PERFORMANCE APPRAISAL OF EFFLUENT TREATMENT PLANT AT UNITED BREWERIES LIMITED, BHIWADI

A Dissertation Submitted in Partial Fulfillment
of the Requirements
for the Award of the Degree of
Master of Engineering
in
Civil Engineering
(Environmental Engineering**)**

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CERTIFICATE

This is to certify that the project titled **"PERFORMANCE APPRAISAL OF EFFLUENT TREATMENT PLANT AT UNITED BREWERIES LIMITED, BHIWADI, DISTT. ALWAR (RAJASTHAN)"** being submitted by **Mr. Sameer Gaur,** is a bonafide record of student's own work carried out by him under our guidance & supervision in partial fulfillment of requirements of award of the degree of **Master of Engineering (M.E.) in Civil Engineering with specialization in Environmental Engineering .**

The work embodied in this major project has not been submitted for the award of any other degree.

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ABSTRACT

The United Breweries Limited plant at Bhiwadi, Distt Alwar (Rajasthan) produces beer of different strengths. Since the brewery uses organic materials for manufacture of beer, the wastewater generated is of very high strength in terms of BOD, COD & TSS. The wastewater generated as a result of the manufacture of beer is treated in effluent treatment plant in the premises of the unit. A qualitative analysis was carried out to ascertain the performance of the brewery wastewater effluent treatment plant at United Breweries Limited. The overall performance of the plant was generally satisfactory.

Physical & chemical parameters viz. pH, chemical oxygen demand(COD), biological oxygen demand(BOD), mixed liquor suspended solids(MLSS), sludge volume index(SVI), volatile acids, alkalinity, total suspended solids(TSS), Total Dissolved Solids(TDS) etc. were analyzed besides understanding the various processes behind manufacturing of beer. The averaged brewery wastewater influent inflow into the effluent treatment plant was 568.2 m^3/d with peak flow amounting to 640 m^3/d which is very less than the design flow of 850 m^3/d. The BOD, COD and TSS removal in effluent treatment plant (ETP) was 95.43%, 90% and 74% respectively. The mixed liquor suspended solids values and sludge volume index were found to be within limits. The study further revealed that total dissolved solids (TDS) removal in effluent treatment plant (ETP) is not satisfactory being 12.43 %. The BOD and COD removal in anaerobic hybrid reactor came out to be 78% and 74.77% respectively. The pH values in anaerobic hybrid reactor (AHR) were indicative of proper & smooth functioning of

anaerobic hybrid reactor. Total volatile acids in anaerobic hybrid reactor (AHR) were within specified range indicative of proper functioning of anaerobic hybrid reactor (AHR) & also of avoidance of upsetting of anaerobic treatment setup. For tackling foaming problem, a biogas defoamer has been provided in anaerobic digestion setup to counter it. The biogas produced as a result of anaerobic treatment is being flared & hence there is a loss of precious energy. This biogas generated in anaerobic hybrid reactor may be utilized as an energy source. Final effluent from the effluent treatment plant may be used for keeping the premises green. Total suspended solids (TSS) and total dissolved solids (TDS) removal efficiency may be increased by increasing the detention time and doses of coagulants respectively.

CONTENTS

List of Tables

List of Figures

5.33 BOD reduction in % in ETP 112

Chapter 1

INTRODUCTION

1.1 Introduction

Prior to independence India had primarily an agrarian economy and hence its population has been predominantly rural in character. However, after its independence it has been on the move for rapid industrialization. The industrialization & accompanying urbanization have created a growing demand for large quantities of protected water for public water supplies & for industries. Yet another important problem associated with industrialization & urbanization is the sanitary disposal of waste waters.

At present, many of the industries in the country do not have the proper arrangements for the treatment of industrial wastes. With the rapid industrialization, the waste disposal problem is assuming serious proportions. Although the industries are aware of the water pollution potential of their wastes and are trying to reduce pollutants by installing primary & secondary treatment methods, the efforts, on the whole are from satisfactory and the pollution has reached an alarming state in majority of major river basins. Water pollution due to indiscriminate discharges of untreated liquid wastes has become very acute. The industrial centres of India have become the foci of pollution & some stretches of rivers have become virtually unfit for use.

Although quite a few industries are not treating their wastes, they are aware of the pollution caused by the discharges of the wastes into the water courses and the social obligations thereto.

Many of the industries are now taking steps to assess the pollution caused by the wastes from their industries & finding out methods of treatment. The pollutional effects of brewery wastes are due to high BOD & color. Stagnation of the effluent on land results in obnoxious conditions in the region. If the soil is porous, the effluent may also affect the ground water quality. Discharge of untreated brewery effluent into water courses results in rapid depletion of the oxygen content of the water, making the environment unfit for fish life. The effluent may also impart color and odour to the water and result in unsightly conditions in the water course.

At present, many of the industries in the country do not have proper arrangements for treatment of industrial wastes. With the rapid growth of industrial sector, waste disposal problem is assuming serious proportions. Although the industries are made aware of the water pollution problems by central pollution control board & state pollution control boards due to the waste discharges and ordered to reduce the pollutants by installing primary and in some cases secondary treatment methods, the efforts on the whole remain far from satisfactory. Due to not so satisfactory efforts, the pollution has reached an alarming state in majority of large river basins in India.

1.2 Objectives of the Study

The objective of the present study of wastewater effluent treatment plant at United Breweries Limited was to:

1. To perform a qualitative analysis based on the physical & chemical parameters at various stages of treatment in effluent treatment plant.
2. To evaluate the performance of various units of ETP & suggest for any shortcoming of any unit.
3. To assess the energy requirements of unit & to suggest for any measures that can be adopted to result in saving of energy demands.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

There are large number of breweries in India. Since the locations of breweries fall in the rural areas where there are generally no large water courses for effective disposal of the effluents by dilution, severe pollution of the small rivers and foul smell in the vicinity of breweries is commonly experienced. The brewery industry, the public health officials and other regulatory agencies like central pollution control board, state pollution control boards etc. recognize this problem .They understand the problem of adverse effects of the effluents on surface water bodies as well as ground water resources. The agencies and officials are anxious for abetment of pollution & nuisance created by those effluents.

2.2 Status of Beer Manufacturing in India

Beer is a popular beverage all over the world and contains alcohol ranging from 5 to 9 %. It is found effective in improving appetite and is considered good for health. Formulations of beer manufacturing are done with the availability of raw materials in that particular part where the brewery is established. Beer units are concentrated in the state of Maharashtra, Karnataka, U.P. and Goa with no units in Assam, Tripura, Tamil Nadu, Gujarat, Orissa, and Bihar.

Table 2.1: Beer Production in India (Thousand liters)

Trends in Beer Production ('000 liters)

Year	Beer Production
1995-96	361,680
1996-97	353,064
1997-98	402,660
1998-99	462,782
1999-2000	446,788
2000-01	564,800
2001-02	637,200
Source: CMIE & MFPI	

Presently, some 36 units are manufacturing beer in India with an estimated output of 670 million liters.

2.3 Beer Manufacturing Process

The grain used as the raw material is usually barley, but rye, maize, rice and oatmeal are also employed. In the first stage the grain is malted, either by causing it to germinate or by artificial means. This converts the carbohydrates to dextrin and maltose, and these sugars are then extracted from the grain by soaking in a mash tun (vat or cask) and then agitating in a lauter tun.

The resulting liquor, known as sweet wort, is then boiled in a copper vessel with hops, which give a bitter flavour and helps to preserve the beer. The hops are then separated from the wort and it is passed through chillers into fermenting vessels where the yeast is added-a process known as pitching-and the main process of converting sugar into alcohol is carried out. The beer is then chilled to , centrifuged and filtered to clarify it; it is then ready for dispatch by keg, bottle, aluminium can or bulk transport. The beer manufacturing processes are discussed in detail below:

Mashing: Malt is added to heated, purified water and, through a carefully controlled time and temperature process, the malt enzymes break down the starch to sugar and the complex proteins of the malt to simpler nitrogen compounds. Mashing takes place in a large, round tank called a "mash mixer" or "mash tun" and requires careful temperature control. At this point, depending on the type of beer desired, the malt is supplemented by starch from other cereals such as corn, wheat or rice.

Lautering: The mash is transferred to a straining (or lautering) vessel which is usually cylindrical with a slotted false bottom two to five centimeters above the true bottom. The liquid extract drains through the false bottom and is run off to the brew kettle. This extract, a sugar solution, is called "wort" but it is not yet beer. Water is "sparged" (or sprayed) though the grains to wash out as much of the extract as possible. The "spent grains" are removed and sold as cattle feed.

Boiling and Hopping: The brew kettle, a huge cauldron holding from 70 to 1,000 hectoliters and made of shiny copper or stainless steel, is probably the most striking sight in a brewery. It is fitted with coils or a jacketed bottom for steam heating and is designed to boil the wort under carefully-controlled conditions.

Boiling, which usually lasts about two hours, serves to concentrate the wort to a desired specific gravity, to sterilize it and to obtain the desired extract from the hops. The hop resins contribute flavour, aroma and bitterness to the brew. Once the hops have flavoured the brew, they are removed. When applicable, highly-fermentable syrup may be added to the kettle. Undesirable protein substances that have survived the journey from the mash mixer are coagulated, leaving the wort clear.

Hop Separation and Cooling: After the beer has taken on the flavour of the hops, the wort then proceeds to the "hot wort tank". It is then cooled, usually in a simple-looking apparatus called a "plate cooler". As the wort and a coolant flow past each other on opposite sides of stainless steel plates, the temperature of the wort drops from boiling to about 10 to 15.5 °C, a drop of more than 65.6 °C, in a few seconds.

Fermentation: The wort is then moved to the fermenting vessels and yeast, the guarded central mystery of ancient brewer's art, is added. It is the yeast, which is a living, single-cell fungi, that breaks down the sugar in the wort to carbon dioxide and alcohol. It also adds many beer-flavouring components. There are many kinds of yeasts, but those used in making beer belong to the genus saccharomyces. The brewer uses two species of this genus. One yeast type, which rises to the top of the liquid at the completion of the fermentation process, is used in brewing ale and stout. The other, which drops to the bottom of the brewing vessel, is used in brewing lager. During fermentation, which lasts about seven to 10 days, the yeast may multiply six-fold and in the open-tank fermenters used for brewing ale, a creamy, frothy head may be seen on top of the brew.

Filtration: Filtering the beer stabilizes the flavour, and gives beer its polished shine and brilliance. Not all beer is filtered. Filters come in many types. Many use pre-made filtration media such as sheets or candles, while others use a fine powder made of, for example, diatomaceous earth, also called kieselguhr, which is introduced into the beer and recirculated past screens to form a filtration bed.

Filters range from rough filters that remove much of the yeast and any solids (e.g. hops, grain particles) left in the beer, to filters tight enough to strain color and body from the beer. Normally used filtration ratings are divided into rough, fine and sterile. Rough filtration leaves some cloudiness in the beer, but it is noticeably clearer than unfiltered beer. Fine filtration gives a glass of beer that you could read a newspaper through, with no noticeable cloudiness. Finally, as its name implies, sterile filtration is fine enough that almost all microorganisms in the beer are removed during the filtration process.

Packaging: In the bottle shop of a brewery, returned empty bottles go through washers in which they receive a thorough cleaning. After washing, the bottles are inspected electronically and visually and pass on to the rotary filler. Some of these machines can fill up to 1,200 bottles per minute. A "crowning" machine, integrated with the filler, places caps on the bottles.

The filled bottles may then pass through a "tunnel pasteurizer" (often 23 meters from end to end and able to hold 15,000 bottles) where the temperature of the beer is raised about 60 °C for a sufficient length of time to provide biological stability, then cooled to room temperature. Emerging from the pasteurizer, the bottles are inspected, labelled, placed in boxes, stacked on pallets and carried by lift truck to the warehousing areas to await shipment. Also in the bottle shop may be the canning lines, where beer is packaged in cans for shipment. Packaged beer may be heat-pasteurized or micro-filtered, providing a shelf-life of up to six months when properly stored. Draught beer, since it is normally sold and consumed within a few weeks, may not go through this process. The draught beer is placed in sterilized kegs ready for shipment.

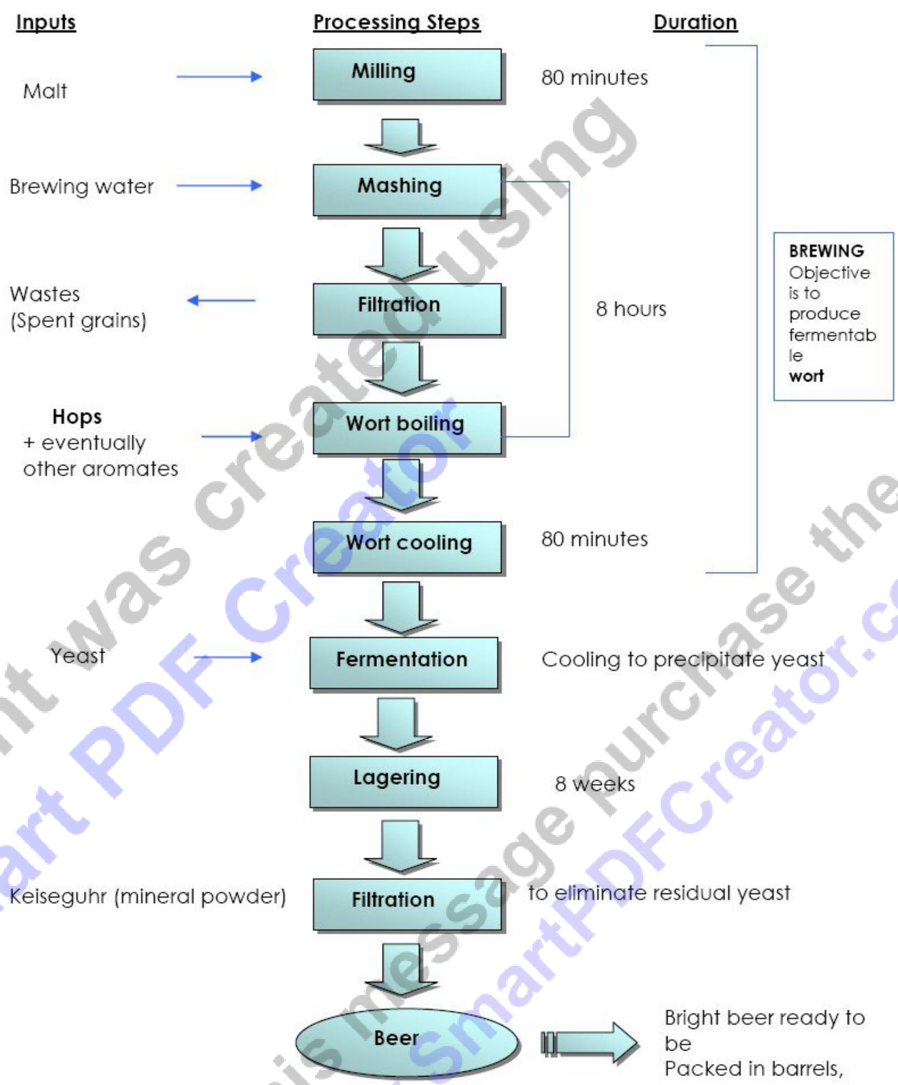

Fig 2.1: Flowchart of manufacturing of beer

2.4 Source, Volume & Characteristics of Effluents

The production of beer involves the blending of the extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast (Wainwright, 1998). The brewing operation employs a number of batch-type operations in processing raw materials to the final beer product.

The production of beer involves the blending of the extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast (Wainwright, 1998). The brewing industry employs a number of batch-type operations in processing raw materials to the final beer product. In the process, large quantities of water are used for the production of beer itself, as well as for washing, cleaning and sterilising of various units after each batch is completed. A large amount of this water is discharged to the drains. For many years the brewing industry has recorded high ratios of water used to beer produced. This can be as high as 10:1 in sites with a large proportion of smallpack production, and as low as 5:1 on some traditional brewing sites (Crispin, 1996). The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced.

Large quantities of good-quality water are needed for beer brewing. In addition to water for the product, breweries use water for heating and cooling, cleaning packaging vessels, production machinery and process areas, cleaning vehicles, and sanitation. Also water is lost through wort boiling and with spent grains.

The pollutant load of brewery effluent is primarily composed of organic material from process activities. Brewery processes also generate liquids such as the weak wort and residual beer which the brewery should reuse rather than allowing to enter the effluent stream. The main sources of residual beer include process tanks, diatomaceous earth filters, pipes, beer rejected in the packaging area, returned beer, and broken bottles in the packaging area. One of the major sources of effluent in a brewing environment emanates from cleaning operations. All vessels and pipelines frequently undergo CIP to ensure that the product is free of undesirable smells and tastes, and fit for human consumption.

According to Binnie and Partners (1986), between 65 and 70% of incoming water forms part of the effluent leaving a brewery. In the process, large quantities of water are used for the production of beer itself, as well as for washing, cleaning and sterilising of various units after each batch is completed. A large amount of this water is discharged to the drains. The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced.

The characteristics of effluents vary depending upon the raw materials used according to the beer of desired strength, the chemicals used in clean in place operations, type of filtration aids used in filtration of beer, fermenting materials & the quantity of these materials etc. Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems. If discharged directly to surface waters, discharge levels should be based on the receiving water use classification.

Table 2.2: General Standards of final effluent from Breweries

Pollutants	Units	Guideline Value
pH	pH	6-9
BOD_5	Mg/L	50
COD	Mg/L	250
Total Suspended Solids	Mg/L	50
Temperature Increase	° C	<3
Total Coliform Bacteria	MPN/100 mL	400
Active Ingredients/Antibiotics	To be determined on a case specific basis	

Breweries typically draw water from wells or from surface intake at a lake or river, and use several different qualities of water, for example, brewing quality water for mashing, deaerated brewing water for dilution, softened water for utility systems and tunnel pasteurizers, washdown water etc. For this reason, breweries often have several sophisticated water treatment facilities.

Table 2.3: Typical Characteristics of Brewery Effluent

Parameter	Unit	Brewery Effluent Composition	Typical Brewery Benchmarks
COD	mg/L	2000-10000	0.5-3 hectoliter(hl) COD/hl beer
BOD	mg/L	1200-4500	0.2 -2 hl BOD / hl beer
TSS	mg/L	200-1800	0.1-0.5 kg TSS/ hl beer
Temp.	mg/L	18-40	-
pH	pH	4.5-10	-
Flow	-	-	2-8 hectolitre(hl) / beer hl

2.5 Methods of treatment

Spent grains: Spent grains from a brewery contains high percentage of organic matter. Removal of these materials from the waste has become an integral part of the waste treatment programme by this industry abroad since many years. These are used as cattle feed as a standard practice abroad.

Some brewers in India are practicing recovery of dried yeast powder of pharmaceutical quality. Bhaskaran reported that the sludge resulting from aeration of brewery waste contained high concentration of vitamin B_{12} of the order of 800 mg/kg of dried sludge and thus can be used as supplementary animal or poultry feed.

