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Chapter 2

Evaluation of Anaerobic Biological Treatment for Wastewater of Ion Exchange (IX) Resin Manufacturing Facility

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ABSTRACT

Ion Exchange (IX) Resin manufacturing unit utilizes considerable amount of water during the course of resin production. The effluent produced is rich in organics and inorganic solids to the tune of 8000-10000 mg/L and 15000-20000 mg/L respectively. The industry under study was having full- fledged effluent treatment plant but was undergoing huge financial loss due to the new norms set by pollution control board. Intensive treatability study was performed to find out the possibility of using anaerobic biological treatment which has not been applied for such type of effluents so far. The study implied that 47-50 per cent COD reduction was possible with anaerobic biological treatment alone and 90-95 per cent COD reduction by anaerobic followed by aerobic biological treatment. A final process design as well as economic study based on the laboratory findings has been carried out.

Keywords: *Resin, Wastewater, COD, BOD, UASBR.*

Introduction

Ion exchange resins consist of a polymeric matrix and a functional group with a mobile ion which can be exchanged with other ions present in the solution to be treated. The most common synthetic structures are – cross liked polystyrene, cross liked polymethacrylate, phenoil-formaldehyde etc. The manufacture of ion exchange resins involve the preparation of a cross liked copolymer followed by sulfonation in the case of strong acid cation resins, or chloromethylation and the amination of the copolymer for anion resins (Dow, 2000). The production process involves use of variety of chemicals like styrene, divenyl benzene, ethylene glycol dimethacrylate, isobutyl alcohol, formaldehyde, methanol, ethylene dichloride, trimethyl amine, dimethyl amine, methacrylates, polyvinyl alcohol, oleum, etc. The unused solvents and chemicals make the effluent from the manufacturing process high in organics, total dissolved solids, and low in pH. Presence of variety of chemicals in the wastewater makes the treatment challenging and requires a cost effective as well as robust process.

Anaerobic digestion is used for treating the high strength organic wastewater. Since the late seventies, anaerobic digestion has experienced an outstanding growth in research and full scale application, particularly for the treatment of food and beverage industry effluent and to a lesser extent for municipal wastewater (Hulshoff Pol *et al.,* 1998; Yu *et al.,* 2004; Fountoulakis *et al.,* 2004; Filik Iscen *et al.,* 2007). Anaerobic digestion is a complex, natural, multi stage process. During the process, organic compounds are degraded through a variety of intermediates into methane and carbon dioxide, by the activity of a consortium of micro organisms. Interdependence of the bacteria is a key factor in the anaerobic digestion process (Parawira *et al.,* 2005). The upflow anaerobic sludge blanket process is one of the most commonly used wastewater treatment system, with several installations treating industrial wastewater (Techobanoglous *et al.,* 2004). The upflow anaerobic sludge blanket reactor (UASBR) is a reactor of upflow where the organic material on its way through the covering of sludge composed of a large population of anaerobic bacteria begins its biodegradation. The reactor is composed of three essential parts: a zone of digestion, a zone of sedimentation, and a separator of gas - solids-liquids. These are integrated into one column where the primary sedimentation process, the bio-digestion of the sludge and the secondary sedimentation is done simultaneously as a primary and secondary treatment of residual waters achieving efficiency in the removal of organic material up to 85 per cent (Sponza, 2001). Anaerobic digestion treatment is one of the technologies being considered to provide a solution to the treatment high strength organic wastewater and maximum amount of biodegradable fraction can be converted into useful energy end product in the form of biogas and fertilizer in the form of digestate (Fernandez *et al.,* 2001; Saravanan *et al.,* 2004; Song *et al.,* 2004).

The objective of the work was to study the anaerobic treatability and possibility of utilizing UASBR in order to optimize the operational cost, reduce green house gas emissions and convert waste into useful end products.

Materials and Methods

Pilot Scale Digester

The UASB reactor was constructed from MS-FRP sheet with 2 m Length, 1 m width, and 4 m height. The working volume of the reactor was 7 m^3 (Figure 2.1).

Sampling ports were provided for collection of samples. A centrifugal pump (Grundfos, Chiu) of capacity 5 m^3/hr was used for feeding wastewater into the reactor. A buffer tank constructed of HDPE with 500 L capacity was utilized as buffer tank.

Seed and Inoculation

The reactor was initially seeded with inoculum from an anaerobically digested sludge of a sewage treatment plant. On subsequent days, Jaggery solution along with urea and DAP was added to obtain the desired mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) in the reactor. After achieving 4 per cent MLSS and 0.75 MLVSS/MLSS ratio, effluent injection at the rate of 0.5 m^3/d started for acclimatization of the micro-organisms. The acclimation period in this study was 60 days.

