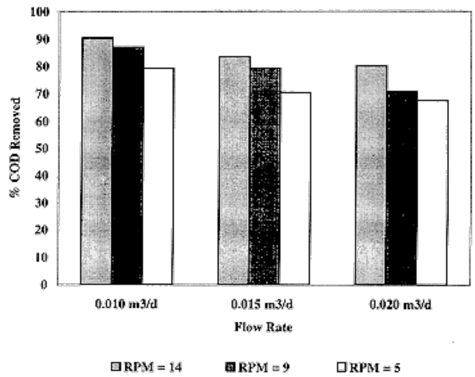


Figure 6. Effect of RPM on C.O.D. removed in the system.

Similarly for the RBC, the required area of the discs works out to be 909 m^2 and assuming the discs of diameter of 3 m, the number of discs required is 65. Provisions of 5 cm center to center spacing between discs, the dimension of the RBC are as follows. Length, 3.8 m with a clearance of 30 cm in each end; width, 3.40 m with a clearance of 20 cm on both sides and depth, 1.40 m at 40 % submergence. A free board of 30 cm and a sludge depth of 30 cm may be added to the depth. The effective volume of the reactor will be 18 m^3. (3.8 m x 3.4 m x 1.4 m) and hence the detention time will be 1.8 days. A round bottom reactor will reduce the detention time further.

However a pilot plant study may be conducted to confirm this applicability.

CONCLUSIONS

The conclusions of this study may be listed as follows.

The wastewater from the seafood processing industry was found to be highly biodegradable having the BOD to COD ratio of 0.7. The anaerobic treatment through the anaerobic contact filter followed by the aerobic polishing treatment by rotating biological contactor was found to be suitable to treat the seafood processing industrial wastewater to bring down the organic load to the tolerance limits.

A very compact and economical effluent treatment system consists of an anaerobic contact filter and a rotating biological contactor can be designed for a seafood processing industry.

For the rotational speed of 14 RPM, BOD of the final effluent could be brought down to less than 100 mg/l, which is the standard prescribed for marine disposal. At this RPM, these standards could be achieved hydraulic flow rates up to 0.020 m3/d. For the rotational speed of 9 RPM, effluent BOD standards were achieved for the flow rates up to 0.015 m3/d. Similarly for the rotational speed of 5RPM, the BOD standards could be achieved only for the flow rate 0.010 m3/d. Hence with these combinations of results, the suitability of implementing the treatment scheme to the industries can be achieved appropriately.

It was noted that an increase in the hydraulic flow rate decreased the organic removal efficiency of the system. Also an increase in the rotational speed of the RBC increased the organic removal of the system.

Anaerobic contact filters are cost effective, requiring lower running cost and maintenance cost.

The synthetic plastic media packed in the anaerobic contact filter are cost effective and do not need replacement for a larger period.

The dissolved oxygen level, temperature, pH values in the RBC reactor were found to be suitable for the normal aerobic microbial activities. The slightly alkaline pH in the reactor indicates a complete aerobic degradation of the organic and hence no pH corrections were necessary.

Uninterrupted power supply is a must for these biological units since a power failure for a sufficient period of time will affect the life of the microorganisms.

There are scopes of further work like a comparative study on the effect of different packing media such as plastic globules, granite stones etc. on the organic removal efficiencies by the anaerobic contact filter. Further some modifications in the rotating biological contactor such as increasing the specific surface area of the bio discs and thereby decreasing the size of the reactor, may also be studied.