Performance monitoring and evaluation of Sewage Treatment Plants based on UASB – Facultative pond

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by

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in the dissertation entitled **"Performance monitoring and evaluation of Sewage treatment plants based on UASB and facultative pond"** in partial fulfillment of the requirement for the award of degree of **Master of Technology** in **Environment Science & Technology**, Thapar University, Patiala, is an authentic record of my own work during the period of twelve months from August 2009 to July 2010, under the supervision of Dr. A.S. Reddy, Department of Biotechnology and Environmental Sciences, Thapar University. This work has not been submitted to this or any other university till now for the award of any other degree, diploma or equivalent course.

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This is to certify that the above statement made by the candidate is correct and true to the best of our knowledge.

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CERTIFICATE

This is to certify that the thesis report entitled **"Performance monitoring and evaluation of Sewage treatment plants based on UASB and facultative pond"** submitted by Tarundeep Gill in the partial fulfilment of the requirement for the award of degree of the **Master of Technology in Environmental Science and Technology** to the Thapar University, Patiala, is a record of student's own work carried out by her under my supervision and guidance. The report has not been submitted for the award of any other degree or certificate in this or any other university or institution.

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ABSTRACT

Anaerobic treatment of municipal wastewater has recently gained worldwide attention due to its effectiveness, low cost, and low energy requirements The UASB has been considered to be the most attractive reactor system due to its simplicity and low operation cost. UASB reactors alone may not be sufficient to treat the sewage to the desired level and compliance with the applicable effluent standards, so effluent from UASB needs further treatment. The main role of the further treatment is to complete the removal of organic matter, as well as to remove the constituents little affected by the anaerobic treatment, such as nutrients and pathogenic organisms. The UASB and polishing pond configuration has been monitored and evaluated at six STPs in operation under the Satluj River Action Plan for one year period on monthly basis.studied in this dissertation work.

The STPs in question are designed, commissioned and operated mainly for the removal or reduction of total suspended solids, BOD, COD and the coliform count (chlorination) from the sewage being treated. In these STPs even nutrients get coincidentally removed. Hence the performance evaluation has been carried out for BOD and COD removal, TSS, MPN and nutrients against the STP.BOD and COD have been the design parameters for the STP. Removal of the parameters TSS, nutrients and coliform count were actually evaluated in order to know how the performance of UASB and polishing pond based STP with that experienced elsewhere. Performance evaluation also involved comparison of the actual performance against the design performance and the estimated performance of the STP.

The performance monitoring and evaluation study of the six STPs has shown that average removal efficiency for BOD, COD, TSS and total nitrogen (over one year period and over the six STPs) of the treated effluent were 70%, 69%, 68%, 12.8%. Excepting for MPN, if not for the role played by the algal cells in the treated effluent, the treatment processes are satisfactory indicating that plants are working properly. This has been the case despite use of chlorination in one of the STPs.

List of figures

List of Tables

CONTENTS **PAGE NUMBER**

CHAPTER 1
INTRODUCTION

1.1 Background information

The Satluj River is heavily polluted by the wastewater discharged specially by Ludhiana, Jalandhar, Kapurthala Phagwara, Phillaur and Sulthanpur Lodi cities of the Punjab State. In an effort to improve the Satluj river water quality, National River Conservation Directorate (NRCD) of Ministry of Environment and Forests (MOEF), Government of India has installed and commissioned till date as many as eight Sewage Treatment Plants (STPs) under the Satluj River Action Plan (SRAP) for the treatment of the municipal sewage generated by these cities prior to discharge into the Satluj river. Punjab water supply and sewerage board (PWSSB) is responsible for running these STPs and treating the municipal sewage and then discharging into the river Satluj. NRCD has entrusted Thapar Univeristy with the responsibility of monthly performance monitoring of these STPs and reporting to the NRCD.

Sewage Treatment Plants (STPs) are supposed to make the municipal sewage compatible for disposal into the environment (surface and underground water bodies or land), to minimize the environmental and health impacts of the sewage, and to make the sewage fit for recycling and reuse (agricultural and aqua-cultural uses and municipal and industrial uses). Six of the STPs, installed and commissioned under the Satluj River Action Plan, are based on the Upflow anaerobic sludge blanket (UASB) and the stabilization pond technologies, one is based on only stabilization pond system & another one is on duckweed system. In both the cases the treatment systems are designed on the basis of empirical equations obtained from the past experience elsewhere. Further, evaluation of the STPs was done for assessing whether they are performing as per the design and for knowing whether the STPs were designed for complying with the purposes to be served is also important.