Sampling and Analysis

The functioning of the reactor was monitored over a period of four months. The samples at feed, in the reactor, and treated effluent were taken on regular basis to monitor the performance of the reactor.

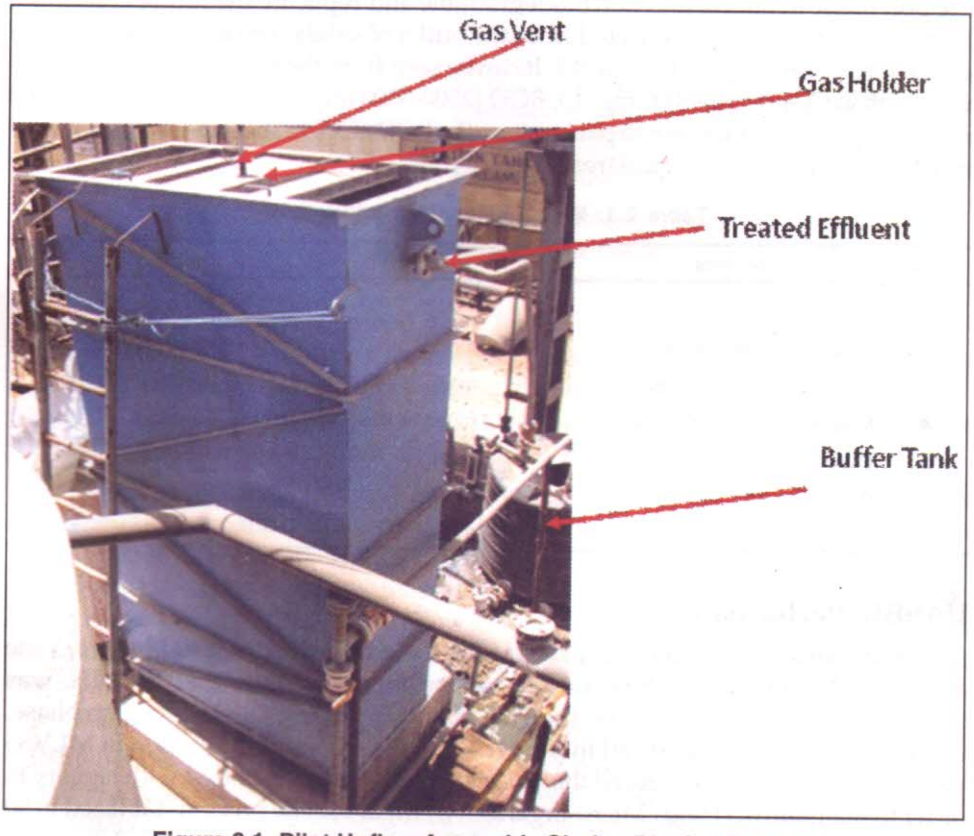

Figure 2.1: Pilot Upflow Anaerobic Sludge Blanket Reactor

Chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), MLSS, and MLVSS were regularly performed for the untreated and treated effluent as well as sludge according to the standard methods (APHA, 1996).

Operating Conditions

The reactor was operated in fill, react, and withdrawal during initial period of operation. After stabilization of the process, the reactor was operated in continuous mode for a period of three months.

Results and Discussion

Characterization of Wastewater

The pilot plant was installed in the Ion exchange resin manufacturing facility located in Ankleshwar, Gujarat to understand the actual operational conditions and the associated difficulties. The manufacturing facility was already having a state of the art effluent treatment facility consisting of collection tank, solids contact clarifier, aerobic reactor based on membranes technology and hence, it was decided to install the pilot plant after clarifier (Figure 2.2) in order to get rid of suspended solids which are polymeric in nature and non biodegradable and replicate the future condition. Hence the samples were collected from the outlet of solids contact clarifier and the characterization is given in Table 2.1. It can be seen from the table that the effluent is very high in COD (7000-8000 mg/L), BOD (2500-3500 mg/L), and TDS (15000-25000 mg/L). Apart from these harsh parameters, the BOD/COD ratio (0.3-0.35) is not very much favourable for biological treatment.