Agricultural utilization: Irrigation on land-In India several breweries located in villages and small towns use their spent wash for irrigation after primary dilution with water. But the dilution & land requirements for this purpose are very high. In addition this method has the disadvantages of contaminating irrigation channels, ground water and creating foul smell when an overdose of the waste was used and application of the acid wastes to agricultural land had therefore to be restricted.

Biological Treatment: Brewery wastes are amenable to biological treatment, both anaerobic and aerobic. Since brewery wastes are of high BOD, normally anaerobic treatment precedes any aerobic biological treatment.

Anaerobic Processes: The anaerobic treatment to brewery wastes can be either anaerobic digestion or anaerobic lagooning. Anaerobic digestion of the raw waste has been found by various workers to be excellent method of reducing about 90% of the BOD of a brewery waste and a burnable gas containing high percentage of methane is recovered as a byproduct from this process. The performance of anaerobic digestion has been studied by Buswell & Le Bosquet Stander, Parthsarthy et. Al; Davidson and rown, Painter, Sen and Bhaskaran, and Radhakrishnan et. al.

Anaerobic Lagooning: Anaerobic lagooning is cheap & effective method of treatment of brewery waste. Subbarao reported 95 % BOD reduction in anerobic lagooning treating brewery wastes.

Aerobic Processes: The conventional aerobic biological processes, trickling filters and activated sludge units have been adopted for treatment of brewery wastes. Extended aeration can also be adopted for treating these wastes.

Table 2.4: Anaerobic Treatment of Brewery Wastes

Treatment details	Influent BOD, mg/L	BOD Removal Efficiency	Loading, kg/m^3/d	Detention time,days
i) Field Units				
Anaerobic Digester	10000	70	1.824	10
Claridigester	10000	95	3.04	6
Anaerobic Lagooning	8000	95	-	45
ii) Pilot Plant				
Undiluted Waste	12000	85	10.208	8-10
Malt Brewery	13000	93	4	6
4 Part waste + 1 part dilution water	15000	80	-	5
3 Part waste+ 2 Parts dilution water	17000	87	-	4

Trickling Filters: Trickling filters, single-stage or two-stage are adopted for treating either diluted brewery waste or pretreated brewery waste. Deep trickling filters of plastic media are found to be useful in treating organic waste that are relatively concentrated.

Table 2.5: Treatment of Brewery wastes in Trickling Filters

Details	**Influent BOD**	**% BOD Removal**	**BOD Loading, $kg/m^3/d$**	**Hydraulic Loading**
Field Units				
Single Stage 6' Deep	600	91.8	1	8.0
Two Stage 3' deep each	445	88.0	2.13	
Pilot Plant Study				
Evaporate Condesate of Brewery Recycle Rate 11:1	240	39.6	1.46	30.0
Effluent of Anaerobic Digestion with BOD of 1250 mg/L with & without Dilution	450	91.0	0.36	0.5
	1250	84.0	1	0.5

Activated Sludge Process: The performance of activated sludge & extended aeration plants for treating diluted pretreated brewery waste have been reported by Bhaskaran, Burkhead and Panlette.

Table 2.6: Treatment of Brewery wastes in Trickling Filters

Details	Influent BOD mg/L	% BOD Removal	Loading, kg/m^3/d	Detention Time Hrs.
Predigested Sludge Brewery treated in Activated Sludge	1000-1200	85-90	-	6.8
Extended Aeration	314-564	77-97 Avg.91.5	2.4	-
Pilot Plant Lab. Work	700	91-95	3.2	-

Luqiong Ling, Kwang Victor Lo et. al studied suspended-growth aerobic sequencing batch reactors (SBR) to assess the effects of hydraulic retention time (HRT) and loading rate on the treatment of brewery wastewater. They found that the maximum suspended solids removal, around 95%, would occur at values of HRT and loading rate of 1.32 days and 13.84 g/L day, respectively. TOC removal was more sensitive to the variations of HRT, however the loading rate was more important than the HRT for suspended solids removal. TOC removal was more sensitive to the variations of HRT however, the loading rate was more important than the HRT for suspended solids removal.

Jill Jordan in year 2001 studied UASB reactor of Biothane Corporation of Camden, New Jersey. The wastewater pretreatment plant was constructed at the same time the new brewery was being built and was able to treat wastewater shortly after the brewery startup. His paper described the selected technology and discussed the process design parameters, system components and system performance for the Yuengling Brewery application. The system has been in continuous operation for two and a half years and reduces the wastewater BOD_5 concentration by close to 90%.

Zhang, Feng, Lü, Xiao-fei (XF) et. al. found on studies of Submerged Membrane Bio Reactor that Under the condition of keeping the influent COD: TN: TP = 100:5:1, submerged MBR has an excellent treatment performance for COD and NH4+ -N, and the removals for COD and NH4+ -N are both beyond 90% under steady state, in addition, MBR has a strong adaptation ability for shock organics loading rate. When the organic loading rate was increased from 0.27g/(g x d) to 0.54g/(g x d) suddenly, there was no big fluctuation for COD in effluent. According to the results of GC/MS, the remaining organics in effluent was mainly alkyl hydrocarbon, and the membrane modules played a main role in stabling permeation quality.

When the sludge in MBR was at the multiplication stage, the system has a removal of about 40% for TN because of biosynthesis and simultaneous nitrification and de-nitrification, in addition, a certain removal for TP was also observed. When the sludge was at the steady stage, the removal for TN decreased to about 30% due to simultaneous nitrification and de-nitrification, whereas, the removal efficiency for TP was very little, and sometimes even below zero.

Baloch, Akuna, Collier et al. in year 2005 studied the performance characteristics of a plug flow phase separated anaerobic granular bed baffled reactor (GRABBR) fed with brewery wastewater at various operating conditions. The reactor achieved chemical oxygen demand (COD) removal of 93-96% with high methane production when operated at organic loading rates (OLRs) of 2.16-13.38 kg COD/ m^3/d. The reactor configuration and microbial environment encouraged the acidogenic dominant zone to produce intermediate products suitable for degradation in the predominantly methanogenic zone. Noticeable phase separation between acidogenesis and methanogenesis mainly occurred at high OLR, involving a greater number of compartments to contribute to wastewater treatment. The highly active nature and good settling characteristics of methanogenic granular sludge offered high biomass retention and enhanced methanogenic activities within the system. The granular structure in the acidogenic dominant zone of the GRABBR was susceptible to disintegration and flotation. Methanogenic granular sludge was a multi-layered structure with Methanosaeta-like organisms dominant in the core.

Bloor, Anderson and Willey et al .studied an aerobic Jet Loop Reactor (JLR) activated sludge process to investigate its suitability for the treatment of industrial wastewaters, specifically brewery wastewater. A loading rate of 50 kg COD/m^3·d was achieved with 97% COD removal for a period of 5 weeks and although the settleability was found to be acceptable non-flocculating motile bacteria caused the effluent to be cloudy and have a high suspended solids concentration in the order of 200–350 mg/l.

Investigations into how this loading rate was achievable and its consequences included measurements of oxygen transfer rate, Specific Oxygen Uptake Rate (SOUR), determination of Monod kinetic coefficients and microscopic examination. Oxygen transfer rates were found to be high, with a low energy efficiency possibly due to the small scale of the rig, SOUR values varied between 100–400 mg O_2/g VSS·h for F/M ratios of 5–8 kg COD/kg MLVSS·d and the maximum growth rate was found to be 12.2/d with a yield of 0.4 kg VSS produced/kg COD removed. Although the Jet Loop Reactor was found to be a suitable method for pretreating brewery wastewater, an effluent polishing stage before final discharge to a water course would be necessary and it was concluded that further investigations into jet design may increase the oxygen transfer efficiency and quality of effluent.

Vijayraghvan; Ahmad & Samson et al. in year 2000 studied anaerobic digestion of organics present in beer brewery wastewater based on hydrogen generation. The advantage of the fermentative method of biohydrogen generation is that it treats the waste and also yields energy value in terms of hydrogen, which is not a greenhouse gas, as a gaseous by-product. The hydrogen-generating microflora was isolated from cow dung through pH adjustment (pH 5) coupled with two consecutive heat treatments (1 hr each). For influent chemical oxygen demand (COD), a concentration of 2,470 mg/L at a hydraulic retention time (HRT) of 1 day resulted in the following values: outlet COD, 760 mg/L; biogas volume, 6.7 L; and hydrogen content, 60%. A 7-day HRT for the influent COD resulted in the following values: outlet COD, 112 mg/L; biogas volume, 9.7 L; and hydrogen content, 62%. The volatile fatty acid content, redox potential, and pH in the reactor were 440 ± 120 mg/L, -360 ± 30 mV, and 5.5 ± 0.2, respectively. The average biogas generation destroyed 0.47 m^3 of COD per kg during anaerobic digestion of beer brewery wastewater based on biohydrogen generation.

Chapter 3

BEER MANUFACTURE AND EFFLUENT GENERATION AT UBL, BHIWADI

3.1 Introduction

United Breweries Limited, the flagship company of the UB Group, has an association with the brewing dating back over five decades, starting with 5 breweries in South India in 1915. United Breweries Group or UB Group, based in Bangalore, is a conglomerate of different companies with a major focus on the brewery (beer) and alcoholic beverages industry. The company markets most of its beer under the Kingfisher brand and has also launched Kingfisher Airlines, an airline service in India, with international flights operating recently. United Breweries is India's largest producer of beer with a market share of around 48% by volume.

The group is headed by Dr. Vijay Mallya who is also a member of the Indian Parliament. United Breweries Limited, (UBL) also referred to as the Beer Division of the UB Group is Led by Mr. Kalyan Ganguly, President & Managing Director.

United Breweries Limited unit at Bhiwadi has 270 employees. The breakup of the employees is as mentioned: 200 casual workers, i.e. unskilled workers, 40 permanent workers, i.e. semi-skilled & skilled workers. The permanent workers include electricians, effluent treatment plant operators & beer manufacturing plant operators. Then there are executives, 30 in number. Annual turnover of the brewery plant unit at Bhiwadi is rupees 100 crores approximately. The yearly production of beer at UBL plant at Bhiwadi is nearly 50,000 kilolitres.

Raw materials used for making beer include rice flakes, malt, sugars, hops. For production of 1 kilolitres of strong beer, i.e. beer containing 7-8% of alcohol, 14.66 kilograms of malt, 7.33 kilograms of rice, 2.17 kilograms of sugars & 0.47 kilograms of hops are consumed. Since the yearly production of beer at UBL plant at Bhiwadi is 50000 kilolitres, that means 733,000 kilograms or 733 tonnes of malt,366,500 kilograms or 366.5 tonnes of rice ,108,500 kilograms or 108.5 tonnes of sugars & 23,500 kilograms or 23.5 tonnes of hops are consumed on an average annually.

Production line at UBL Bhiwadi packs beer in bottles & cans. Each case containing bottles has 12 bottles of 650 milliliters each & containing cans has 24 cans of 500 milliliters capacity each. So each can case contains 12 liters of beer & bottle case has 7.8 liters of beer. Thus every kilolitres of beer means 83 can cases or 128 bottle cases.

3.2 Beer Manufacturing process at United Breweries Limited

In making beer, various raw materials are used in such a manner that maximum yield of alcohol is achieved. The different kinds of raw materials such as malt, rice, maize, barley etc. are used for making wort.

The manufacturing of beer at United Breweries Limited is completed in several stages & in different rooms allocated for the specific stage. The grain used as the raw material is usually barley, but rye, maize, rice and oatmeal are also employed. In the first stage the grain is malted, either by causing it to germinate or by artificial means. This converts the carbohydrates to dextrin and maltose, and these sugars are then extracted from the grain by soaking in a mash tun (vat or cask) and then agitating in a lauter tun.

The resulting liquor, known as sweet wort, is then boiled in a copper vessel with hops, which give a bitter flavour and helps to preserve the beer. The hops are then separated from the wort and it is passed through chillers into fermenting vessels where the yeast is added-a process known as pitching-and the main process of converting sugar into alcohol is carried out. The beer is then chilled to, centrifuged and filtered to clarify it; it is then ready for dispatch by keg, bottle, aluminium can or bulk transport. The various beer manufacturing processes are carried out in different rooms allotted for the specific purpose & discussed in detail below.

3.2.1 Brewhouse

In this room, raw materials like malt, rice, broken rice or a combination of these raw materials is taken. First operation is the grinding of the malt & addition of water & broken rice to make grist. The step where the wort is prepared by mixing the starch source (normally malted barley) with hot water is known as "mashing". Hot water (known as "liquor" in brewing terms) is mixed with crushed malt or malts (known as "grist") in a mash tun. Mashing is done at 45 °C & the mixture is held for 20 minutes at 52 °C.

This temperature is necessary for activation of amino acids. Again at raised temperature of 64 °C, the mixture is held for 40 minutes for activation of β-amylase enzymes. Again at raised temperature of 71 °C, the mixture is held for activation of α-amylase enzymes. This operation takes place in mash kettle.The mashing process takes around 1 to 2 hours, during which the starches are converted to sugars, and then the sweet wort is drained off the grains. The grains are now washed in a process known as sparging". This washing allows to gather as much of the fermentable liquid from the grains as possible. The process of filtering the spent grain from the wort and sparge water is called wort separation. The traditional process for wort separation is lautering, in which the grain bed itself serves as the filter medium.

From mesh kettle, this mixture is sent into a lauter tun where hot trub is separated from the mixture. The boiling is done in wort kettle. This process is called sterilization. Now the hops are added to add bitterness to the final product beer. Hot trub from this room or stage contains proteins & tannin complex. Now the mixture is sent into a whirlpool. In whirlpool, the mixture is rotated like in a washing machine. In the process, hot trub settles. The hot wort coming out of whirlpool is now cooled in plate type heat exchanger. These heat exchangers absorb heat to cool the hot wort upto 10 °C.

3.2.2 Fermentation Room

Now the wort is cold one. So fermentation is done at different temperatures. It is carried out at 10 °C for 24 hours, 12°C for 48 hours & at 16 °C until end gravity of product is got. Maturation and fermentation tank bottoms constitute another source of sludge.

3.2.3 Filtration Room

Beer is filtered using Celite or Hiflo. This is done to remove proteinaceous materials as well unfermented ones. The material used for the filtration consists of diatomaceous earth. Diatomaceous earth has various advantages for filtration in brewing process as reported by Baimel et al.

The conventional dead-end filtration with filter-aids (Kieselguhr) has been the standard industrial practice for more than 100 years and will be increasingly scrutinised from economic, environmental and technical standpoints in the coming century. Approximately two thirds of the diatomaceous earth production is used in the beverage industry (beer, wine, fruit juice and liqueurs).

The conventional dead-end filtration with filter-aids consumes a large quantity of diatomaceous earth (100 g/l of clarified beer) and carries serious environmental, sanitary and economical implications. At the end of the separation process, diatomaceous earth sludge (containing water and organic substances) has more than tripled in weight.

3.2.4 Bright Beer Room

Now the beer is stored in storage tanks.

3.2.5 Waste label

Waste label disposal is related to product decoration and design and the waste label mass fluctuates greatly. On average, a weight of 282 kg/1000 hl of produced beer has been calculated. Waste labels should be avoided or at least limited since they are not simple papers but wet-strength paper impregnated with caustic solution.

3.3 Sources of Effluents at UBL

The production of beer involves the blending of the extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast (Wainwright, 1998). The brewing operation employs a number of batch-type operations in processing raw materials to the final beer product.

In the process, large quantities of water are used for the production of beer itself, as well as for washing, cleaning and sterilising of various units after each batch is completed. A large amount of this water is discharged to the drains. The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced.

For many years the brewing industry has recorded high ratios of water used to beer produced. This can be as high as 10:1 in sites with a large proportion of smallpack production, and as low as 5:1 on some traditional brewing sites (Crispin, 1996). The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced.

The pollutant load of brewery effluent is primarily composed of organic material from process activities. Brewery processes also generate liquids such as the weak wort and residual beer which the brewery should reuse rather than allowing to enter the effluent stream. The main sources of residual beer include process tanks, diatomaceous earth filters, pipes, beer rejected in the packaging area, returned beer, and broken bottles in the packaging area. One of the major sources of effluent in a brewing environment emanates from cleaning operations.

All vessels and pipelines frequently undergo CIP to ensure that the product is free of undesirable smells and tastes, and fit for human consumption. According to Binnie and Partners (1986), between 65 and 70% of incoming water forms part of the effluent leaving a brewery.

In addition to water for the product, at UBL water is used for heating and cooling, cleaning packaging vessels, production machinery and process areas, cleaning vehicles, and sanitary water. Water is also lost through wort boiling and with spent grains. Large quantities of good-quality water are needed for beer brewing. In addition to water for the product, water is used for heating and cooling, cleaning packaging vessels, production machinery and process areas, cleaning vehicles, and sanitation. Also water is lost through wort boiling and with spent grains.

The wastewater is generated at different stages in manufacturing of beer. The wastewater is generated in brewhouse, fermentation room, filtration room & bright beer room. Wastewater generation areas at UBL are:

(1) Process Area: Brewhouse, Fermentation room, Filtration room & Bright beer room

Brewhouse: Wastewater is generated in Cleaning In Place (CIP) operations, Emptying of vessels, Hot Trub generation in whirlpool etc.

Fermentation Room: Wastewater is generated in Yeast room, Cellar house, CIP room

Filtration Room: Wastewater is generated after discharge of Hiflo, Celite powder (coarse & fine) alongwith rejected proteinaceous material.

(2) Bottling hall: Wastewater is generated in Bottling Washer, Pasteuriser, Can Washing, Head brewer.

(3) Cleaning area: Wastewater is generated in Toilets, Washing & cleaning purposes. The wastewater is also generated during CIP of every tank, CIP of fermentation vessels, Trub removal (this trub is different from brewhouse trub), flushing of yeast.

(4) CIP Room: Wastewater is generated during Caustic soda use, water, Foaming agent SU-100 .The figure 3.1 shows the wastewater produced monthwise in ETP at UBL.