Performance evaluation of the sewage treatment plant (based on UASB + Polishing pond), installed at Bhattian, Kapurthala, Phagwara, Jalandhar, Jamalpur, Balloke, has been considered for the present MTech dissertation work.

1.2 Objectives of the study

Objectives of the present study can be stated as following:

1. To evaluate the overall performance of the STPs.
2. To evaluate the performance of UASB
3. To evaluate the performance of Polishing pond

1.3 Importance and usefulness of the work

Increasing scarcity of water in the world along with rapid population increase in urban areas gives reason for concern and the need for appropriate Water Management Practices. Sewage treatment is not a cheap proposition. The greatest challenge in the treatment process is the implementation of low cost sewage treatment.

In contrast to aerobic process, anaerobic treatment process has many advantages. The organic matter (COD) presents in the wastewater in the absence of oxygen is mainly converted in to biogas, which is a valuable product. Very little portion is converted in to the sludge. No major inputs are required to operate the system. They will hopefully lead to more ecologically-sustainable wastewater treatment in the future. Upflow Anaerobic Sludge Blanket reactor (UASB) has proven to be effective alternative for treating wastewater. Upflow Anaerobic Sludge Blanket (UASB) reactor has been widely used to treat variety of industrial and domestic wastewaters all over the world. The wastewater coming of UASB usually requires post treatment in order to meet the prescribed standards. Usually screenings of the sewage and grit removal from the sewage are used as pre-treatment. Both secondary and tertiary treatment technologies, meant for the further removal of biodegradable organic matter (BOD), nutrients (nitrogen and phosphorus) and pathogens, are used as post-treatment to the anaerobic treatment. In my thesis, work on UASB + Polishing pond based Sewage Treatment Plant has been done.

Performance evaluation of the various STPs has been carried out to comment on the performance of the STPs in question. Evaluation of reactor performance and behaviors is extremely useful as it provides information on how under loaded or overloaded the system is, and thus by how much, if any, the loading on the system can be safely increased as the community it serves expands.

Further, study was done on performance of individual unit and overall unit in order to find out the efficiency of the plant. Since this work is related to and part of the project of monitoring of STPs running under Satluj River Action Plan, it will help the ministry in getting information regarding the status of STPs performance and improvement suggestions. It can prove quite useful as compiled information for ready reference and use.

1.4 Contents of the report

Present thesis work on performance evaluation of Upflow Anaerobic Sludge Blanket Reactor + Polishing Pond based Sewage Treatment Plants includes altogether five chapters and a reference section.

Chapter - 1 is **"Introduction".** It provides brief background information of the study, explicitly states objectives of the study, brings into light the importance of the work, and provides overview of the contents of the report and limitations of the study are given in the end.

Chapter -2 is **"Literature Review".** This chapter presents the literature review on UASB reactor & Polishing Pond. Their treatment process, design constituents and their post-treatment options are covered in this chapter.

Chapter -3 is **"Materials and Methods".** This chapter identifies the work elements of the present study and brings forth the approach followed for carrying out the work on identified work elements. Comprehensive detail of the STP in question along with a schematic flow diagram is also covered in this chapter. References to the analytical techniques used in the assessment associated with the study are also provided herein.

Chapter –4 is **"Results and Discussion".** Results of the present study are covered in this chapter and discussed herein.

Chapter -5 is **"Summary and Conclusions".** This is the last chapter. It summarizes the outcomes of the present study and draws conclusions. It goes further to bring forth the limitations of the study and indicates what else can be done in the future studies.

CHAPTER – 2

LITERATURE REVIEW

2.1 Upflow Anaerobic Sludge Blanket (UASB) reactor for Sewage Treatment

Since 1982, in several parts of the world experiments have been undertaken to assess the applicability of the UASB system - the Upflow Anaerobic Sludge Blanket system, described in detail by several authors **(Lettinga et al., 1980, Lettinga and Hulshoff Pol, 1984)** for the direct treatment of sewage in warm climates. Experiences in Brazil **(Souza, 1986)**, Indonesia **(National Institute for Public Health et al. 1988)**, India **(Siddigi, 1990)** and Colombia **(Schellinkhout et al., 1985)** showed that a BOD reduction of 75% is feasible under tropical conditions and somewhat lower in colder areas **(Vieira and Souza, 1986)**. It is also indicated that considerable cost reductions could be achieved in comparison to other treatment systems. In 1990, thus far largest sewage treatment plant based on UASB technology was built in the Colombian city of Bucaramanga (600 000 in hab, 900 m + sea level). Smaller plants are being operated in Kanpur, India (5 000 m^3/day), Colombia (20,000 population equivalent (PE).