Table 2.1: Wastewater Characteristics

Sl.No.	Parameters	Unit	Inlet
1.	pH	–	7.0-9.0
2.	Total dissolved solids	mg/L	15000–25000
3.	Total suspended solids	mg/L	100-200
4.	Volatile suspended solids	mg/L	50-150
5.	COD	mg/L	7000-8000
6.	BOD	mg/L	2500-3500
7.	Oil and grease	mg/L	< 30

UASBR Performance

Acclimatization of micro organisms for the wastewater was judged from the analysis of MLSS and MLVSS in the reactor and the organic loading rate (OLR) was increased or decreased based on the MLVSS in the reactor. During start up phase, ups and downs were observed in the MLVSS value. If sharp reduction in MLVSS value (25 per cent) was observed than wastewater feed was replaced with Jaggery in order to maintain 0.5 Food/Micro-organism (f/m) ratio. The process stabilized in 60 days and after that continuous increase in MLVSS was observed (Figure 2.2).

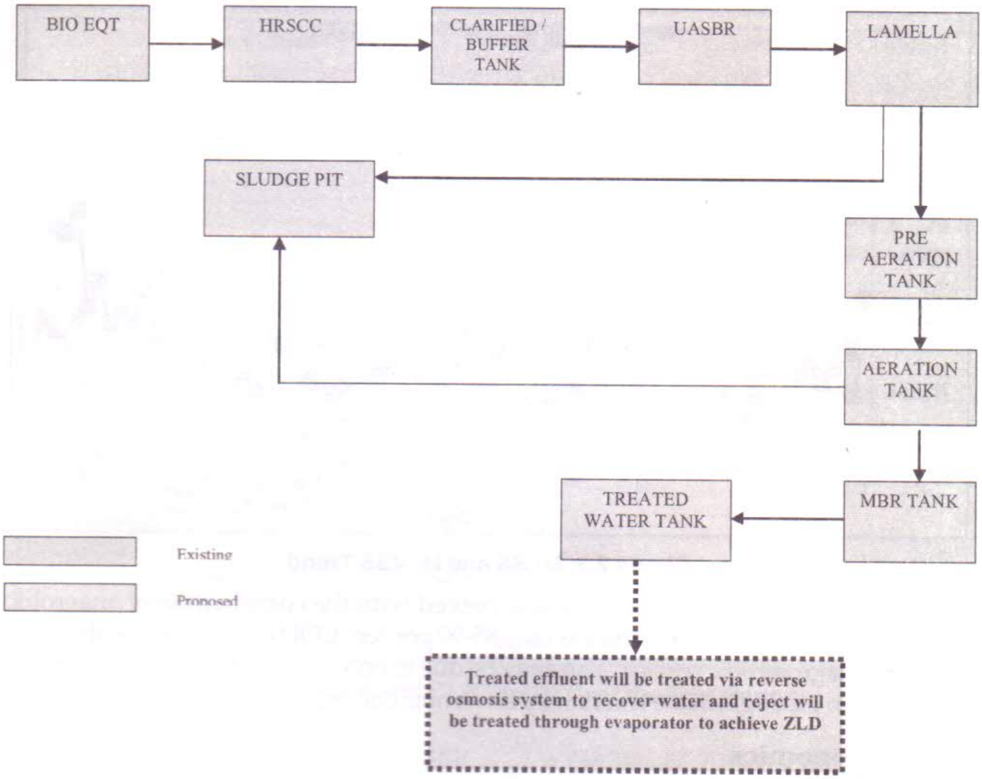

Figure 2.2: Schematic Diagram of Effluent Treatment Plant for Resin Manufacturing Facility

OLR was always maintained above 1 kg COD/m^3/d by combination of organics supplied from process effluent and jaggery. Initial OLR from effluent was kept as low as 0.5 kg/m^3/d and increased in a stepped manner to 4.5 kg/m^3/d over a period of 75 days (Figure 2.3). The process was found stabilized at this point and the system operated for almost 1 month with this OLR with consistency.

Upflow velocity is regarded as one of the main parameter significantly affecting microbial ecology and characteristics of UASBR. It also helps in flushing the hazardous gases thereby keeping the system in healthy condition. The optimum upflow velocity for the wastewater and the system under study was found to be 0.5 m/h. In order to maintain the desired OLR and upflow velocity, the feed to UASBR is 4-5 times of the influent and hence the same was recycled back to buffer tank/UASBR feed tank. This also helps in minimizing the toxicity and shock load to UASBR.

The COD reduction in the initial phase of the start up was on the higher side due to higher percentage of COD from the jaggery which is easily biodegradable. COD reduction stabilized to 47-50 per cent (Figure 2.4) which was desired by the manufacturing facility and based pilot plant observation, full scale plant was observed.