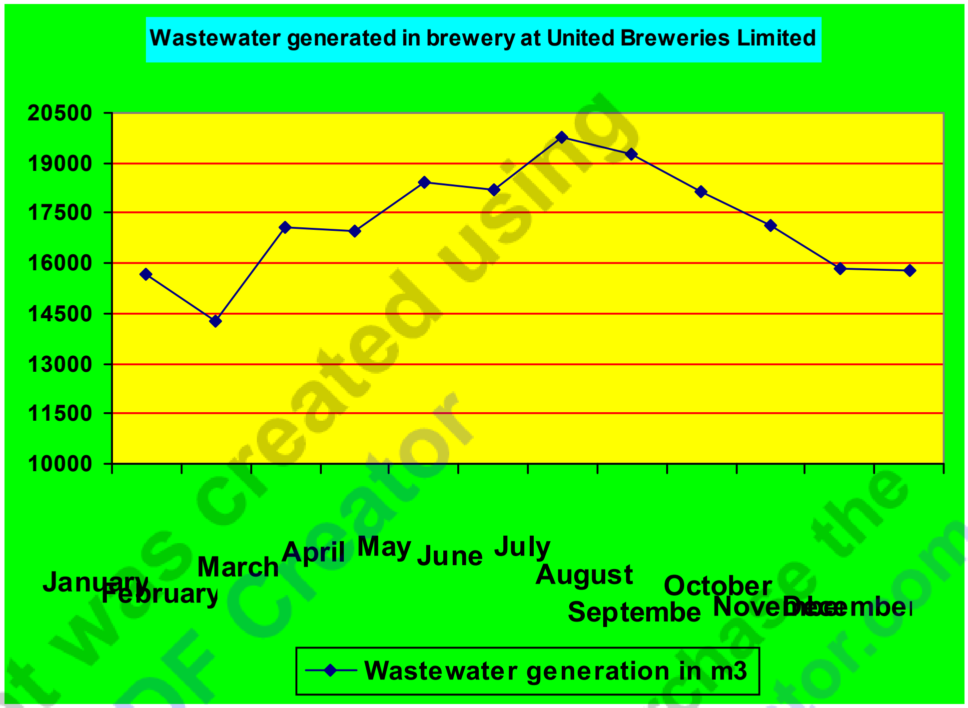

Fig 3.1: Monthwise wastewater generation at ETP of UBL

Chapter 4

PEFORMANCE APPRAISAL OF ETP AT UNITED BREWERIES LIMITED, BHIWADI

4.1 Component units of ETP at UBL plant

The Effluent Treatment Plant at UBL Limited has various component units like screen chamber, equalization tank, anaerobic hybrid reactor (AHR), aeration tank followed by secondary clarifier. The unit has provided sludge drying beds for the conditioning of sludge before its final disposal.

Bar screens remove large and floating solids from wastewater if any. Equalization tank has been provided by the unit to achieve equalization of flow and characteristics of wastewater prior to further treatment. This is followed by anaerobic treatment which is carried out in anaerobic hybrid reactor (AHR). Anaerobic treatment is followed by aerobic treatment which is carried out in aeration tank functioning on the principles of Activated Sludge Process.

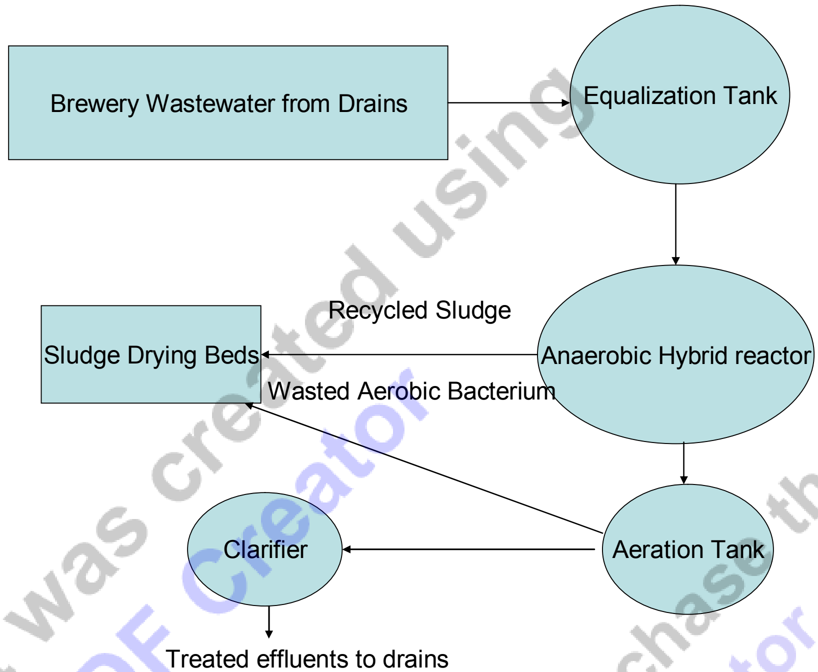

Figure 4.1: Effluent Treatment Plant (Illustration) at United Breweries Limited

4.2 Wastewater Treatment

4.2.1 Screen Chamber

Bar screen chambers remove large objects e.g. bottle caps, broken glass, labels, grain, etc. coming in effluent of brewery .The Bar screen chambers at UBL measures 0.5m x 1.5 m in plan with 0.5 m depth. The total volume of the chambers is 0.75 m^3.

Figure 4.2: Screen Chambers at Effluent Treatment Plant

Table 4.1: Dimensions of Screen Chambers

Chambers	2
Plan Dimensions	0.5 m* 1.5 m
Side Water Depth	0.5 m
Volume	0.375 m^3
Total Volume	0.75 m^3

4.2.2 Equalization tank

Equalization tank normalizes the flow and characteristics of wastewater. This is achieved by providing enough detention period so that the different streams of wastewater emanating from and industrial unit find a chance to intermingle with each other and result in flow and characteristics equalization. The equalization tank has been provided with arrangement of keeping the its contents in agitated condition thus preventing any chance of deposition at its bottom. This is achieved by a system of air blowers and diffusers.

Figure 4.3: Equalization Tank at ETP of United Breweries Limited

Figure 4.4: Equalization Tank at ETP of United Breweries Limited

Flow equalization is used to overcome the operational problems caused by flow rate variations, to improve the performance of the following (downstream) processes & to reduce the size & cost of downstream treatment facilities.

Flow equalization is damping of the flowrate variations so that a constant flowrate is achieved. The equalization tank is beneficial in the sense that biological treatment is enhanced and pH can be stabilized. Not only the effluent quality & thickening performance of following tanks or unit is enhanced, it also results in lesser chemical application ahead.

Table 4.2: Dimensions of Equalization Tank

Shape	Circular
Material of Construction	R.C.C
Diameter	10.4 m
Side Water Depth	3.35 m
Free Board	1.35 m
Volume	284.43 m^3
Hydraulic Retention Time	8.03 Hrs
Design Flow	850 m^3/d

4.2.3 Anaerobic Hybrid Reactor (A.H.R)

Anaerobic Hybrid reactor provided at UBL Limited, is a combination of Upflow Anaerobic Sludge Blanket (UASB) & Upflow Fixed Film Reactor(UFF). It combines process advantages of both & minimizes shortcomings of the both UASB & UFF. The fixed media provided in UFF portion is PVC cross fill media. Wastewater enters AHR through an extensive influent distribution system located at the floor level of reactor.

Recycled effluent is drawn using recycle pumps & mixed with raw wastewater as it enters reactor. This raw wastewater & recycled wastewater is anaerobically treated. Wastewater enters bottom sludge blanket zone where it is anaerobically biodegraded to stabilized form. Wastewater is polished & clarified as it passes through fixed media section of AHR. Anerobically treated wastewater overflows to aeration tank for secondary treatment & gets clarified in clarifier.

Biogas is collected through biogas collector system built under floating anaerobic reactor roof & extracted by biogas blower system & transferred to flare for burning. Excess sludge settled at bottom is extracted by AHR recycle sludge pump & discharged into sludge drying beds where dried sludge cakes are suitably used or disposed off & sludge filtrate is sent to equalization tank.

Anaerobic sludge blanket comes into intimate contact with upcoming raw wastewater which is mixed with recycle wastewater drawn from reactor top. Bulk of anaerobic reaction takes place in sludge zone due to contact between organics present in raw wastewater with anaerobic sludge. Recycle of anaerobically treated wastewater from AHR top serves to buffer pH of inlet wastewater thereby minimizing alkali consumption & promote mixing inside AHR.

As wastewater traverses media upwards anaerobic bacteria tend to attach on to media & polish off residual BOD & COD present in wastewater. Media also acts as clarification zone & removes residual total suspended solids (TSS). This residual TSS may flow out of AHR if fixed media is not present. Separation & retention of anaerobic biomass within AHR achieves a high SRT for system even though low HRT is provided. AHR achieves high BOD & COD removal along with high biogas production

Organic matter is consumed as a source of energy & food by microorganisms. There are three prominent stages in anaerobic treatment by anaerobic bacteria:

(1) Hydrolysis

(2) Acid Formation

(3) Methane formation

Incoming raw wastewater contains both complex & simple soluble (dissolved) & insoluble (undissolved) organic matter.

Hydrolysis: Insoluble organic matter is made soluble in this stage. Hydrolysis is carried by enzymes secreted from microorganisms. Enzymes dissolve solid organic wastewater so that bacteria uses them as food. After organic matter is made soluble, it works as food for next step, i.e acid formation.

Acid Formation: Soluble complex organic matter (cellulose, starch, proteins, fats & carbohydrates) are broken down into less comlex organic matter, i.e. sugars, amino acids & long chain volatile acids biochemically. Sugars, amino acids & long chain volatile acids are intermediate products which are subsequently broken down into simple organic matter (short chain volatile acids mainly acetic acid & propionic acid) Microorganisms which convert organic matter to volatile acids are known as acid formers or acidogens.

Methane Formation: Anaerobic microorganisms known as methane formers convert volatile acids produced in formation step into mainly methane,CH_4 & Carbon dioxide ,CO_2. Methanogens depend upon acidogens to supply volatile acids so that they may produce CH_4 &CO_2.Anaerobic digestion steps occur simultaneously in reactor so that acidogens & methane formers exist as a mixed population in reactor. Environmental conditions for most efficient operation must be favourable for both acidogens & methane formers. Volatile acids produced during acid formation get converted into biogas rapidly. If unfavourable environmental conditions exists either one or both the populations will become inhibited resulting in less efficient anaerobic digestion.

Most favourable aspect of anaerobic digestion is maintaining environment suited to both acidogens & methanogens. Now the thing is that methane formers depend upon acid formers to supply volatile acids so that they may produce CH_4 & CO_2. When the population of both methane formers & acidogens are in balance, volatile acids are produced rapidly. But if methane formers are not present in sufficient numbers or if they are inhibited by unfavourable environmental conditions, the volatile acids are produced more rapidly than they are used & will accumulate more than required for efficient operation & the concentration of volatile acids is increased. Now increased volatile acids formation leads to decreased system pH further inhibiting methane formers. Now the more concerning thing is that acid formers have an advantage over methane formers since these have rapid growth rate & are less sensitive to environmental conditions like pH & temperature. For that matter at low pH methane formers growth is prohibited while acid formers continue to produce volatile acids. The impact of high volatile acids production is that anaerobic process, hence functioning is inhibited. The result of that is that COD removal is poor & low biogas production.

Figure 4.5: Anaerobic Hybrid Reactor at Effluent Treatment Plant

Biogas generated is mostly insoluble in water. It is collected in topmost part of AHR, freeboard zone of AHR. Two types of covers are provided: Fixed & Floating type. A floating cover membrane tends to balloon upwards as biogas accumulates. AHR membrane cover at UBL is fabricated out of specially imported XR-5 geothermal membrane with floating foam cushions underneath & weighted pipes installed over the cover. AHR membrane cover is resistant to chemicals, UV, IR & ozone crack & has a long operating life. There is provision for uniform lifting of cover membrane from all sides once biogas production starts. Biogas blowers draw biogas directly from AHR top & convey it to biogas flare. Biogas is flared under normal conditions. The biogas flare is equipped with flare tip, wind shield & electric spark ignition system.

Table 4.3: Dimensions of Anaerobic Hybrid Reactor

Diameter	12.5 m
Side Water Depth	7.0 m
Sludge Zone Depth	3.6 m
Media Zone Depth	2.4m
Volume	858.59 m^3
Clear Liquid Depth	1.0 m
Free Board	0.7 m
Specific Surface area	100 m^2/m^3
Hydraulic Retention Time	24.24 hrs
COD loading Rate	2.97 kg COD/m^3-day

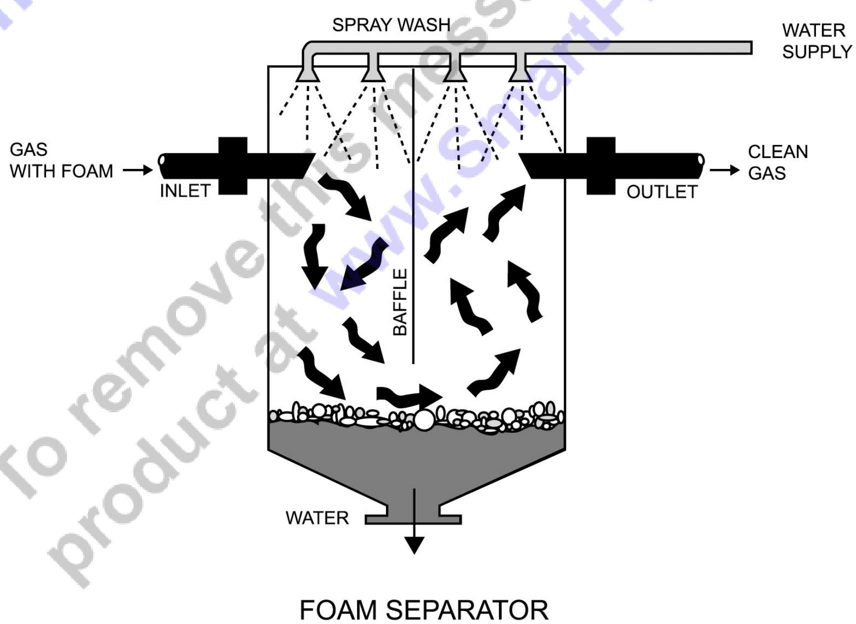

Figure 4.6: Biogas Defoamer

Figure 4.7: Biogas Flare Stack at ETP of United Breweries Limited

4.2.4 Aeration Tank

Anaerobically treated wastewater is biodegraded aerobically. Air is supplied using air blowers. Aerobic treatment unit comprises of aeration tank & clarifier. At UBL, Anaerobically treated wastewater from AHR is conveyed by pipes. The aerobic treatment is based on extended activated sludge aeration process. Aerobic microorganisms are cultured in tank & sludge is wasted to sludge drying beds.

Figure 4.8: Aeration tank at ETP of United Breweries Limited

Figure 4.9: Aeration tank at ETP of United Breweries Limited

Surface area generated due to thousands of fine orifices is huge. Dissolved oxygen produced by these diffusers is consumed by aerobic bacteria present. Constant air bubbling ensures adequate & homogeneous mixing. It is cost effective & energy efficient. Microorganisms degrade organic matter present in wastewater resulting in more aerobic bacteria along with CO_2 & H_2O as byproducts. An excess aerobic bacterium generated in aeration tank is wasted to sludge drying beds.

From aeration tank, mixed liquor flows to clarifier by gravity. Settled sludge from bottom of clarifier is sent to aeration tank on a continuous basis. Continuous sludge recycle from clarifier to aeration tank maintains required inventory of aerobic microorganism in aeration tank so that wastewater is biologically wasted to required quality. Excess aerobic sludge is wasted to sludge drying beds system. Some quantity of nutrients & micronutrients such as Nitrogen, Phosphorus & trace metals is necessary to run it.

Table 4.4: Dimensions of Aeration Tank

Material of Construction	RCC
Plan Dimensions diameter	14.5 m
Side Water Depth	4.0m
Free Board	0.5m
Volume	$338m^3$
HRT	9.54 hrs
MLSS	3500-4000 mg/L
F/M Ratio	0.09 kg BOD/kg MLSS day
Pumps for aeration	2,1 working & 1 standby

4.2.5 Clarifier

Clarifier is provided with a scum baffle / scum skimmer arrangement. Scum collection box & air eductor arrangement waste floating scum to aeration tank on intermittent basis. Treated wastewater from aeration tank overflows into clarifier, circular in shape. Mixing provided in tank uniformly disperse aerobic bacterial flocs in tank. Quiscient settling conditions are provided in clarifier & bacterial flocs bioflocculate & settle down as sludge at bottom of clarifier. Clear supernatant liquid is overflowed for disposal.

As sludge scraper assembly with a central drive head rotates, scraper blades at the bottom scrap settled sludge at the bottom into sludge hopper. From clarifier sludge hopper, sludge is transferred to sludge drying beds. Floating scum on clarifier surface is transferred back to aeration tank. Settled sludge is recycled back to aeration tank.

Figure 4.10: Clarifier at ETP of United Breweries Limited

Figure 4.11: Clarifier at ETP of United Breweries Limited

Table 4.5: Design Parameters of Clarifier

Diameter	10.4 m
Side Water Depth	4 m
Plan area	84.98 m^2
Total volume	322.61 m^3

4.2.6 Sludge Drying Beds

Excess biological sludge formed during aerobic biological treatment process & anaerobic process is wasted in sludge drying beds. Wasted sludge from anaerobic & aerobic process is distributed on top of beds .Liquid from sludge percolates downwards & collected by underdrainage system. It is sent back to equalization tank. Dried sludge on top is removed with shovels. Withdrawn excess sludge generated in AHR & pump it to sludge drying beds. The pipes are provided at the floor of AHR. Sludge wasting pipes occupy the whole plan area of AHR & are supported on PCC block supports. Orifices are provided in sludge wasting pipes.

Figure 4.12: Sludge Drying Beds at E.T.P of United Breweries Limited

4.3 Sampling

Sampling is an extremely important consideration in properly characterizing wastewater for wastewater characterization & analysis. Flow rate and wastewater quality change continuously, and these changes may affect the ability of a wastewater treatment plant to perform properly. Obtaining samples that will actually represent the wastewater flow throughout the months and years to come is difficult at best.

Diurnal fluctuations occur in concentration and flow volume; seasonal fluctuations occur in concentration, flow volume, and temperature; and industrial contributions to the collection system may cause wastewater characteristics to change on a short- or long- term basis. Given the variable nature of wastewater and the necessity of attaining it may be necessary to collect samples that will represent "average" characteristics and approximate characteristics under more extreme conditions.

4.4 Methodology

Performance appraisal of existing ETP at UBL Limited was carried out by carrying and sampling of effluent streams at inlet and outlet of different units of ETP, and determining the efficiency of each unit. For the purpose of performance appraisal sampling and analysis was spread over a period of 12 months of time. Sampling for wastewater flow rate from the unit and characteristics of different streams was carried out for 9-10 times in each month, spread suitably over a period of month to reflect any changes in wastewater flow and composition.

Treatment plant was visited several times to understand the working of various units & determine treatment efficiencies of various units viz.

anaerobic hybrid reactor, aeration tank, clarifier & sludge drying beds. Also to evaluate performance of various units effluent treatment plant at United Breweries Limited ,samples were taken from inlet of anaerobic hybrid reactor, outlet of anaerobic hybrid reactor, outlet of aeration tank & outlet of clarifier. Sampling tests on brewery wastewater were carried out according to the standard methods of examination for water & wastewater. Grab samples of wastewater streams were collected for the purpose of analysis.

Chapter 5

RESULTS & DISCUSSIONS

5.1 Equalization Tank

As shown in table no 5.1, the average daily flow of wastewater from united breweries limited ranged from 500 m^3/d to 640 m^3/d . The flow was high in summer months to meet the increased consumption & demand of beer particularly in July & August (635.2 & 633.51 m^3/d respectively & low in winter months particularly December & January (517.53 & 510.8 m^3/d respectively) as shown in figure 5.1.

5.2 Anaerobic Hybrid Reactor

pH value of brewery wastewater recorded ranged from 5.7 to 7.6 for brewery wastewater at inlet(as influent) to anaerobic hybrid reactor as shown in figure no. 5.3. pH of the influent wastewater was slightly on the acidic side because brewery wastewater is acidic (pH being in 3-4) & dosing of chemicals is done to adjust pH. pH value at outlet of anaerobic hybrid reactor varied between 6.8 to 9.2 as shown in figure no. 5.5. The monthly averaged values of pH at Inlet of AHR and outlet of AHR are shown in table no. 5.2 and depicted in figure no. 5.2 and figure no. 5.4 respectively.