Successful use of anaerobic reactors (especially up-flow anaerobic sludge blanket reactors, (UASB) for the treatment of raw domestic sewage in tropical and subtropical regions opened the opportunity to substitute the aerobic processes with the anaerobic technology for the removal of organic matter from the influent wastewater. Despite the success, effluent from the anaerobic reactors, treating domestic sewage, requires post-treatment in order to achieve the discharge standards prevailing in most countries. The use of UASB technology for sewage treatment has been explored as a feasible option in many developing countries like Colombia, Indonesia, Brazil, China, and India. Capital costs for the UASB process are lower than those for other anaerobic processes since the separation of gas, liquid and solids takes place entirely in the reactor and no support medium for bacterial attachment is required. An USAB reactor has four major components: (1) sludge bed; (2) sludge blanket; (3) gas-solids separator (GSS); and (4) settling zone. Influent wastewater enters the reactor at the bottom and is biologically degraded in both the sludge bed and the sludge blanket.

Gas is separated from the liquid by the GSS device. A quiescent zone is created in the settling zone. Most of the sludge particles that have entered the settling zone can settle back to the reactor while the rest are washed out via the effluent.

Ruiz (1998) studied the treatment of domestic wastewater from the city of a Coruna (Spain) in laboratory scale UASB digester at 20°C at HRT > 24 hr. The COD & SS removal efficiencies remained practically constant and higher than 85%. By reducing the HRT from 25 to 5 hr COD removal efficiency decreased 53% and SS removal to 63%. The methane recovered in biogas amounted to 25-30% of influent COD. Increase of efficiency by about 5% was reported when the UASB was used with a completely mixed sludge digester system for external digestion & stabilization of accumulated solids into the UASB.
Granulation of sludge is an indication of successful operation of the UASB system. Efficient performance of the reactor can be obtained with the formation of highly settleable sludge. Three stages in the granulation of seed sludge are identified

(Hulshoff Pol.et.al, *(*1986) studied that if in the first stage, organic loading applied is lower than 2 kg COD/m³/d then the sludge bed expands significantly as a result of gas production. During the second stage, organic loading rate was increased to about 2-5 kg COD/m³/d, an increase in gas production rate results in the wash-out of fluffy sludge. Growth is predominant in the form of dense heavy sludge particles. In the third stage, organic loading is even higher and can be set to its maximum design value.

Mirsepasi.et.al (2006) carried out the performance evaluation of full scale UASB reactors in treating stillage wastewater. In this study two full-scale UASB reactors (420 m³) were investigated. Conventional parameters such as pH, temperature and efficiency of COD, BOD, TOC (total organic carbon) removal and also the upflow velocity, organic loading rate (OLR) and hydraulic retention time were investigated. It was concluded that COD removal efficiency can be enhanced by enhancing of organic loading rates (OLRs) and upflow velocity, by decreasing hydraulic retention time (HRT) and by operating the reactors with new sludge.

Singh K.S.et.al (2006) studied on the feasibility of treating municipal wastewater by UASB system under low-temperature conditions. Two reactors were started-up at 20^0C & subsequently operated at temperatures of 32, 20, 15, 11 and 6^0C applying several hydraulic retention times (HRTs) ranging from 48 to 3h during an operational period of 900 days. Chemical oxygen demand (COD) removal efficiency ranged from 70 to 90% upto an HRT of 6h and 11^0C. The performance of reactor was not satisfactory during 6^0C operation. Sulfate reduction played an important role in COD reduction. Hydraulic regime in the reactor was impacted by the change in operating temperature. The study demonstrated that UASB system could be applied successfully for post-treatment/treatment of municipal wastewater under low-temperature conditions.

Seghezzo L, (2004), studied treatment of domestic wastewater in the anaerobic upflow sludge blanket reactors (UASBR), and determined the hydraulic and kinetic factors affecting the performance of the system in the process of develop a compact treatment system for the regions of Turkey having a mild and warm climate. Hydraulically, the UASBR used in this study can be considered as a completely mixed compartment and a plug flow compartment in series. Volume of the plug flow compartment constitutes about 10 % of the whole system. Characteristics of the feed were different in each stage (like flow, hydraulic retention time, organic loading rate).Organic loading rates were varied in the range of 0.2–1 kg COD/m3.d. Domestic wastewaters can be anaerobically treated in mesophilic UASBR's with 70% COD removal without any chemical treatment. The effluent suspended solid concentrations were very low and rarely exceeded 50 mg/l. The results obtained perfectly fit the second order multiple substrate kinetics model at steady state operating conditions.