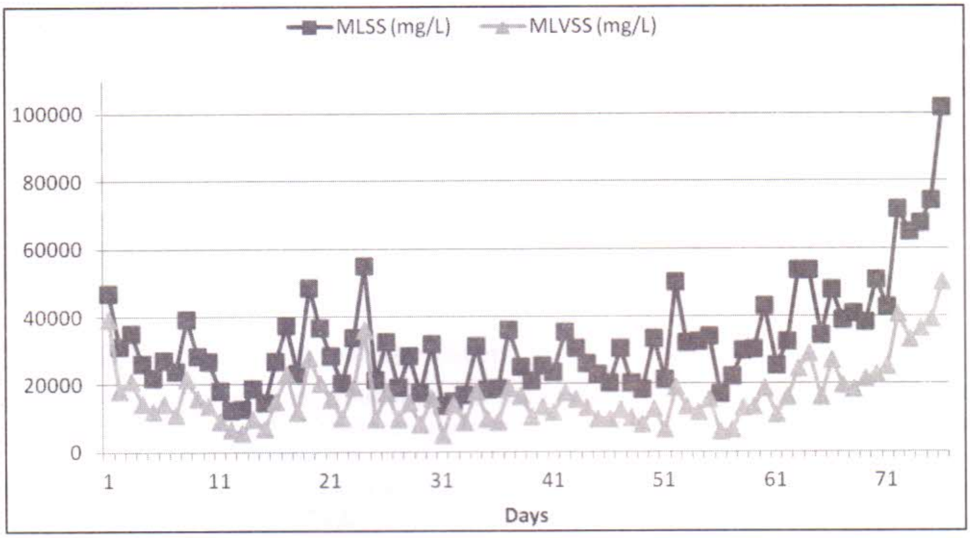

Figure 2.3: MLSS and MLVSS Trend

COD reduction of 90-95 per cent was achieved with the combination of anaerobic followed by aerobic reactor, whereas only 85-90 per cent COD reduction was observed with two stage aerobic reactor. This may be due to conversion of non biodegradable fraction into biodegradable fraction by anaerobic bacteria.

Cost Economics

The manufacturing unit was planning to increase the production of IX resins, which will lead to increase in flow as well as organic load to the ETP. The expansion of the manufacturing facility will lead to increase in the flow to ETP from 180 m^3/day to 240 m^3/d with marginal or no change in the COD and BOD. A cost comparison of UASBR against installation of an aerobic reactor was carried out which is presented in Table 2.2.