The COD values ranged between 8040 & 9880 mg/L at inlet of AHR and corresponding COD values varied between 1200 & 2120 mg/L as shown in figure no. 5.7. The COD removal in % ranged between 75.67 & 85.16 as shown in figure no. 5.8 .The removal efficiency of anaerobic hybrid reactor at United Breweries Limited came out to be nearly 78 % It is quite higher than 72 to 75 % of Upflow Anaerobic Sludge Blanket (without any modification) . The removal efficiency of the anaerobic hybrid reactor came out to be low because of low hydraulic retention time of the reactors & there is likelihood of entrapped suspended solids. The monthly averaged values of COD are shown in table no. 5.3 with depiction in figure no. 5.6.

Biochemical oxygen demand(BOD) at the inlet of anaerobic hybrid reactor varied between 2520 & 3500 mg/L and corresponding BOD values varied between 320 and 960 mg/L at the outlet of AHR . This has been shown in figure no. 5.10. The BOD removal in % ranged between 59.43 & 92.59 as shown in figure no. 5.11. The BOD removal efficiency of the anaerobic hybrid reactor came out to be 74.77 %. It is quite good. The monthly averaged values of BOD reduction are shown in table 5.4 with depiction in figure no 5.9.

As shown in figure no. 5.8, the volatile acids varied between 540 and 980 mg/L at outlet of anaerobic hybrid reactor as shown in figure no. 5.13. Total volatile acids should not be greater than 1000 mg/L. The monthly averaged values of volatile acids are shown in table no. 5.5 with depiction in figure no. 5.12.

The reason behind this is that:

Increased volatile acids will further inhibit the methanogens which convert the substrates in to biogas & help in proper running of anaerobic reactor. Methanogens & acidogens carry the anaerobic digestion process in dynamic equilibrium & dominance of acidogens can inhibit anaerobic reactions & hence hinder the proper functioning of anaerobic reactor. The substrates that methanogens consume are carbon dioxide & hydrogen, formate, acetate, methanol, methylamines & carbon monoxide.

The typical energy yielding conversion equations involving the above mentioned substrates yield either carbon dioxide & water or carbon dioxide & methane. Methanogens & acidogens form a syntropic relationship or mutual beneficial combination & methanogens convert fermentation end products such as hydrogen, formate & acetate to methane & carbon dioxide.

Methanogens are able to utilize the hydrogen produced by the acidogens because of their efficient hydrogenase. Because methanogens are able to maintain an extremely an extremely low partial pressure of hydrogen, the equilibrium of fermentation reaction is shifted towards the formation of more oxidized end products i.e formate & acetate. The utilization of hydrogen produced by the acidogens & other anerobes by methanogens is called interspecies hydrogen transfer. In effect methanogens remove compounds that will inhibit the growth of acidogens.

Total alkalinity at outlet of anaerobic hybrid reactor of brewery wastewater supernatant varied a great deal in range of 2000 to 3420 mg/L as shown in figure 5.19. The value of alkalinity of supernatant should be in the range of 2000 -4000 mg/L for proper working of anaerobic hybrid reactor. The monthly averaged values of alkalinity acids are shown in table no. 5.7 with depiction in figure no. 5.18. Sufficient alkalinity presence means that methanogenic bacteria can function & pH levels are maintained since lower alkalinity levels mean pH can go lower than 6.2 leading to acidic conditions & inhibit functioning of methanogenic bacteria. The rugged nature of the acid formers and the sensitive nature of the methane formers creates a bio system that is easily upset. The methanogens are temperature and pH sensitive. They operate in a pH range of 6.5 to 7.5. Movement to either side of this range quickly affects their metabolic rates and slows or stops methane production.

The production & accumulation of foam is a common problem associated with many anaerobic digesters. Foam is caused by many operational conditions. Foam first appears in the annular space between the floating cover & the digester wall & may completely coat the floating cover & spill over the coping of the digester wall Foam presents safety, housekeeping & malodour concerns as well as maintenance & operational problems.

Foam occurs when gas bubbles become entrapped in a liquid matrix. Gas commonly associated with anaerobic digestion include carbon dioxide, hydrogen sulfide, methane & nitrogen. Foaming occurs because surface tension of the sludge or liquid is reduced resulting in accumulation of solids over entrapped gas bubbles. Operational problems associated with foam production & accumulation include reduced sludge feed pumping & inversion of digester solids profile, that is thick solids are located at top of the digester & dilute solids are located at the bottom of the digester.

Maintenance problems associated with foam production & accumulation include fouling of gas collection compressors & recirculating pipes & gas binding of sludge recirculating pumps. The United Breweries Limited has eliminated this foaming by installing gas defoamer.

5.3 Activated Sludge Treatment

pH ranged from 7.4 to 9.2 for brewery wastewater at outlet of aeration tank This has been shown in figure no. 5.15. pH varied between 7.5 and 9.4 for brewery wastewater coming out of clarifier as shown in figure no. 5.17. The monthly averaged values of pH at outlet of aeration tank and outlet of clarifier are shown in table no. 5.6 with depiction in figure no. 5.14 and figure no. 5.16 respectively. pH of effluent from aeration tank & clarifier was in alkaline range which is favorable for bacteria growth which serves as a post treatment of anaerobic hybrid reactor. The pH range shows that wastewater was particularly alkaline This is because United Breweries Limited uses sodium hydroxide for Clean-In-Place purposes particularly fermenters.

Sludge volume index has been used as an indicator of settling properties of sludge. The values obtained in tests from outlet of aeration tank varied between 47 to 88 as shown in figure no. 5.21. SVI should be between 40 to 100 for good settling. So considering this the value seems good. That is sludge is settling well. The monthly averaged values of SVI are shown in table no. 5.8 with depiction in figure no. 5.20.

As shown in figure no 5.23, Values of mixed liquor suspended solids of aeration basin varied between 1900 & 2820 mg/L. The averaged monthly values of MLSS are shown in table no. 5.9 with depiction in figure no 5.22. This is in agreement with the fact that the aeration basin, MLSS is one of the most important operating parameters. Mixed - liquor concentrations significantly less than 1,000 mg/L do not settle well, while mixing and oxygen transfer may become limiting at MLSS above 6,000 mg/L. For a given process requirement, a higher MLSS concentration would require a smaller biological reactor but a larger clarifier to accommodate.

5.4 Effluent Treatment Plant

The COD values varied between 8040 and 9640 mg/L at anaerobic hybrid reactor inlet and the corresponding COD values at clarifier outlet varied between 240 & 660 mg/L as shown in figure no. 5.24. The variation shows that characteristics of brewery wastewater are little varied. The removal efficiency of effluent treatment plant installed at United Breweries Limited was 95.43 %. The monthly averaged values of COD reduction are shown in table no. 5.10 with depiction in figure no. 5.24.

As shown in figure no. 5.26, total suspended solids (TSS) varied between 1280 and 1840 mg/L at inlet of anaerobic hybrid reactor and the corresponding values of total suspended solids (TSS) at the clarifier outlet varied between 240 and 640 mg/L. The % TSS removal varied between 60.49 and 84.33 mg/L as shown in figure 5.27. The T.S.S removal efficiency of the effluent treatment plant is 74 % as shown in table no 5.9. The monthly averaged values are shown in table no. 5.11 with depiction in figure no. 5.25.

Total dissolved solids values at inlet of anaerobic hybrid reactor varied between 2020 mg/L & 3060 mg/L as shown in figure no. 5.29 and the corresponding values at clarifier outlet were measured to be between 1780 and 2620 mg/L. The % TDS removal varied between 1 & 25.43 as shown in figure no. 5.30. The % TDS removal was found to be 12.32 % as shown in table no. 5.12. The monthly averaged values are shown in figure no. 5.28. Total dissolved solids concentration is high at inlet of anaerobic hybrid reactor because of chemicals application in Clean-In-Place operations. This chemical contributes heavily to total dissolved solids & doesn't get removed with coagulants.

The reasons for this is that the use of alkaline cleaners with medium and low sodium concentrations can lead to reductions in sodium discharge from CIP in the range of 78-99% & reduce total dissolved solids in influent to anaerobic hybrid reactor. Even further reductions in sodium levels can be achieved by using KOH based products which do not contain sodium at all (almost 100% reduction in sodium discharge from CIP). However, the cost of KOH based cleaning agents is higher than that of NaOH, which is currently limiting its wide spread application in processing plants.

As shown in figure no. 5.32, biochemical oxygen demand(BOD) at the inlet of anaerobic hybrid reactor varied between 2180 & 3640 mg/L and the corresponding values of BOD at the outlet of clarifier varied between 180 & 640 mg/L. The % BOD removal varied between 77.5 and 94.31 as shown in figure 5.33. The BOD removal efficiency of the effluent treatment plant came out to be 90 % as shown in table 5.13 .The monthly averaged values of BOD reduction are shown in table no. 5.13

with depiction in figure 5.31. It is very good & has been possible because of a combination of an anaerobic hybrid reactor & activated sludge process.

5.5 Biogas Generation Potential

It was calculated based on the equation:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

From the equation it was calculated that every kilogram of COD produces 0.35 m^3 of CH_4 at STP.

5759 Kg of COD produces = 5759 * 0.35 = 2015.65 m^3 of CH_4

Table 5.1: Observed Variation of Wastewater flow in ETP

AvgFlo(	3 /D M	6:	6:	6:	6:	6:	6:	6:	6:	6:	**6:**
g AvFl	3 /H M	2(	2(	2(	2(	2(	2(	2(	2(	2!	
ToFa	3 /H M	1!	1!	1!	1!	8, 1!	1!	1!	1!	1!	
Flow4	3 /H M	2(	2!	27	27	27	2:	2(	2!	27	
Flow3	3 /H M	2(	2(	2!	2!	2!	2!	27	27	2!	
Flow2	3 /H M	2(	2.	2:	2!	2.	2!	2!	27	2.	
Flow1	3 /H M	2!	2!	4 2!	2(	2(	27	2.	2!	2(	
Flown	3 /H M	2(	2(	2(	27	2!	2(	2!	2(	2!	
Flow1	3 /H M	2!	2!	2.	2!	2.	2:	2.	2!	2(	
Dat		**1/**	**4/**	**7/**	**1/**	**1(**	**17**	**2'**	**2!**	**08 2!**	**A**

g Av	**M^3/DA**	60	60	62	60	62	61	62	61	60	60	**61**
Av	**M^3/HR**	25	25	26	25	26	25	25	25	25	25	
Tol	**M^3/HR**	15	15	15	15	15	15	15	15	15	5 1	
Flo	**M^3/HR**	27	24	28	29	28	24	27	26	25	2	
Flo	**M^3/HR**	23	31	28	20	27	28	27	25	27	26	
Flo	**M^3/HR**	20	27	25	20	27	25	27	23	20	24	
Flo	**M^3/HR**	23	24	25	20	20	27	27	20	25	20	
Flo	**M^3/HR**	20	25	23	22	22	24	20	27	20	27	
Flo	**M^3/HR**	24	18	25	20	24	25	24	25	24	23	
Dat		**1/**	**4/**	**20 7/**	**10**	**13**	**17**	**21**	**08 24**	**27**	**30**	**A**

g AvF	**M^3/DA**	54	55	56	57	53	56	58	54	56	56	**55**
vg A F	**M^3/HR**	22	22	23	23	22	23	24	22	23	23	
ToE	**M^3/HR**	13	13	14	14	13	14	8 14	13	14	14	
Flo	**M^3/HR**	25	28	27	21	18	20	28	18	27	20	
Flo	**M^3/HR**	23	21	20	27	24	20	20	18	21	25	
Flo	**M^3/HR**	25	21	18	22	22	25	20	21	18	20	
Flo	**M^3/HR**	.5 21	23	22	25	21	23	25	25	20	23	
Flo	**M^3/HR**	23	22	23	25	24	21	22	23	24	24	
Flo	**M^3/HR**	18	21	22	22	22	23	24	23	22	22	
Dat		**1/**	**4/**	**00 7/**	**1(**	**13**	**08 17**	**21**	**24**	**27**	**30**	**A**

Avg Flow (	**M³/D**	53	55	50	50	51	55	53	53	52	53	**53**
Avg Flow	**M³/H**	22	22	23	2	21	23	22	22	21	22	
Total Flow	**M³/H**	13	13	14	12	12	13	13	13	13	13	
Flow 4 pa	**M³/H**	22	24	20	17	17	17	18	18	21	24	
Flow 3 pa	**M³/H**	25	24	22	17	20	25	27	20	20	22	
Flow 2 pa	**M³/H**	20	21	21	24	10	25	18	19	20	.2 23	
Flow 1 pa	**M³/H**	21	23	20	19	22	20	22	21	22	22	
Flow noa	**M³/H**	24	24	20	23	20	23	21	20	20	20	
Flow 1 a	**M³/H**	18	20	23	24	20	27	25	20	20	21	
Date		**1/**	**4/**	**20 7/**	**0/ 1**	**13**	**17**	**21**	**24**	**27**	**30**	**A**

g Av	**^{3}/DA M**	52	53	51	50	51	51	50	51	53	51	50	**51**
g Av	**^{3}/HR M**	21	22	21	20	21	21	21	21	22	.3 21	20	
Tot	**^{3}/HR M**	13	13	12	12	12	12	12	12	13	12	12	
Flo	**^{3}/HR M**	22	21	22	12	21	20	17	24	24	16	17	
Flo	**^{3}/HR M**	28	25	16	20	15	17	17	25	20	27	19	
t Flo	**^{3}/HR M**	20	20	23	24	25	20	18	17	15	17	20	
Flo	**^{3}/HR M**	22	24	20	24	23	27	25	16	18	21	23	
Flo	**^{3}/HR M**	20	21	23	23	24	25	20	21	25	24	18	
Flo	**^{3}/HR M**	17	21	16	20	16	18	21	24	25	21	20	
Dat		**1/**	**4/**	**7/**	**10**	**13**	**17**	**21**	**24**	**26**	**29**	**31**	**A**

g Av	^{3}/DA M	50	50	51	50	51	51	51	51	51	50	**51**
g Av	^{3}/H M	20	20	21	20	21	21	21	21	21	21	
Tot	^{3}/H M	12	12	12	12	12	12	12	12	12	12	
Flo	^{3}/H M	20	18	17	18	23	25	27	26	22	21	
Flo	^{3}/H M	20	18	18	16	11	20	20	21	16	16	
Flo	^{3}/H M	20	18	22	22	23	22	22	21	19	20	
Flo	^{3}/H M	21	22	22	24	18	21	20	22	23	21	
Flo	^{3}/H M	23	22	22	26	26	22	20	15	22	21	
Flo	^{3}/H M	18	23	24	15	26	17	17	21	23	24	
Da		**1/**	**4/**	**7/**	**10**	**12**	**13**	**17**	**21**	**25**	**29**	**A**

g Av	**^{3} DA M**	5	5	5	5	5	5	5	5	5	5	**5**
Av	**^{3} /H M**	2	2	2	2	2	2	2	2	2	2	
To	**^{3} /H M**	1	1	1	1	1	1	1	1	1	1	
Fl	**^{3} /H M**	1	1	1	2	2	1	1	1	1	2	
Fl	**^{3} /H M**	2	2	1	2	1	2	2	2	2	2	
Fl	**^{3} /H M**	2	2	2	1	2	1	1	1	2	2	
Fl	**^{3} /H M**	1	1	2	1	1	2	1	1	2	1	
Fl	**^{3} /H M**	2	2	2	7 2	2	2	2	2	2	2	
Fl	**^{3} /H M**	1	1	2	2	2	1	2	2	2	2	
Da		**1/**	**4/**	**7/**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**A**

g F Av(	**3/DA M**	53	7. 55	54	55	54	50	50	50	55	57	**55**
g F Av	**3/HF M**	22	23	22	22	22	23	23	23	22	23	
Tol	**3/HF M**	13	13	13	13	13	14	14	14	13	14	
Flo	**3/HF M**	20	21	22	23	6. 21	27	21	28	20	20	
Flo	**3/HF M**	21	25	21	22	23	21	23	22	21	20	
Flo	**3/HF M**	29	20	21	20	17	18	19	24	21	22	
Flo	**3/HF M**	17	30	30	21	22	22	23	24	25	28	
Flo	**3/HF M**	20	21	22	24	25	20	28	2	20	23	
Flo	**3/HF M**	23	20	18	19	20	23	24	20	22	21	
Dat		**1/**	**4/**	**7/**	**10**	**13**	**17**	**20**	**23**	**26**	**29**	**A**

Fl Av	**M^3/DA**	5	57	5	54	55	57	53	57	55	5	**5**
Flo Av	**M^3/HR**	23	24	23	22	23	23	22	24	23	23	
Tol	**M^3/HR**	14	14	14	13	13	14	13	14	13	14	
Flo	**M^3/HR**	3	7 20	27	18	19	25	20	27	28	20	
Flo	**M^3/HR**	20	21	22	20	27	17	10	19	20	20	
Flo	**M^3/HR**	28	25	22	21	20	27	25	24	10	21	
Flo	**M^3/HR**	20	3	22	24	25	20	27	28	29	28	
Flo	**M^3/HR**	21	23	22	20	2	21	18	27	21	22	
Flo	**M^3/HR**	18	22	23	20	24	25	18	17	21	21	
Da		**1/**	**4/**	**7/**	**10**	**13**	**17**	**20**	**23**	**26**	**29**	**A**

Fl Av	**3 /DA M**	58	62	57	59	59	58	58	61	60	59	**59**
Fl Av	**3 /HR M**	24	25	23	24	24	24	24	25	25	24	
Tot	**3 /HR M**	14	15	14	14	14	14	14	15	15	14	
Fl	**R 3 /H M**	31	22	22	22	20	24	21	22	21	22	
Fl	**3 /HR M**	25	20	23	24	25	22	25	20	27	31	
Fl	**3 /HR M**	25	20	23	24	24	25	26	27	20	23	
Fl	**3 /HR M**	22	24	20	27	20	28	27	28	0. 31	23	
Fl	**3 /HR M**	20	30	23	22	22	24	24	25	27	20	
Fl	**3 /HR M**	21	24	25	27	28	21	22	23	25	20	
Da		**1/**	**4/**	**7/**	**10**	**14**	**17**	**20**	**23**	**27**	**30**	**A**
Fl Av	**3 /DA M**	58	63	60	62	61	61	60	62	61	61	**61**

Fl Av	**^{3}/HR M**	24	20	25	25	25	25	25	25	25	25	
Tol	**^{3}/HR M**	14	15	15	15	15	15	15	15	15	15	
at 4 Flo	**^{3}/HR M**	31	20	27	28	23	24	25	20	27	20	
Flo	**^{3}/HR M**	22	24	25	21	23	31	28	30	28	27	
Flo	**^{3}/HR M**	21	20	22	28	30	28	24	21	20	22	
Flo	**^{3}/HR M**	20	25	20	24	22	21	2 21	21	20	28	
Flo	**^{3}/HR M**	20	24	25	27	20	21	23	20	21	23	
Flo	**^{3}/HR M**	24	30	23	25	20	20	27	28	29	24	
Dat		**1/**	**4/**	**7/**	**10**	**13**	**16**	**19**	**22**	**25**	**28**	**A**