Nidal Mahmoud (2008) reported that treating high strength sewage during hot period in Palestine in a UASB-digester system is very promising. Here, high strength sewage was passed through one-stage upflow anaerobic sludge blanket (UASB) reactor and a UASBdigester system. The one-stage UASB reactor was operated in Palestine at a hydraulic retention time (HRT) of 10 h and at ambient air temperature for a period of more than a year in order to asses the system response to the Mediterranean climatic seasonal temperature fluctuation. Afterwards, the one-stage UASB reactor was modified to a UASB-digester system by incorporating a digester operated at 35^0C.

The achieved removal efficiencies in the one-stage UASB reactor for total, suspended, colloidal, dissolved and VFA COD were 54, 71, 34, 23%, and _7%, respectively during the first warm six months of the year, and achieved only 32% removal efficiency for COD total over the following cold six months of the year. The modification of the one-stage UASB reactor to a UASB-digester system had remarkably improved the UASB reactor performance as the UASB-digester achieved removal efficiencies for total, suspended, colloidal, dissolved and VFA COD of 72, 74, 74, 62 and 70%.

Yu.et.al (2000) studied the effect of Fe2+ on sludge granulation in Upflow Anaerobic Sludge Blanket Reactors. In the experiment 6 identical reactors operated in parallel, 1 being control (with addition of FeCl2.H2O) were dozed with varying concentration of Fe2+ (150 to 800 mg/l). Introduction of Fe2+at concentrations 300 and 450 mg/L enhanced the granulation process in UASB reactors, while a low dosage of Fe2+ at 150 mg/L had little effect on the sludge granulation. The Fe2+ concentration in granules was proportional to the influent Fe2+ concentration, FeS and the compounds formed by iron and exo-polysaccharide polymers were the main precipitates in the granules. Specific activity of the granules decreased with increasing Fe2+ concentration in the feed. Presence of a large amount of minerals deposited within the granules, significant decrease of water content in granules, and the possible toxicity of high-concentration Fe2+ accumulated inside granules might have been responsible.

Kripa Shankar.et.al (2006) studied the effects of Sludge Blanket Height, Flow pattern and temperature in 2 upflow anaerobic sludge blanket (UASB) reactors (operated for approximately 900 days) treating municipal wastewater under low temperature conditions. A modified solid distribution model has been formulated by incorporating the variation of biogas production rate with change in temperature. It was confirmed by experimental observations of solid profile along the height of the reactor that the model simulated the solid distribution well. Mathematical analysis of tracer curves indicated the presence of a mixed type of flow pattern in the sludge-bed zone of the reactor. It was found that the dead-zone and bypass flow fraction were impacted by the change in operating temperatures.

Maximum biological loading rate that can be allowed in the reactor depends on the methanogenic activity of the sludge. For domestic sewage, the methanogenic activity usually ranges from 0.3 to 0.4 kg COD/VS.d. **(Chernicharo, 2007)**. Methanogenic bacteria are highly sensitive to temperature and the temperature at which the process is operated is a very crucial factor. Operations under both mesophilic and thermophilic conditions have been investigated **(Hulshoff Pol.et.al, 1983)**. Granular sludge is formed under mesophilic conditions, 30-35°C **(Lettinga and Velsen, 1980)** and also under thermophilic conditions, 55°C. Although granulation is faster under thermophilic conditions, the mechanism underlying the granulation process under both conditions is similar. At low temperatures, growth of active biomass may be so slow that it is very difficult and time-consuming to accomplish the granulation process. It has been reported that specific activity of sludge at 35°C is more than twice to that at 20°C, and about six times to that at 10°C. For this reason, process start-up should be done in mesophilic (or thermophilic) conditions even for reactors designed to be operated at low temperatures. In all circumstances, a sharp temperature change is detrimental to microorganisms and should be avoided **(Souza, 1986).**

Elmitwalli and Otterpohl (2007) studied feasibility of grey water treatment in an upflow anaerobic sludge blanket (UASB) reactor operated at different hydraulic retention time (16, 10 and 6 h) and controlled temperature of 30 °C. The results showed a total COD removal of 52–64% at HRT between 6 and 16 hr. The UASB reactor also removed 22–30% and 15–21% of total nitrogen and total phosphorous, respectively.

Pontes and Chernicharo.et.al (2003) studied the influence of excess sludge produced in Trickling filter (TF) on the performance of a UASB reactor used for combined treatment of domestic wastewater and trickling filter sludge. Experiment was conducted in 2 phases. In the 1st phase the UASB/TF system was fed with domestic sewage directly. In 2nd phase, beside domestic sewage aerobic sludge from TF was also fed to the UASB reactor. It was found that the return of excess aerobic sludge produced in TF, has not affected the performance of the UASB rector and final quality of effluent was even better during phase 2nd, in term of COD, BOD & TSS.