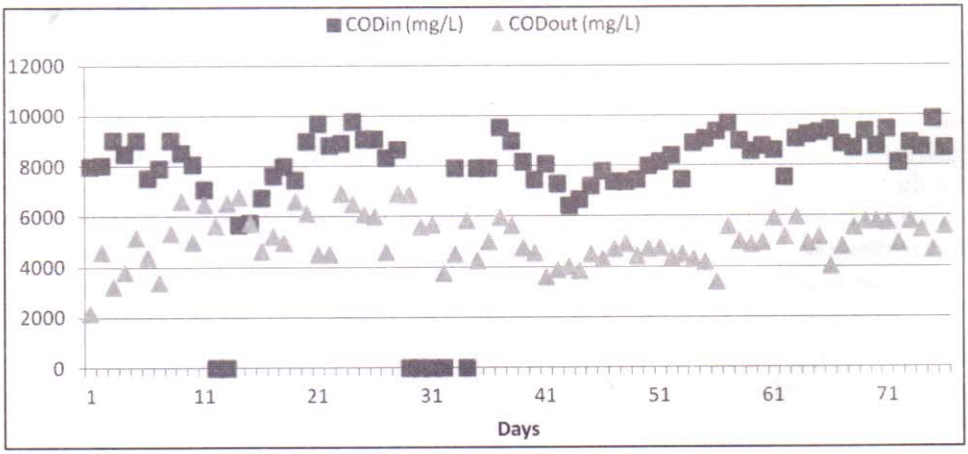

Figure 2.4: COD Profile Over the Trial Period

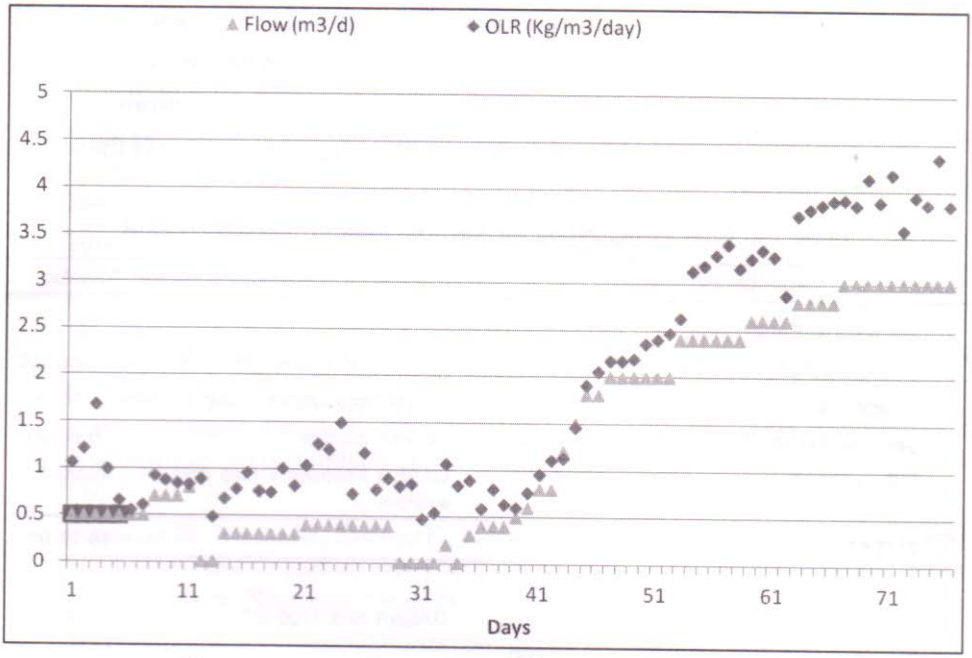

Figure 2.5: Flow and OLR Profile Over the Trial Period

Extra investment in case of UASBR	= (88.18 – 84.70) Lacs INR
	= 3.48 Lacs INR
Savings in operating cost	= (11.02 – 1.07) Lacs INR
	= 9.95 Lacs INR
Payback period	= 3.48/9.95
	= 0.35 yr = 4.5 months

Apart from the above said advantage, savings in term of methane generation and power production can also be considered.

COD reduction in the reactor = 3500 mg/L x 240 m^3/d/1000

= 840 kg/d

Approx. Methane generation @ 0.40 m^3 CH_4/kg COD reduced

= 0.40 x COD reduction

= 0.40 x 840 = 336 m^3/d

= 14 m^3/hr

Power production = (Vol. of methane x cal. Value x Engine eff.)/860

= 14 mm^3/hr x 9500 Kcal/m^3 x 0.35/860

= 54 KWH

Savings in term of power consumption @ Rs. 6 per unit

= 54 KWH x 24 hr x 365 days x 6 Rs.

= 28.3 Lacs INR per annum

The cost benefit analysis indicates long term advantage of UASBR over the widely used aerobic reactor.

Table 2.2: Cost Comparison for Aerobic Reactor Versus UASBR

Sl.No.	2 Stage Aerobic Reactor		Anaerobic Followed by Aerobic Reactor	
1	Mechanical Equipments			
	AT Blower(2x1010 m^3/hr)	5,60,000	UASBR feed pump (60 m^3/hr)	68,000
	Sludge pump(2 x 10 m^3/hr)	50,000	Sludge recirculation pump (1 m^3/hr)	50,000
	Sec. clarifier mechanism	1,80,000	Lamella clarifier	5,00,000
	Diffuser (100)	4,50,000	UASBR Internals + Gas flare system	40,00,000
	TOTAL	**12,40,000**		**46,18,000**
2	Civil Equipments @ 6000 INR/$m3^3$			
	Aeration Tank (1145 m^3)	68,70,000	UASBR tank (700 m^3)	42,00,000
	Sec. Clarifier(60 m^3)	3,60,000		
	TOTAL	**72,30,000**		**42,00,000**
	GRAND TOTAL	**84,70,000**		**88,18,000**
3	Operating Cost @ 4.5 INR/KWH (INR/ANNUM)			
	AT Blower	10,08,000	UASBR feed pump	1,41,000
	Sec. clarifier mechanism	52,000	Sludge pump	29,000
	Sludge recirculation pump	42,000		
	TOTAL	**11,02,000**		**1,70,000**

Conclusion

The following conclusions can be drawn from the present study-

1. UASBR can be successfully employed for the treatment of IX resin manufacturing facility wastewater.
2. The optimum COD removal efficiency of reactor found to be 50 per cent corresponding to optimum HRT and organic loading rate of 3 days and 4.5 kg/m^3/d respectively. The removal efficiency is expected to improve over the operational period.
3. The stabilization/acclimatization period for the system is 60 days.
4. Sludge recycling mode was found to be effective technique for process stabilization.
5. Cost benefit analysis indicates UASBR a better choice if compared to extended aerobic reactors.
6. UASBR is also helpful in reducing green house gas emissions.

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