Flo Av	^{3}/DA M	63	63	64	63	63	63	63	**63**
Fl Av	^{3}/HR M	26	26	26	26	26	26	26	
Tol	^{3}/HR M	15	15	16	15	15	15	15	
Flo	^{3}/HR M	24	25	26	27	23	24	27	
Flo	^{3}/HR M	27	25	26	28	28	25	25	
Flo	^{3}/HR M	27	28	19	20	23	24	27	
Flo	^{3}/HR M	25	21	26	26	24	23	24	
Flo	^{3}/HR M	26	27	29	28	30	31	24	
Flo	^{3}/HR M	26	30	32	28	27	28	29	
Da		**1/1**	**5/1**	**9/1**	**13**	**17**	**21**	**25**	**Av**

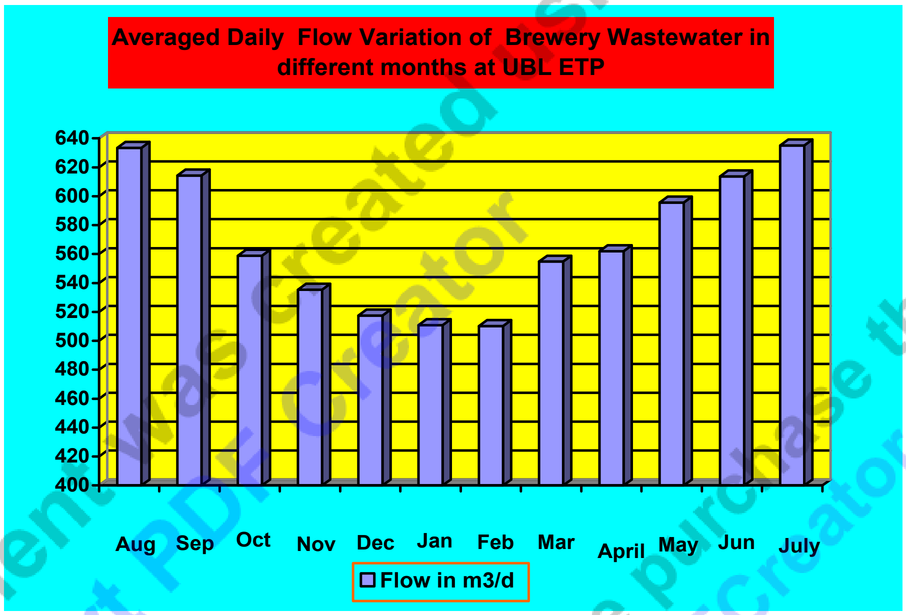

Figure 5.1: Averaged daily flow of brewery wastewater influent in different months at ETP

Table 5.2: pH values at Inlet & Outlet of AHR

Month	pH at AHR Inlet	pH at AHR Outlet
Aug 2008	6.4	8.1
Sep 2008	6.6	7.8
Oct 2008	6.8	7.9
Nov 2008	6.5	8
Dec 2008	6.2	8.1
Jan 2009	6.6	8.2
Feb 2009	6.8	8.3
Mar 2009	6.7	7.9
Apr 2009	6.3	8.1
May 2009	6.4	8.2
Jun 2009	6.7	8.3
Jul 2009	6.4	8.3
Average Value	**6.5**	**8.1**

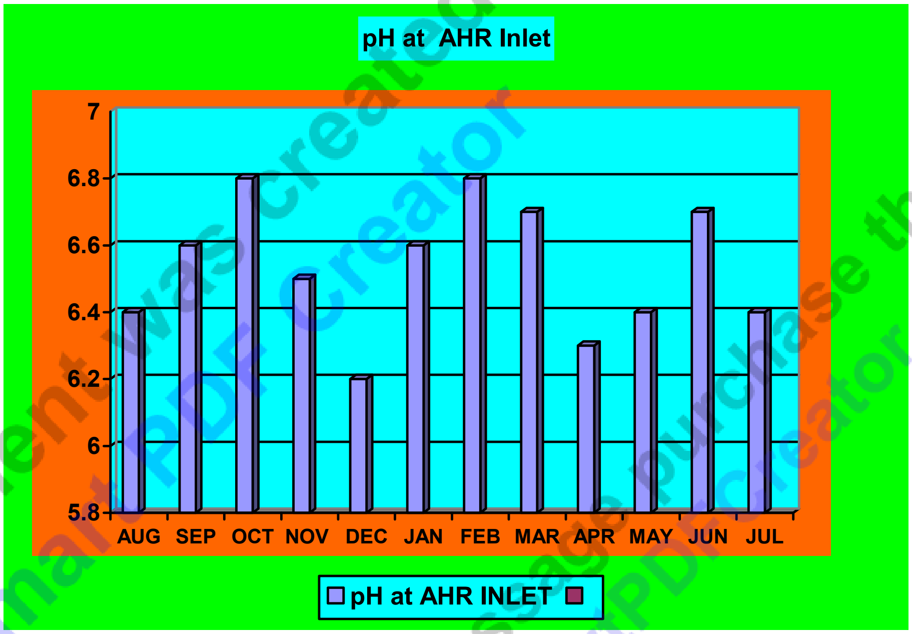

Fig 5.2: pH at AHR Inlet at ETP (Averaged monthly values)

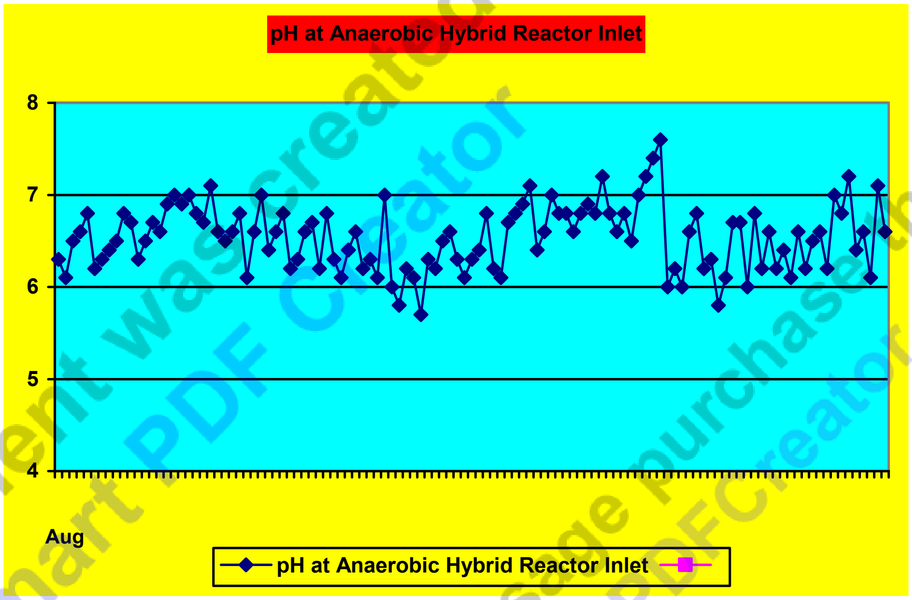

Fig 5.3: pH at AHR Inlet at ETP (All values recorded)

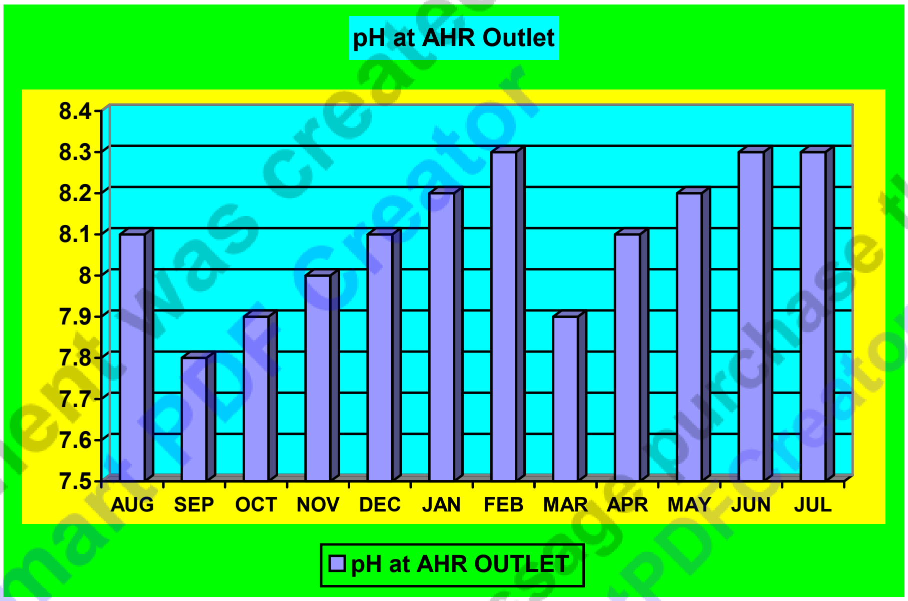

Fig 5.4: pH at AHR Outlet at ETP (Averaged monthly values)

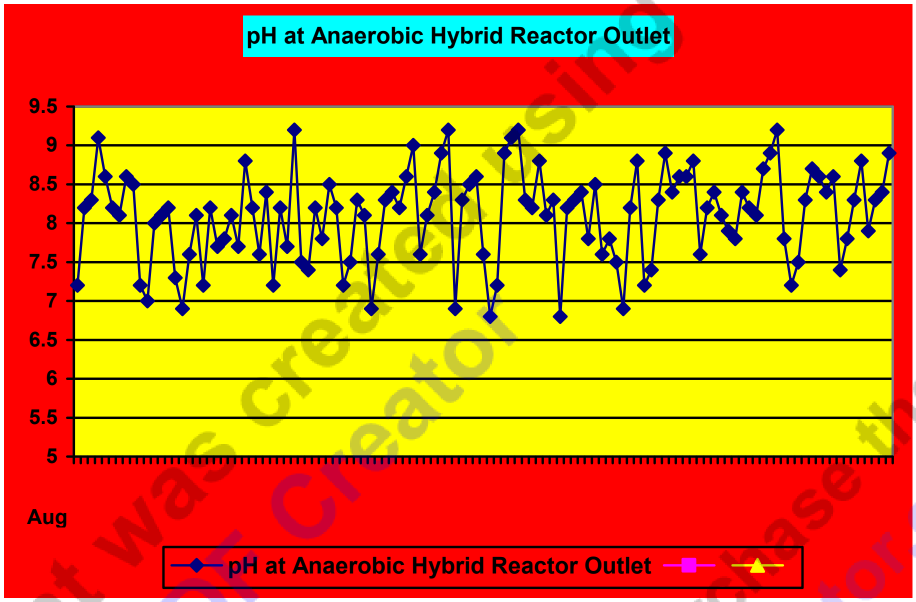

Fig 5.5: pH at AHR Outlet of ETP (All values recorded)

Table 5.3: COD Reduction in A.H.R at UBL

Month	C.O.D at A.H.R Inlet, mg/L	C.O.D at A.H.R Outlet, mg/L	Reduction in C.O.D at A.H.R, mg/L	Reducti on % of C.O.D in A.H.R
Aug 2008	9280	1660	7660	82.54
Sep 2008	9000	1680	7320	81.33
Oct 2008	9140	1680	7460	81.66
Nov 2008	9060	1740	7320	80.79
Dec 2008	8880	1660	7220	81.31
Jan 2009	8820	1620	7200	81.63
Feb 2009	8400	1660	6740	80.23
Mar 2009	8820	1620	7200	81.63
Apr 2009	8640	1640	7000	81.02
May 2009	9020	1540	7480	82.93
Jun 2009	9100	1720	7380	81.1
Jul 2009	9260	1600	7660	80.97
Average Value				**78**

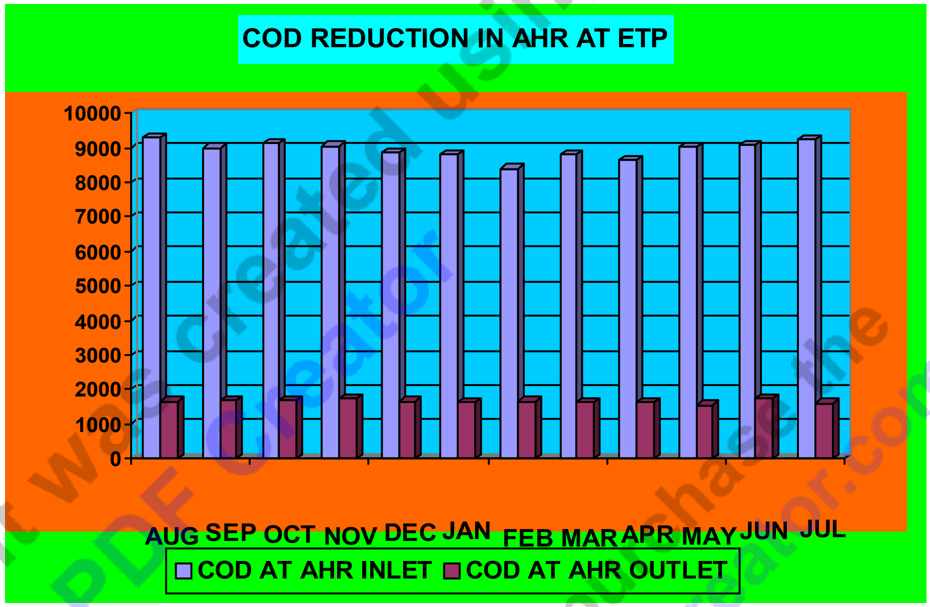

Fig 5.6: COD reduction in AHR (Averaged monthly values)

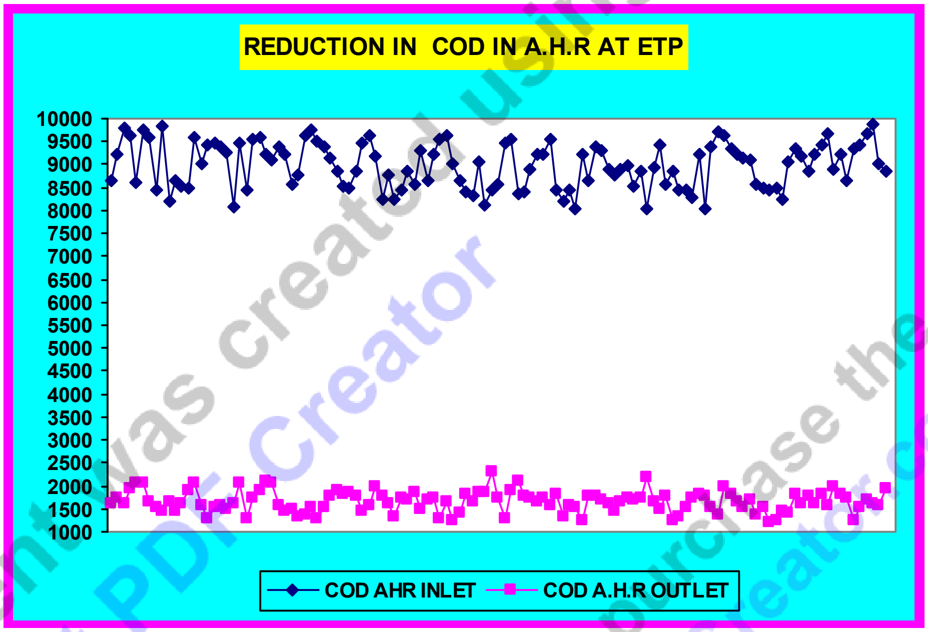

Fig 5.7: COD reduction in AHR (All values recorded)

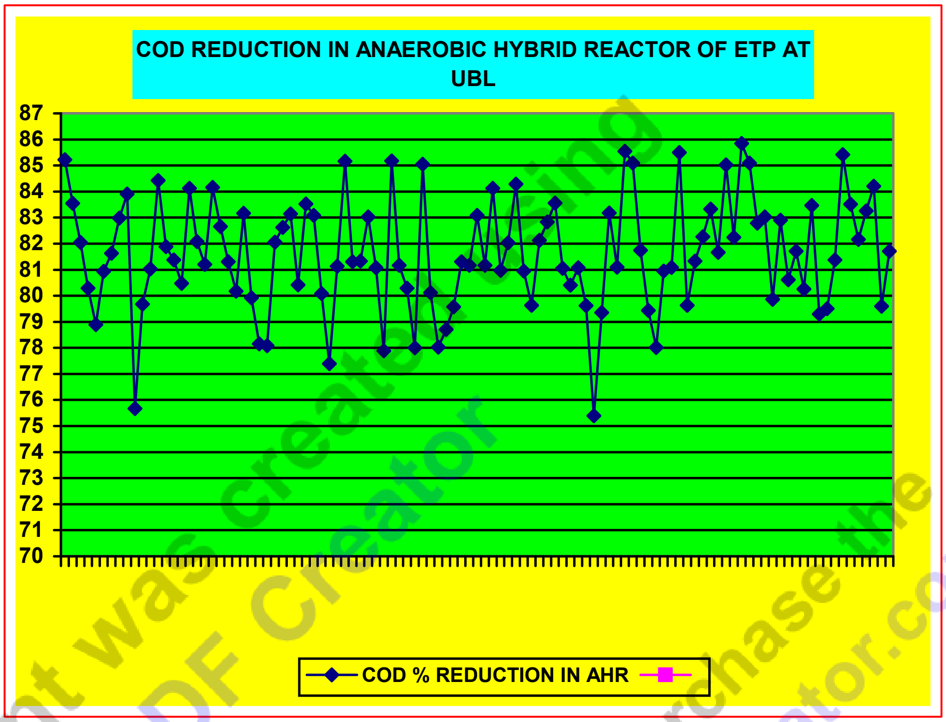

Fig 5.8: COD reduction in % in AHR (all values recorded)

Table 5.4: BOD Reduction in AHR at UBL

Month	B.O.D at the Inlet of A.H.R, mg/L	B.O.D at the Outlet of A.H.R, mg/L	Overall Reduction of B.O.D in A.H.R, mg/L	Overall % Reduction of B.O.D in A.H.R
Aug 2008	3020	780	2240	74.17
Sep 2008	3000	660	2540	84.67
Oct 2008	2920	740	2180	74.66
Nov 2008	3320	820	2500	75.3
Dec 2008	3220	760	2460	76.4
Jan 2009	3180	840	2340	73.58
Feb 2009	3160	680	2480	78.48
Mar 2009	3100	840	2260	72.9
Apr 2009	3180	920	2260	71.07
May 2009	2960	860	2100	70.95
Jun 2009	3040	900	2140	70.39
Jul 2009	3140	600	2540	80.89
Average Value				**74.77**