Tiwari.et.al, (2006) reported that the process of granulation is affected by environmental and operational conditions in the reactor. According to the authors granule composition strongly depends on the operational temperature. Sudden temperature change could results in granule disintegration. Divalent ions such as Ca+ & Fe2+ enhance the granulation by ionic bridging. Preferred conditions for the granulation are high partial pressure of H2 and neutral pH.

Singh and Viraraghvan (2003) studied feasibility of treating municipal waste water by UASB system under low temperature conditions and the effect of HRT and temperature on COD, BOD and SS removal. It was found that up to temp. 11°C and HRT 6hr, reactor performed well in terms of removal efficiency. A decrease in removal efficiency of COD & BOD was observed when HRT was reduced to 4hr and 3hr, which was severe at low temperature. Temperature did not affect significantly the SS removal efficiency. The study concluded that a UASB reactor could be start-up successfully for application at low temperature for municipal waste water in cold region (average temperature 15-20°C).

J.A. alvarez.et.al (2004) find out the anaerobic treatment of raw domestic wastewater by a novel technology consisting of an Up-flow Anaerobic Sludge Bed (UASB) reactor combined with a completely mixed digester for the stabilisation of the UASB sludge was assessed. A pilotscale plant of the so-called UASB-Digester system was located at the municipal wastewater treatment facility of Santiago de Compostela (Northwest of Spain). The main aim of the Digester was to enhance the biodegradation of influent solids retained in the UASB reactor at low temperatures, then increasing its specific methanogenic activity. The sludge drawn from the middle zone of the UASB entered the upper zone of the Digester and then circulated from the bottom of the Digester to the UASB bottom. Circulating in an automated semi-continuous way, the flow of this sludge stream was selected in order to set a previously defined hydraulic retention time (HRT) (16-27 d) in the digester. The Digester temperature was set at an optimum value ranging from 25 to 35ºC. The steady state efficiency of the UASB system, at 6-8 h of HRT, 15-16ºC of temperature and 330-360 mg l-1 of influent total chemical oxygen demand (TCOD) was 79% of total suspended solids (TSS) removal, 52% of TCOD removal and 60% of biological oxygen demand (BOD5) removal. The hydrolysis of retained solids reached 85%, while excess sludge generation was only 7% of influent TCOD. A stable anaerobic (pre)treatment of diluted domestic wastewater was reached as the sludge concentration in the reactor remained mainly constant and the specific methanogenic activity showed a slight increase.

J.R.Banu.et.al (2007) studied on treatment of domestic wastewater using a laboratory scale Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactor. The reactor with a working volume of 5.9L and plastic cut rings as a packing media was operated at varying Hydraulic Retention Time (HRT) for a period of 110 days. While the COD removal varied from 75-86%, the BOD removal was in the range of 70-91%. Methane contect in the biogas was 62%. VFA levels fluctuating between 100 & 186mg/l. During the treatment, nutrient levels exhibited an increasing trend. It appears to be promising alternative for the treatment of domestic wastewater in developing countries.

Bhunia and Ghangrekar in 2008 carried out a study to correlate biogas-induced mixing and granulation in upflow anaerobic sludge blanket (UASB) reactors, treating low-strength as well as high-strength biodegradable wastewaters. A dimensionless granulation index (GI) was framed taking into account the mixing in sludge bed due to produced biogas. Analysis of full-scale, pilot-scale and lab-scale UASB reactors treating actual wastewaters reveals the significance of biogas-induced mixing, represented by GI, on the granulation of biomass in the reactors. For obtaining proper granulation resulting in higher chemical oxygen demand (COD) removal efficiency, it it is recommended to maintain GI values in the range of 15,000–57,000.

UASB cannot fully replace aerobic treatment. A combined anaerobic/aerobic system may provide a more reliable and cost effective way for the wastewater treatment**.** Recent investigations have demonstrated that it is feasible to utilize a combined technology, consisting of an upflow anaerobic sludge bed (UASB) reactor for anaerobic pre-treatment, followed by aerobic post treatment, to efficiently treat municipal wastewater. In such systems the excess sludge produced in the aerobic stage is recycled to the anaerobic unit for stabilization. This configuration is an attractive alternative for secondary wastewater treatment because the costs associated with sludge digestion are eliminated.

Machdar.et.al (2000) studied the performance of up-flow anaerobic sludge blanket (UASB) in combination with down-flow hanging sponge (DHS) system for sewage treatment at an average wastewater temperature of 15°C for 6 months. The results showed that a combined system operated at a total HRT of 10.7 hr and total solid retention time (SRT) of 88 days represented a cost effective sewage treatment process. It proved the most efficient combined process and it not only removed COD total (90%), BOD5 total (98%), TSS (94%), ammonia (86%) and faecal coliform (99.92%) but also reduced the excess sludge production.