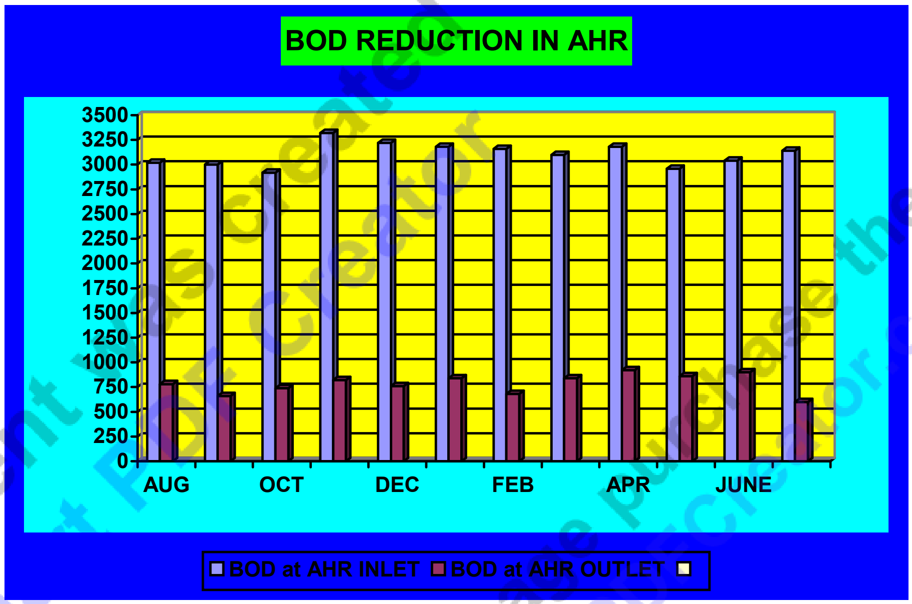

Figure 5.9: BOD Reduction in AHR (Averaged Monthly Values)

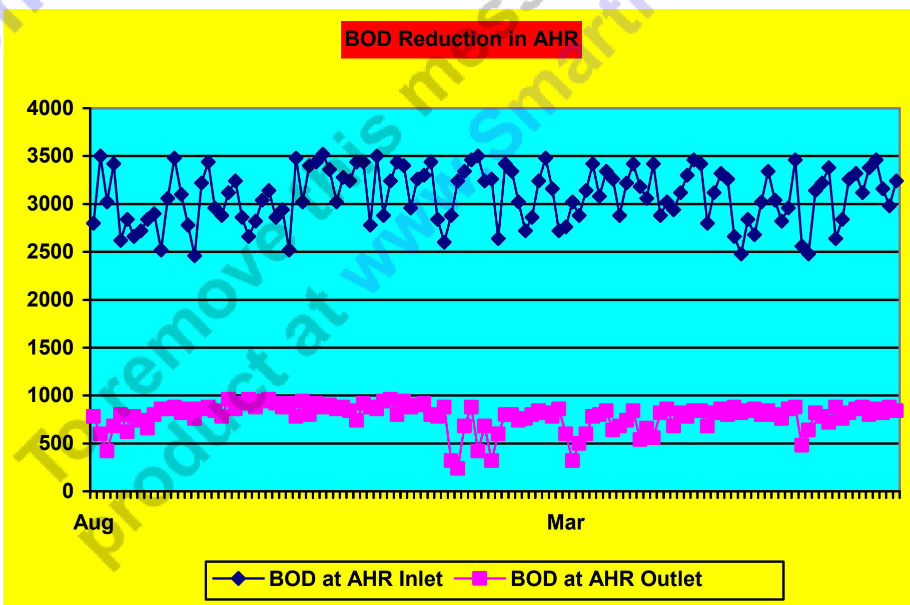

Fig 5.10: BOD reduction in AHR (All values recorded)

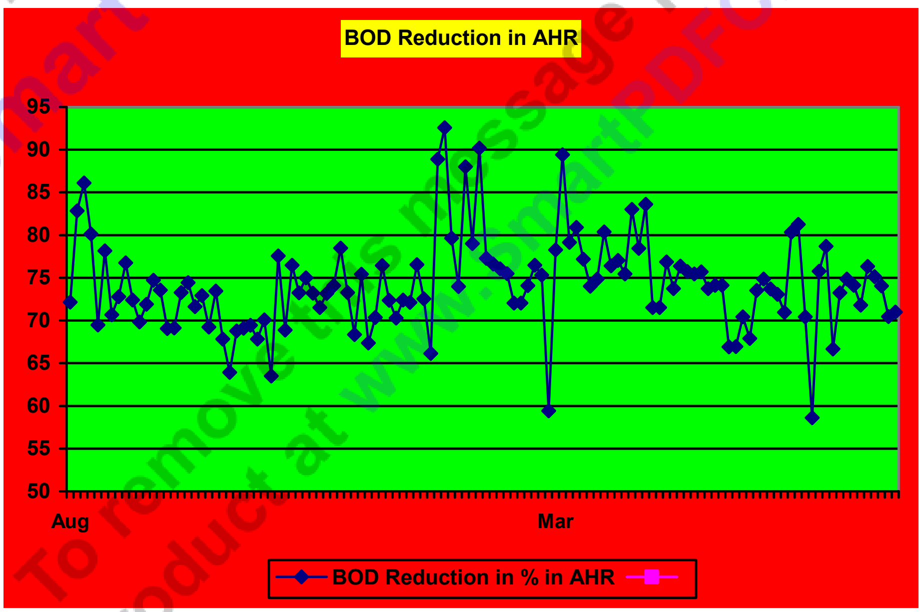

Fig 5.11: BOD reduction in % in AHR (All Values Recorded)

Table 5.5: Total Volatile Acids in A.H.R

Month	**Total Volatile Acids (VA) for Proper Functioning of A.H.R, mg/L**	**Total VAs at Outlet of A.H.R, mg/L**
Aug 2008	1000	760
Sep 2008	1000	840
Oct 2008	1000	780
Nov 2008	1000	800
Dec 2008	1000	860
Jan 2009	1000	780
Feb 2009	1000	800
Mar 2009	1000	760
Apr 2009	1000	740
May 2009	1000	720
Jun 2009	1000	880
Jul 2009	1000	820
Average Value		**795**

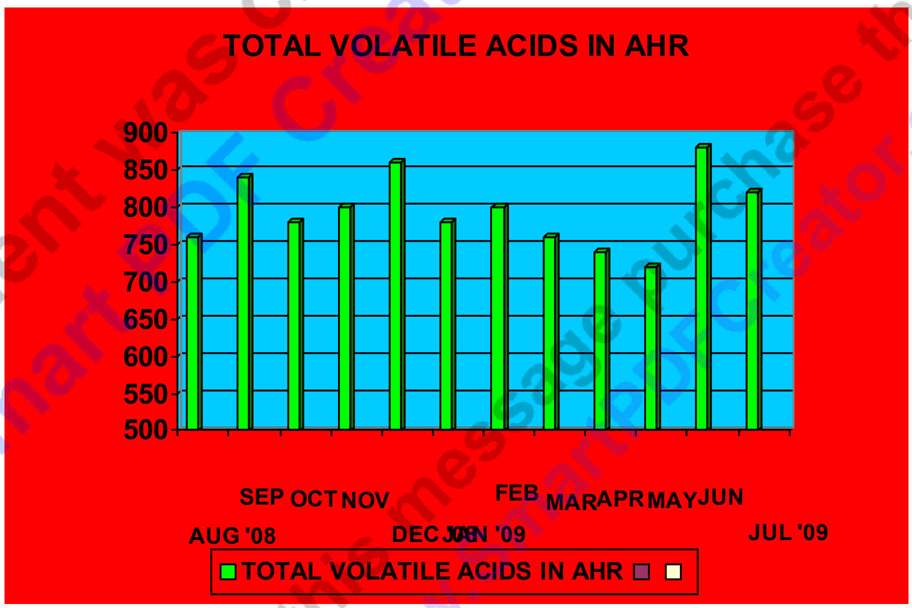

Figure 5.12: **Total Volatile Acids in AHR (Averaged Monthly Values)**

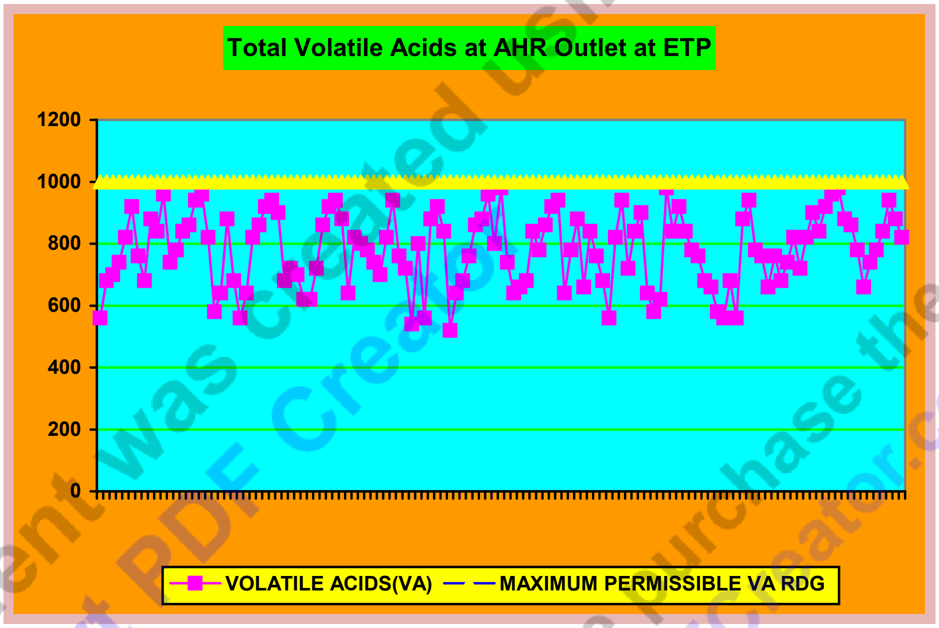

Fig 5.13: Total Volatile Acids at Outlet of AHR (All Values Recorded)

Table 5.6: pH values at Aeration Tank & Clarifier Outlet

Month	pH at Aeration Tank Outlet	pH at Clarifier Outlet
Aug 08	8.5	8.1
Sep 08	8.6	7.6
Oct 08	8.4	8.4
Nov 08	8.1	8.3
Dec 08	7.8	8.6
Jan 09	7.9	8.2
Feb 09	7.9	7.8
Mar 09	8.4	7.9
Apr 09	8.2	7.8
May 09	8.1	8.0
Jun 09	8.3	7.7
Jul 09	8.2	8.5
Average Value	**8.2**	**8.1**

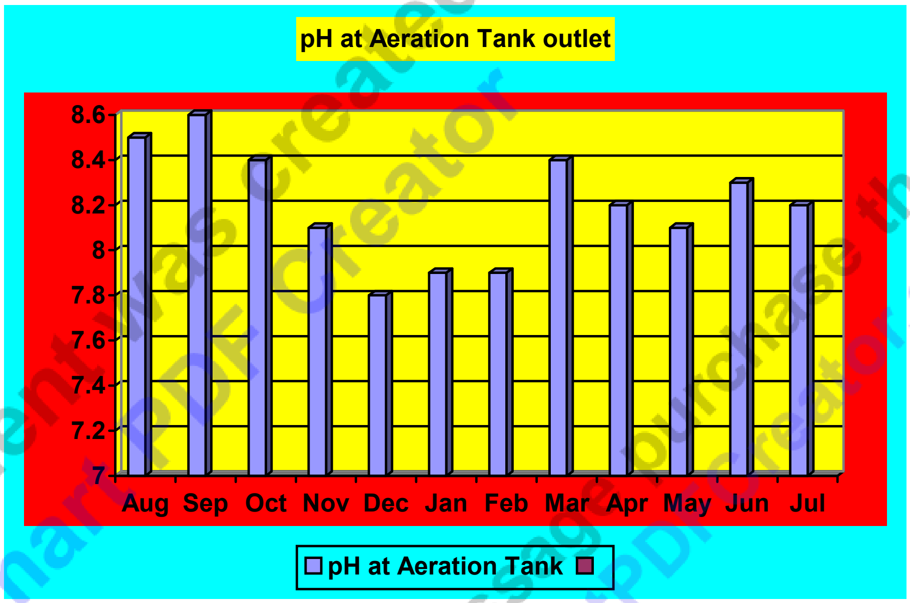

Fig 5.14: pH at Aeration Tank Outlet (Averaged Monthly Values)

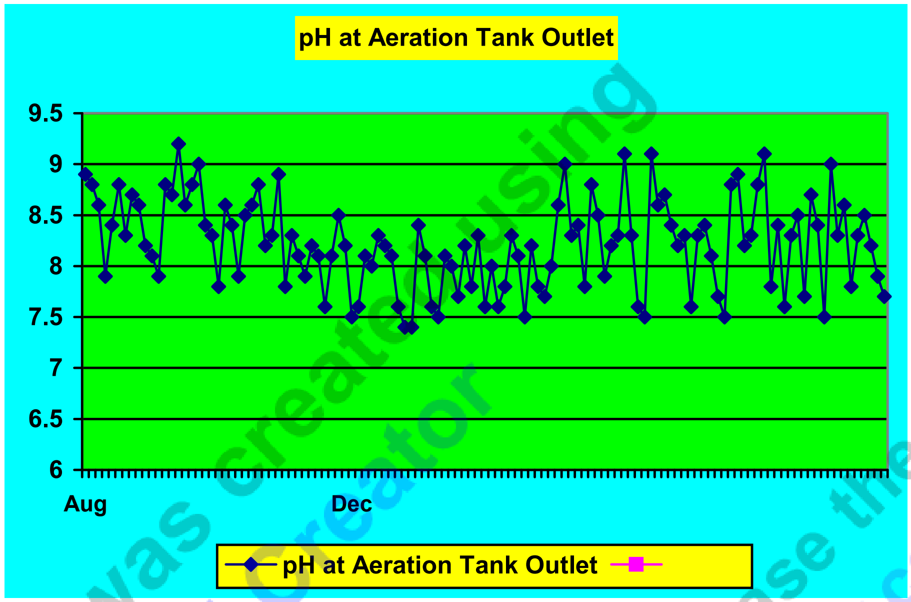

Fig 5.15: pH at Aeration Tank Outlet (All Values Recorded)

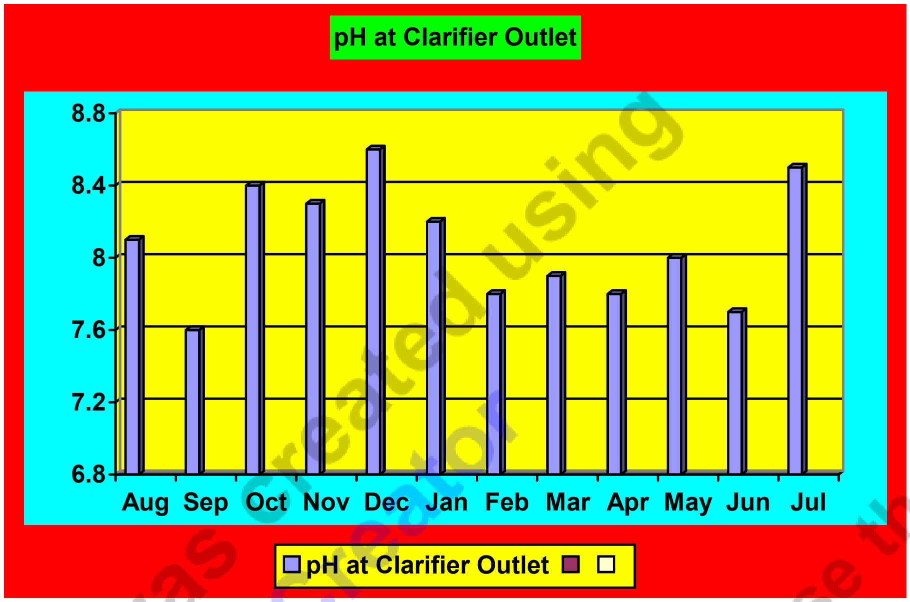

Fig 5.16: pH at Clarifier Outlet (Averaged Monthly Values)

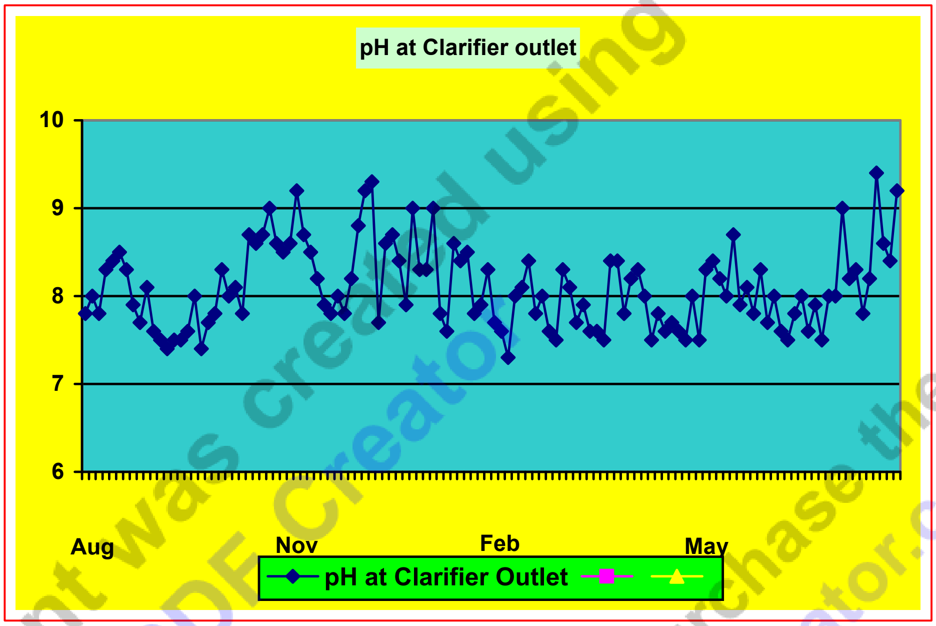

Fig 5.17: pH at Clarifier Outlet (All Values Recorded)

Table 5.7: Alkalinity in Aeration Tank of ETP at UBL

Month	Minimum Value of Alkalinity mg/L	Value of Total Alkalinity in Aeration Tank, mg/L	Maximum Value of Alkalinity, mg/L
Aug 2008	2000	2640	4000
Sep 2008	2000	2560	4000
Oct 2008	2000	2620	4000
Nov 2008	2000	2400	4000
Dec 2008	2000	2720	4000
Jan 2009	2000	2800	4000
Feb 2009	2000	2720	4000
Mar 2009	2000	2660	4000
Apr 2009	2000	2700	4000
May 2009	2000	2520	4000
Jun 2009	2000	2440	4000
Jul 2009	2000	2500	4000
Average Value		**2607**	

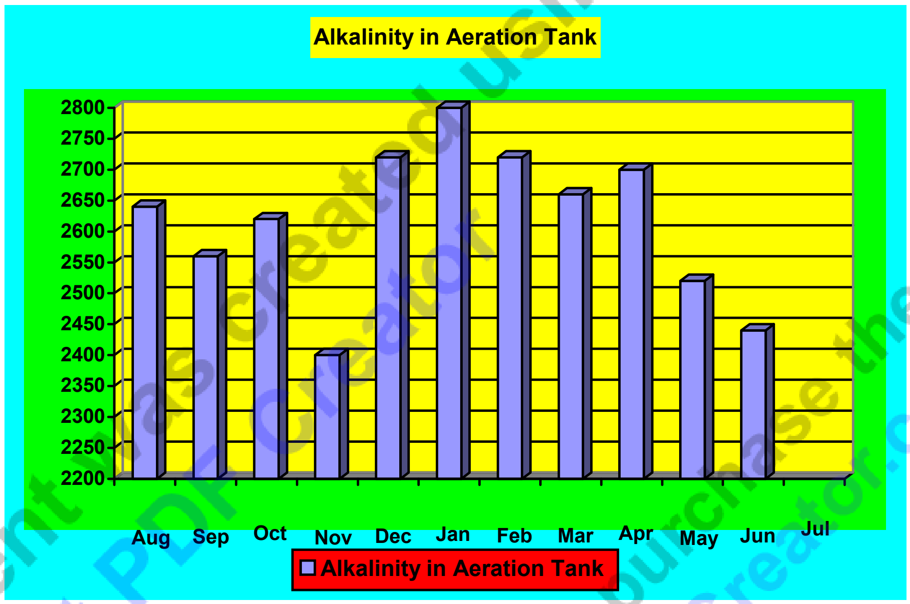

Fig 5.18: Total Alkalinity at AHR outlet (Monthly Averaged Values)

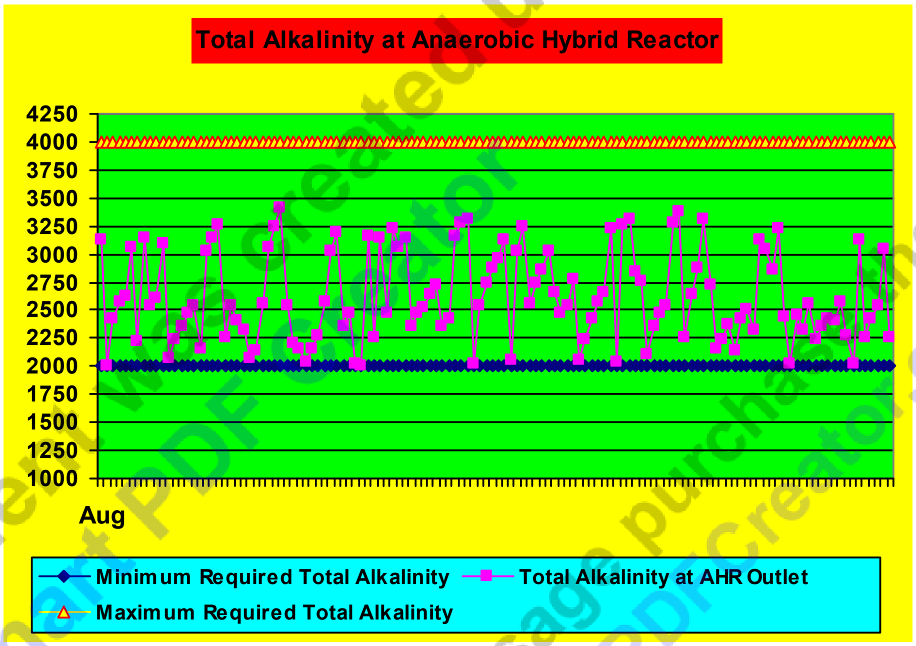

Fig 5.19: Total Alkalinity at AHR outlet (All Values Recorded)

Table 5.7: SVI in Clarifier of ETP

Month	SVI in Aeration Tank
Aug 2008	70
Sep 2008	65
Oct 2008	68
Nov 2008	62
Dec 2008	64
Jan 2009	60
Feb 2009	66
Mar 2009	64
Apr 2009	68
May 2009	58
Jun 2009	56
Jul 2009	54
Average Value	**63**

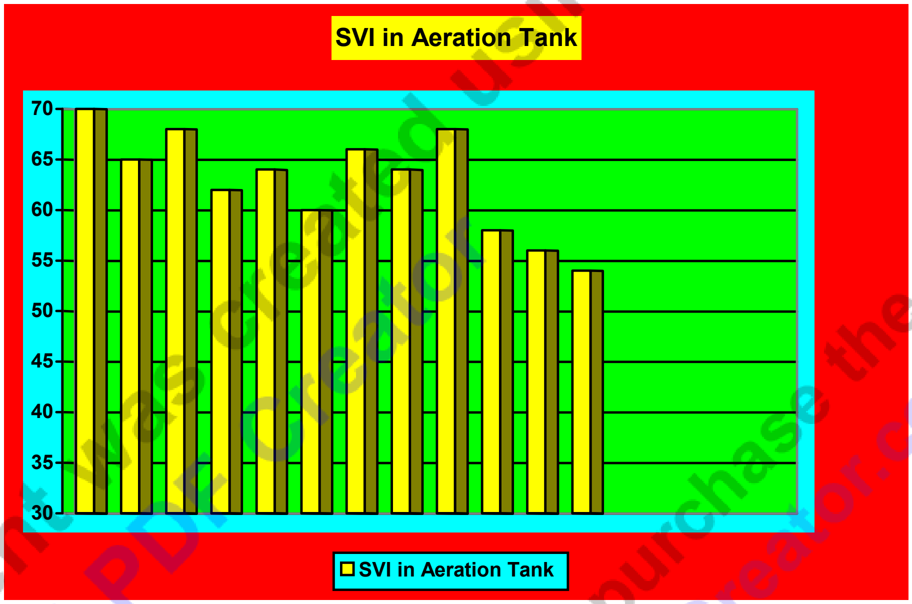

Figure 5.20: **SVI in Clarifier (Averaged Monthly Values)**

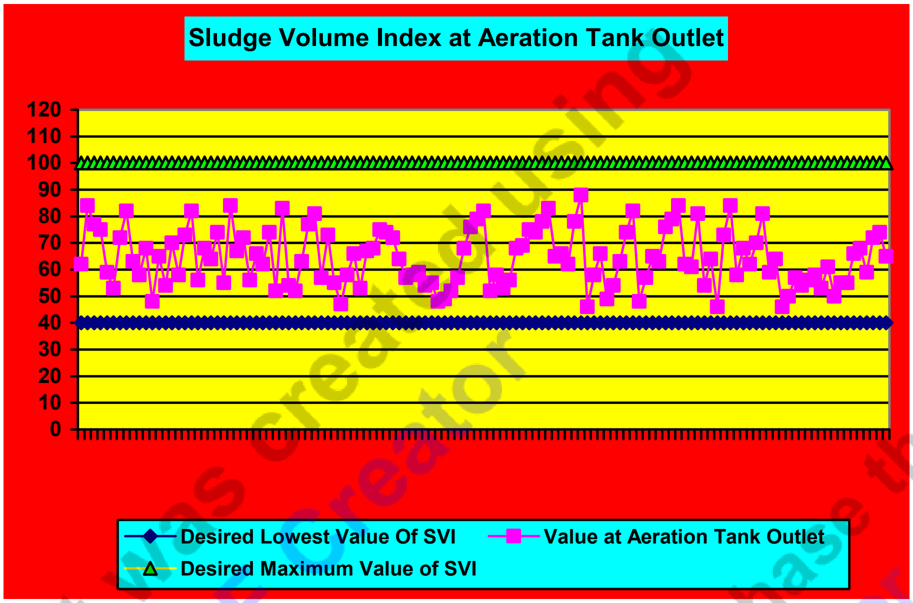

Fig 5.21: Values of SVI in Clarifier (All Values Recorded)

Table 5.9: Mixed Liquor Suspended Solids in aeration tank at ETP

Month	Minimum MLSS conc. Mg/L	Value of MLSS in Aeration Tank, mg/L	Maximum Value of MLSS required, mg/L
Aug 2008	1000	2440	6000
Sep 2008	1000	2560	6000
Oct 2008	1000	2380	6000
Nov 2008	1000	2360	6000
Dec 2008	1000	2320	6000
Jan 2009	1000	2400	6000
Feb 2009	1000	2460	6000
Mar 2009	1000	2480	6000
Apr 2009	1000	2420	6000
May 2009	1000	2380	6000
Jun 2009	1000	2060	6000
Jul 2009	1000	2340	6000
Average Value		**2383**	

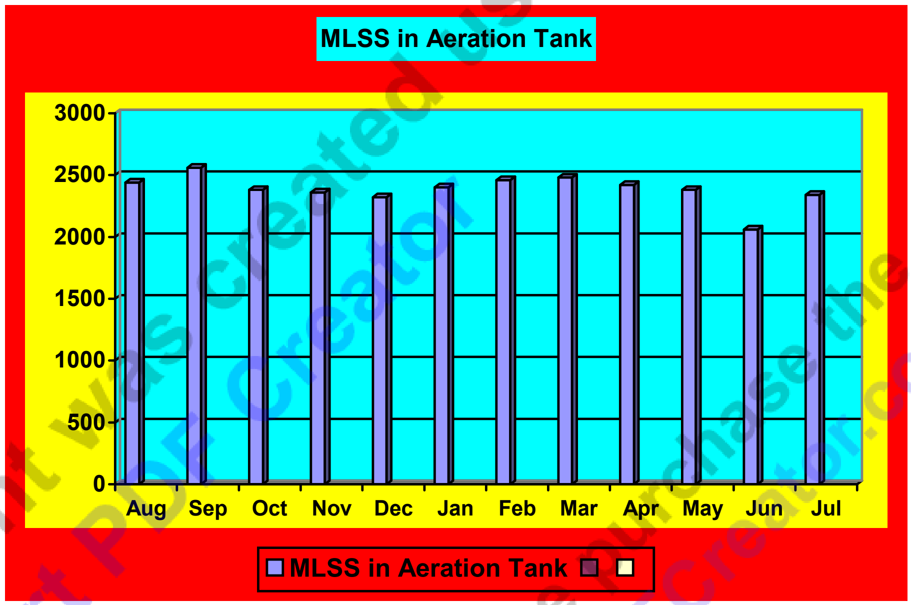

Fig 5.22: MLSS in Aeration Tank (Monthly Averaged Values)

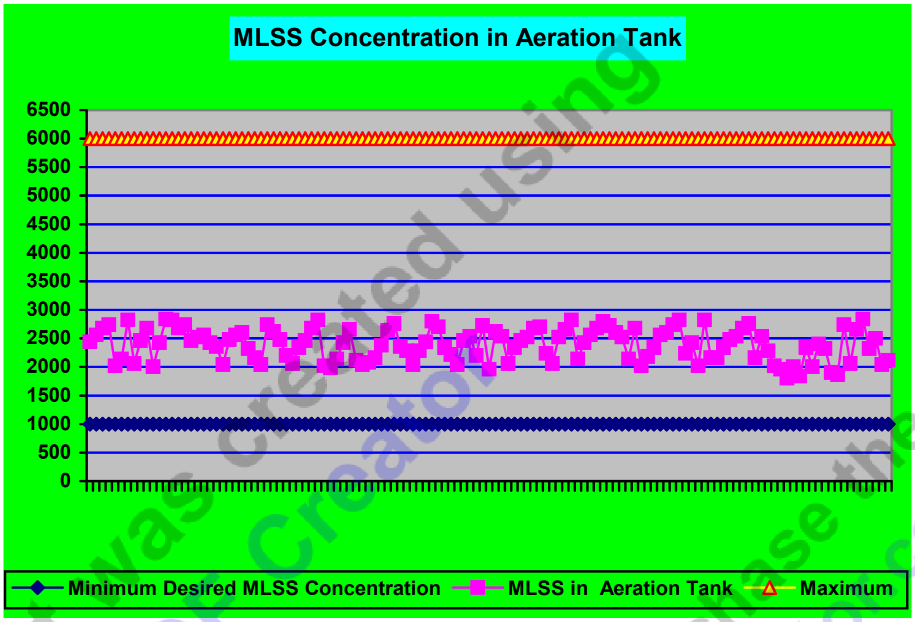

Fig 5.23: MLSS in aeration tank of ETP (All Values Recorded)

Table 5.10: COD Reduction in E.T.P at UBL

Month	C.O.D at A.H.R Inlet, mg/L	C.O.D at Clarifier Outlet, mg/L	Reduction in C.O.D in ETP	Reduction % of C.O.D in E.T.P
Aug 2008	9280	431	8839	95.24
Sep 2008	9000	378	8622	95.8
Oct 2008	9140	358	8782	96.08
Nov 2008	9060	390	8670	95.7
Dec 2008	8880	425	8455	95.21
Jan 2009	8820	413	8407	95.32
Feb 2009	8400	380	8020	95.48
Mar 2009	8820	407	8413	95.38
Apr 2009	8640	358	8282	95.86
May 2009	9020	404	8616	95.52
Jun 2009	9100	543	8557	94.03
Jul 2009	9260	426	8834	95.4
Average Value				**95.43**

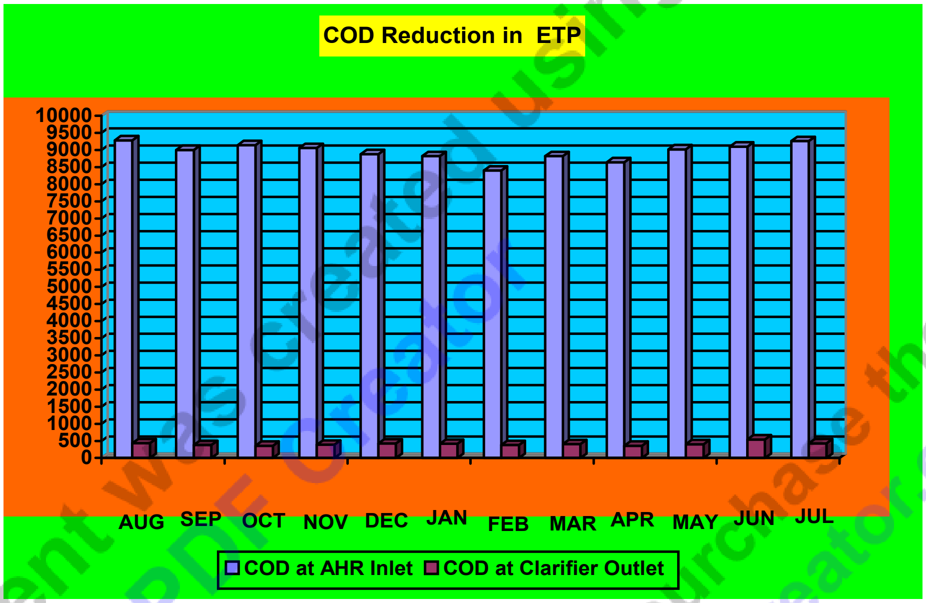

Figure 5.24: Total COD reduction in ETP (Averaged Monthly Values)

Table 5.11: TSS Reduction in Effluent Treatment Plant

Month	T.S.S at A.H.R Inlet, mg/L	T.S.S at Clarifier Outlet, mg/L	Reduction in T.S.S in E.T.P, mg/L	Reduction % of T.S.S in E.T.P
Aug 2008	1580	380	1200	75.95
Sep 2008	1640	360	1280	78.05
Oct 2008	1620	400	1220	75.31
Nov 2008	1600	420	1180	73.75
Dec 2008	1640	440	1200	73.17
Jan 2009	1660	460	1200	72.29
Feb 2009	1580	480	1100	69.62
Mar 2009	1620	440	1180	72.84
Apr 2009	1600	460	1140	71.25
May 2009	1580	380	1200	75.95
Jun 2009	1640	500	1140	69.51
Jul 2009	1840	360	1480	80.43
Average Value				**74**

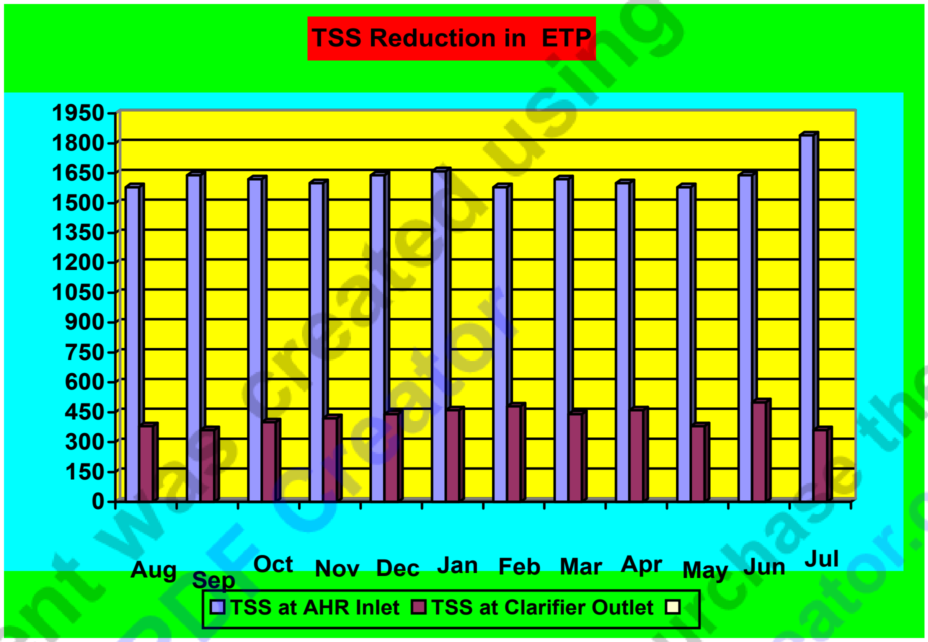

Figure 5.25: **Total TSS reduction in ETP (Monthly Averaged Values)**

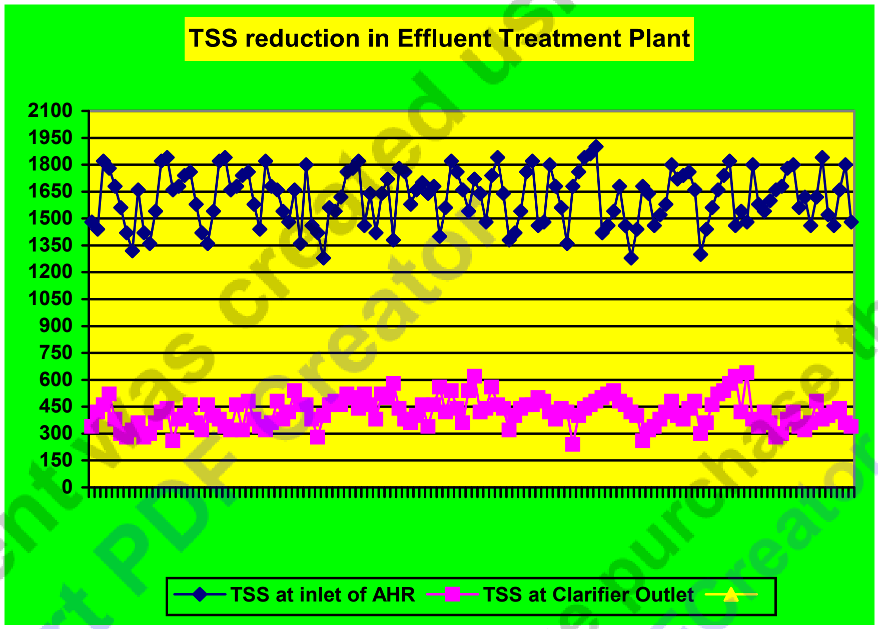

Figure 5.26: TSS reduction in ETP (All Values Recorded)