Motta.et.al (2008) compared the two anaerobic pre-treatment technologies, namely, the anaerobic fluidized bed reactor (AFBR) and the UASB, and demonstrated that both have similar performances with regard to chemical oxygen demand (COD) removal, suspended solids removal, and gas generation. Much more efficient sludge stabilization was achieved in the UASB. In addition, the UASB required significantly lower energy for effluent recirculation than the AFBR. Thus it concluded that UASB would be more economical to operate.

Motta.et.al (2007) favoured the use of a combined upflow anaerobic sludge bed (UASB)/ aerobic solids contact system (ASC) for the treatment of municipal wastewater and demonstrated the technical feasibility of using the UASB process as both a pre-treatment unit and a waste activated sludge digestion system. Although the UASB reactor had low TSS and TCOD removal efficiencies, the overall UASB/ASC system was capable of meeting secondary-effluent water quality requirements with an overall HRT of at least 5 hr. UASB produces methane gas at an average rate of 6.47 ml per litre of the sewage treated. UASB/ASC process was not only effective for 12 providing secondary wastewater treatment, but it also minimized the surplus sludge production and produced a well-stabilized sludge.

Pontes.P.P.et.al (2003) worked on the influence of the excess sludge produced in a trickling filter (TF) on the performance of a UASB reactor used for the combined treatment of domestic sewage and aerobic sludge. During phase 1 of the research, the UASB reactor/TF system was fed with domestic sewage pumped directly from the sewer collector of Arrudas stream, in Belo Horizonte – Brazil. During phase 2, besides feeding the reactor with domestic sewage, the UASB reactor was also fed the aerobic sludge from the trickling filter. The UASB reactor, with a volume of 420 litres, was operated at a mean hydraulic detention time of 5.6 hours in both operational phases. After 133 days of continuous monitoring, no detrimental effect was noticed on the performance of the UASB reactor regarding the return of the aerobic sludge produced in the TF. On the contrary, the COD results indicated a higher percentage of compliance with the discharge standards set forth by the Brazilian environmental legislation. During phase 2 of the research, when the UASB reactor was used for combined treatment of domestic sewage and excess aerobic sludge from the TF, the anaerobic effluent presented mean concentrations of 108 mgCOD.L–1, 57 mgBOD.L–1 and 18 mgTSS.L–1.

Pant.et.al (2004) presented a study reports on the onsite evaluation of two pilot scale disinfection units. One of the pilot plants is based on chlorination, and other is based on fixed film aerobic process (biotower). Evaluation study consisted of onsite monitoring of COD, BOD5 and TSS and fecal coliform over a period of three months. Samples were collected from the inlet and outlet of the pilot plants. These pilot plants were evaluated so as to have an appropriate disinfection technology for the treatment of the effluents from upflow anaerobic sludge blanket reactor (UASBR) based sewage treatment plants which could meet the biological quality standards. All the influents samples collected from both the pilot plants contained fecal coliform ranging from 105 to 106 MPN/100 ml. The results show that the fecal coliform removal is up to 98.2% and 100% for biotower and chlorination, respectively. Both, the chlorination and down hanging sponge-biotower (DHS-biotower) improved the quality of effluent from the UASBR in terms of COD, BOD5 and TSS. Though chlorination performed better compared to the DHS-biotower, however, it has additional risk associated with the formation of trihalomethanes (THMs).

Tawfik.et.al (2003) studied the treatment of domestic sewage in a combined Upflow Anaerobic Sludge Blanket Reactor and Rotating Biological Contactor (UASB/RBC) system for irrigation purposes and concluded that an efficient pre-treatment of sewage implies a substantial reduction of organic loading rate (OLR) applied to the RBC and consequently improved the residual of total COD, ammonia and *E. coli* in the final effluent. The results supported the use of combined system UASB/RBC for treatment of domestic wastewater for reuse in irrigation.

Sperling.et.al (2001) indicated the advantages of combining anaerobic and aerobic processes and worked on the pilot-scale comprising of an UASB reactor followed by an activated sludge system for treating municipal wastewater in Brazil. The plant was intensively monitored and operated for 261 days, divided into five different phases, working with constants and variable inflows. The plant showed good COD removal, with efficiencies ranging from 69% to 84% for the UASB reactor, from 43% to 56% for the activated sludge system and from 85% to 93% for the overall system. The final effluent suspended solids concentration was very low. Based, on the overall performance of the system, it is belived that, the system shows better results, low hydraulic detention time (4h for UASB, 2.8h for aerobic reactor and 1.1h for final clarifier), also saves the energy consumption and the possibility of thickening and digesting the aerobic excess sludge in the UASB reactor itself.

2.2 Facultative pond

Anaerobic reactors hardly produce effluents that comply with usual discharge standards established by environmental agencies. Taking into consideration the intrinsic limitations associated with the anaerobic systems and the need to develop technologies that are more appropriate to the reality of developing countries, it is important to include a post-treatment stage for the effluents generated in anaerobic reactors. Therefore, the effluents from anaerobic reactors usually require a post-treatment step as a means to adapt the treated effluent to the requirements of the environmental legislation and protect the receiving water bodies.

The main role of the post-treatment is to complete the removal of organic matter, as well as to remove constituents little affected by the anaerobic treatment, such as nutrients (N and P) and pathogenic organisms. The UASB reactor + polishing pond configuration is a very interesting alternative from the technical–economical–environmental point of view. This alternative is even more attractive when the effluent from the pond can be used for agricultural purposes, since the polishing ponds aim mainly at the removal of pathogenic organisms.

Facultative ponds are largely used for post-treatment of effluents from anaerobic ponds. They are usually 1-2 m deep and are geometrically designed to have high length-to-width ratio (up to 10:1) to simulate a plug flow regime (Mara et al. 1992) When an efficient anaerobic pre-treatment is applied prior to the sewage discharge into a pond, the concentrations of organic matter and suspended solids are largely reduced, and consequently it will be required only a complementary removal of these two constituents, needing much lower hydraulic retention times. In these conditions, the limiting factor that determines the minimum retention time, (therefore, the volume and the area of a pond system), will usually be the removal of pathogenic organisms, and not the stabilisation of the organic matter. For this reason, the nomenclature polishing pond has been adopted to name those ponds intended for the post-treatment of effluents from efficient anaerobic systems, thus distinguishing them from the stabilisation pond, which treats raw sewage **(Cavalcanti, 2003)**.

They are designed for BOD removal on the basis of relatively low surface loading (100- 400kg BOD/ha.d) to permit the development of a healthy algal population as the oxygen for BOD removal is generated by algal photosynthesis. The algae give facultative ponds a dark green colour. Ponds may occasionally appear red or pink (especially when overloaded) due to the presence of anaerobic purple sulphide-oxidising photosynthetic bacteria **(Mara and Pearson, 1986).**

Photosynthetic activity of the algae results in a diurnal variation of dissolved oxygen (DO) concentration and pH. DO concentration can rise to more than 20 mg/l (i.e., highly supersaturated conditions) and pH to more than 9.4 (these are both important factors in the removal of faecal bacteria and viruses. Ammonia and sulphide toxicity have been observed to be pH-dependent**.** As the pH of a facultative pond increases, the unionized form of ammonia increases while sulphide production decreases. The effect of this toxicity is to inhibit algae growth and production and these mechanisms are thought to be self-sustaining. In facultative ponds BOD removal of about 70 % on an unfiltered basis and more than 90 % on a filtered basis can be achieved.

Wastewater treatment plants using UASB reactors followed by polishing ponds also have a very simplified flow sheet in figure: 2.1. Besides the preliminary treatment units (screen and grit chamber), the flow sheet comprises the anaerobic treatment unit, the polishing pond (either a single baffled pond or ponds in series), and the dewatering unit for the sludge produced in the UASB reactor which is already thickened and stabilized.

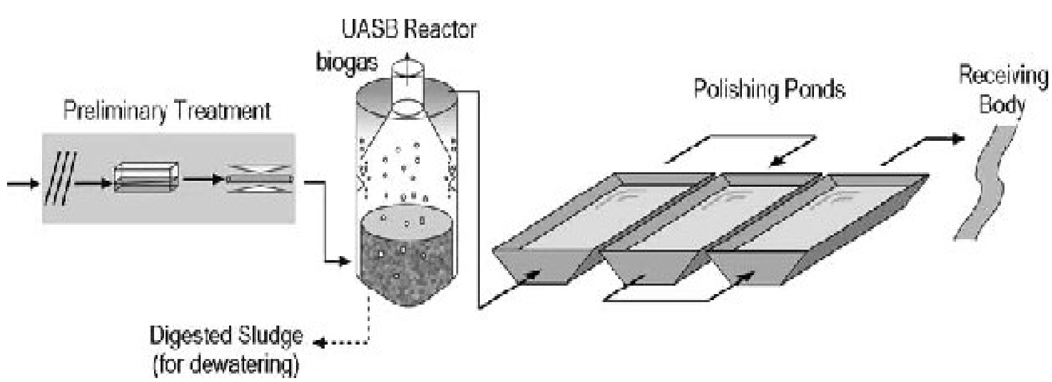

Figure:2.1 Typical configuration of a treatment plant with UASB reactor and polishing ponds (von Sperling & Chernicharo 2005).