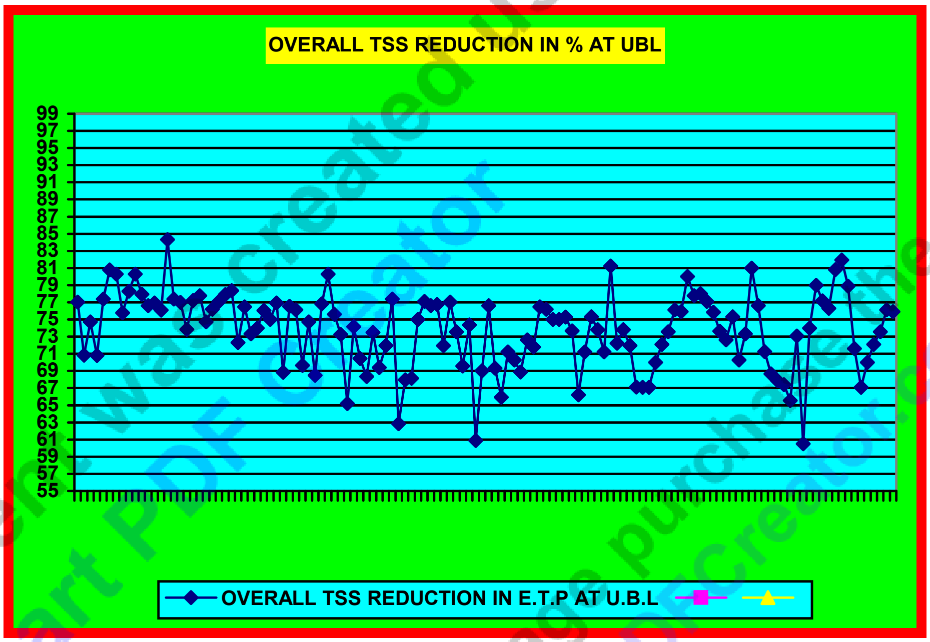

Figure 5.27: TSS reduction in % in ETP (All Values Recorded)

Table 5.12: TDS Reduction in Effluent Treatment Plant

Month	T.D.S at A.H.R Inlet, mg/L	T.D.S at Clarifier Outlet, mg/L	Decrease in T.D.S in E.T.P, mg/L	% Decrease of T.D.S in E.T.P
Aug 2008	2340	2200	140	5.98
Sep 2008	2320	2060	260	7.76
Oct 2008	2280	2180	100	4.38
Nov 2008	2360	2020	340	13.56
Dec 2008	2280	1980	300	11.4
Jan 2009	2260	2120	140	9.32
Feb 2009	2420	2080	340	10.34
Mar 2009	2240	2040	200	11.61
Apr 2009	2140	1940	300	14.16
May 2009	2300	1900	400	16.52
Jun 2009	2220	1860	360	17.12
Jul 2009	2320	2060	260	10.34
Average Value				**10.95**

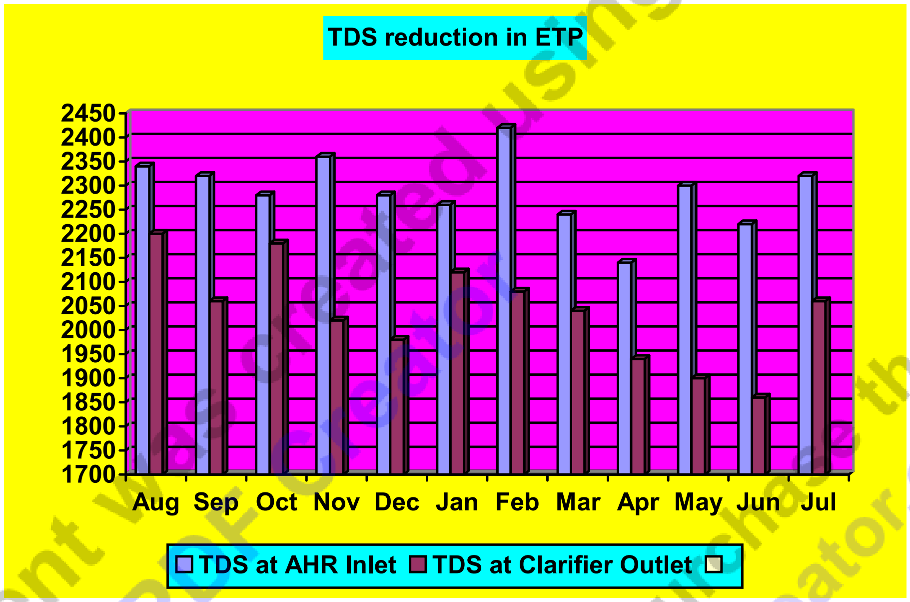

Figure 5.28: TDS decrease in ETP (Monthly Averaged Values)

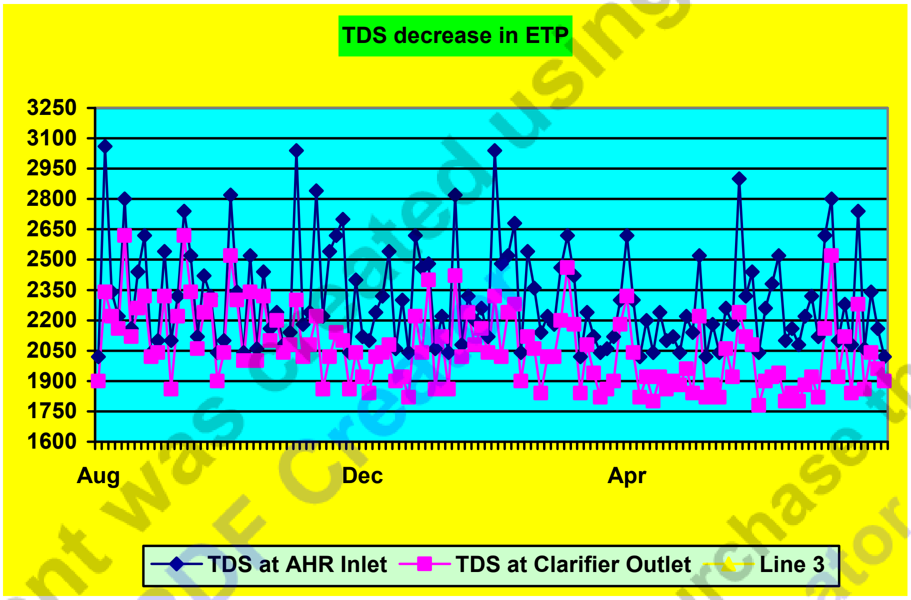

Figure 5.29: TDS decrease in ETP (Monthly Averaged Values)

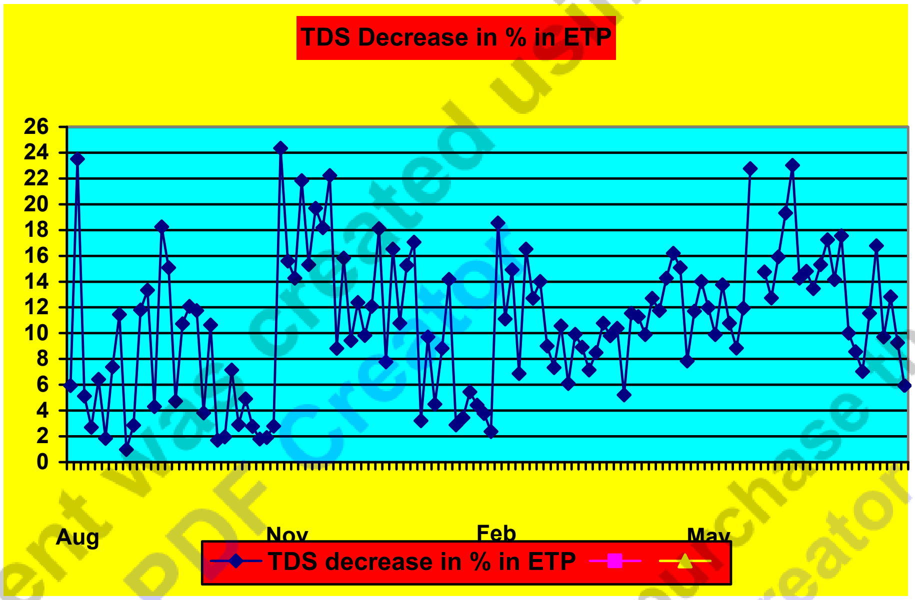

Figure 5.30: TDS decrease in ETP (Monthly Averaged Values)

Table 5.13: BOD Reduction in Effluent Treatment Plant

Month	B.O.D at the Inlet of A.H.R, mg/L	B.O.D at Clarifier Outlet, mg/L	Overall Reduction of B.O.D in E.T.P, mg/L	Overall % Reduction of B.O.D in E.T.P
Aug 2008	3020	360	2660	88.08
Sep 2008	3000	280	2720	90.67
Oct 2008	2920	280	2640	90.41
Nov 2008	3320	300	3020	90.96
Dec 2008	3220	300	2920	90.68
Jan 2009	3180	280	2900	91.19
Feb 2009	3160	340	2820	89.24
Mar 2009	3100	320	2780	89.68
Apr 2009	3180	280	2900	91.19
May 2009	2960	260	2700	91.21
Jun 2009	3040	360	2680	88.16
Jul 2009	3140	360	2780	88.53
Average Value				**90**

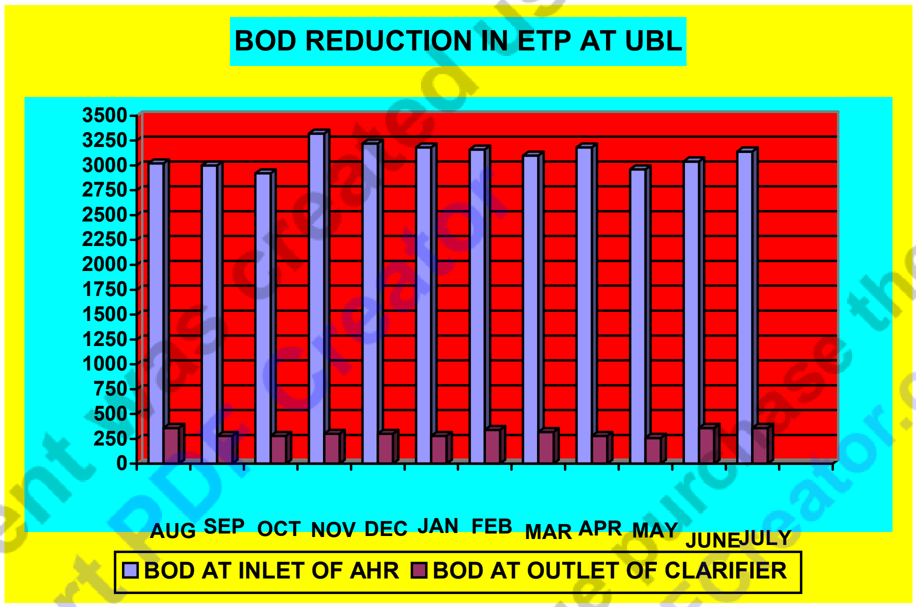

Fig 5.31: BOD reduction in ETP (Monthly Averaged Values)

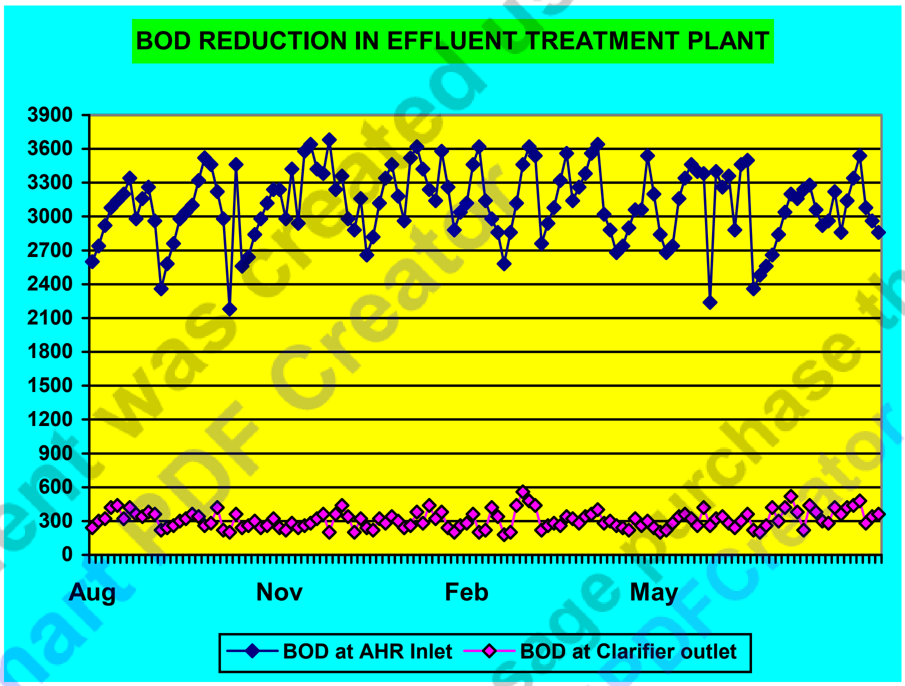

Fig 5.32: Reduction in BOD in ETP (All Values Recorded)

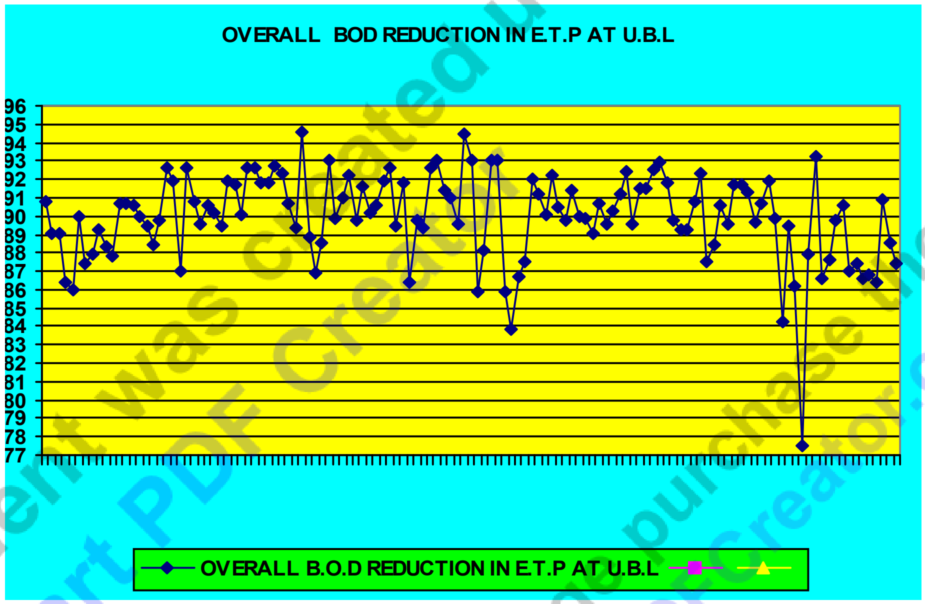

Fig 5.33: Reduction in BOD in % in ETP (All Values Recorded)

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn based on the study:

1. It was observed that flow of wastewater amounted to 568.2 $m^{3.}$ The observed flow was lower than designed flow of 850 m^3 meaning that plant was running underloaded. The flow was high in summer months & low in winter but still very less than the designed flow of 850 $m^{3.}$

2. The effluent treatment plant at United Breweries Limited is quite efficient at reducing COD & BOD of influent wastewater with removal efficiency being 95.43% & 90%.

3. The total suspended solids (TSS) removal efficiency of the effluent treatment plant was 74%. The removal efficiency is not satisfactory & it can be improved.

4. The decrease in total dissolved solids in effluent treatment plant was very less. The % decrease in total dissolved solids (TDS) was 12.43. There is a scope for better and efficient removal of TDS.

5. The values of total dissolved solids(TDS) at the anaerobic hybrid reactor were very high. The high value of total dissolved solids may be attributed to chemicals use in Clean-In- Place application & also in dosing application. The chemicals used in clean-in –place having high concentration of sodium are not good. The chemical being used at United Breweries Limited for clean-in-place is NaOH which contributes to high levels of sodium, hence high total dissolved solids.

6. Sludge volume index (SVI) values are within specified range of 40-100 mg/L. This indicates towards good settling properties of sludge in clarifier.

7. It was observed that averaged value of MLSS was 2383 mg/L. It was very less than the design value of 3500-4000 mg/L. The all values recorded also were very less than the design range values.

8. Total alkalinity in anaerobic hybrid reactor came out to within proper working range of 1000-4000 mg/L for anaerobic digetser. It indicates towards proper working of anaerobic digester, in this case anaerobic hybrid reactor. Since the acids that are being produced tend to lower the pH, it is important to maintain enough alkalinity in the digester to buffer the effect of the acids. This is necessary to keep the pH above 7.0 and hence help in production of maximum methane.

9. Total volatile acids value in anaerobic hybrid reactor (AHR) came out to be below 1000. For methane production in AHR it is very essential that this value remains below 1000 mg/L. This is because it is an indication that methanogenic bacteria are dominating & are producing methane contributing in proper working of anaerobic hybrid reactor.

10. The COD and BOD removal efficiency of the anaerobic hybrid reactor (AHR) came out to 78 % and 74.77 respectively. The COD and BOD removal is fairly good. But still it can be improved.

11. Value of pH at inlet of anaerobic hybrid reactor ranged between 5.7 and 7.6. Methanogens present in AHR are pH sensitive. They operate in a pH range of 6.5 to 7.5. Movement to either side of this range quickly affects their metabolic rates and slows or stops methane production. The methane formers are the bottleneck in the system and must be catered to. Whenever methane production drops the volatile fatty acids begin to build up quickly due to the robust nature of the acid forming bacteria. Any shift adverse to the methane formers increase

acids which in turn reduces the methane formers. The values recorded showed that working of AHR was good at most of the times as the values recorded were in within the range.

12. Foaming problem which may hinder anaerobic treatment is overcome by provision of a biogas defoamer in effluent treatment plant setup.

13. The under drainage system in sludge drying beds was working well and sludge was being disposed off.

Recommendations:

1. Biogas generated at UBL in anaerobic hybrid reactor may be utilized as energy source. At united breweries limited, flaring of biogas accumulated inside anaerobic hybrid reactor (AHR) is being done. The COD removal efficiency according to the tests came out to be 78 %. From calculations, the CH_4 generated at designed capacity of 850 m^3 came out to be 2015.65 m^3. This much quantity of methane generated is being wasted.

2. The final treated effluent is being sent to drains at U.B.L plant. This effluent can be used in plant premises for keeping the premises green.

3. The plant at present is running underloaded. Its capacity may be fully utilized.

4. The total suspended solids removal efficiency may be increased by increasing detention time.

5. The total dissolved solids removal was poor. This may be improved by increased doses of coagulants like polyelectrolyte & lime in clarifier.

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