Von Sperling and Mascarenhas (2004) have conducted a study and have shown that a domestic sewage treatment system comprised of a UASB reactor followed by four very shallow (0.40 m-depth) polishing ponds in series, operated with very low detention times (1.4–2.5 days in each pond), was able to achieve excellent results in terms of BOD and E. coli removal, and also good results in terms of ammonia removal. The average concentrations observed in the final effluent were 44 mg BOD/L), 3.8x102 MPN/100ml) and 7.3 mg NH4-N/L). Polishing pond systems are capable to produce effluents with helminth eggs concentrations predominantly equal to zero, and satisfying the WHO guidelines for unrestricted and restricted irrigation **(Von Sperling.et.al, 2002).**

Von Sperling.et.al, (2002) studied on the removal efficiency and derives the decay coefficients of *Escherichia coli* in a combined UASB (Upflow Anaerobic Sludge Blanket) reactor – maturation pond system. The system is comprised of demonstration-scale units, treating actual domestic sewage from a town in Brazil. The UASB reactor (9 m3) is a partitioned reactor, representing a novel configuration, constituted of three digestion compartments, three gas separation devices and a single settler compartment for solids separation **(Chernicharo & Cardoso, 1999)**. Two maturation (polishing) ponds in parallel (baffled and unbaffled), each with 8 m x 4 m external dimensions, are included in the system, with the main objective of removing pathogens. The UASB – pond systems showed very good *E. coli* removal efficiencies, especially considering the low overall HDT (between 6 and 9 days in the ponds). The UASB reactor removed around 1 log unit of *E. coli*, whereas the ponds showed removal efficiencies varying from 1 to 4 log units in the four operating phases. The best operating conditions were with an average HDT of around 9 days in each pond and a liquid depth of only 0.6 m. Although there was no substantial difference in the effluent *E. coli* concentrations, the unbaffled pond had higher Kb values (varying from 0.96 to 2.42 d-1) than the baffled one (varying from 0.55 to 0.95 d-1). In the unbaffled pond, the observed Kb values are greater than those predicted according to von Sperling's (1999) model, while in the baffled pond there is a reasonable agreement.

2.3.1 Design considerations of the UASB reactor

One of the most important aspects of the anaerobic process applying UASB reactors is its ability to develop & maintain high-activity sludge of excellent settling characteristics. For this purpose, several measures should be taken in relation to the design of the system. The main design criteria for reactors treating organic wastes of either domestic or industrial nature are presented below.

2.3.1 Volumetric hydraulic load (VHL) and Hydraulic detention time (t)

The volumetric hydraulic load is the amount (volume) of wastewater applied daily to the reactor, per unit of volume. The hydraulic detention time is the reciprocal of the volumetric hydraulic load,

$$VHL = \frac{Q}{V} \qquad \text{----------- (2.1)}$$

Where:

$VHL =$ Volumetric hydraulic load ($m^3/ m^3.d$)

$Q =$ Flowrate (m^3/d)

$V =$ Total volume of the reactor (m^3)

$$t = \frac{V}{Q} \qquad \text{------------ (2.2)}$$

Where t is hydraulic detention time (d)

Experimental studies demonstrated that the volumetric hydraulic load should not exceed the value of $5.0m^3/m^3.d$ **(Chernicharo, 2007)**, which is equal to a minimum hydraulic detention time of 4.8 hr. Recommended hydraulic detention times for UASB reactors treating domestic sewage are shown in table 2.1 **(Chernicharo, 2007)**. Hydraulic detention time parameter is directly related to the upflow velocity in the reactor also depends on the size of the reactor. For an average temperature close to 20°C, HRT can vary from 6 to 16 hrs, depending on the type of the wastewater

(Chernicharo, 2007). The detention time for maximum flow rate, should not be shorter than 4 hrs, and the maximum flow peaks should not extend beyond 4 to 6 hrs.

By knowing the influent flow rate and assuming HRT, volume of the reactor can be calculated as:

$$V = Q \times t \qquad \text{------------ (2.3)}$$

Table-2.1: Recommended HRTs for UASB reactors treating domestic sewage

Sewage temperature (^{0}C)	Hydraulic Retention Time	
	Daily average	Minimum (during 4-6 hr)
16 to 19	>10 to 14	> 7 to 9
20 to 26	> 6 to 9	> 4 to 6
> 26	> 6	> 4

Source: Chernicharo, 2007 (adapted from Lettinga and Hulshoff Pol, 1991)

2.3.2 Organic loading rate (Lv)

Volumetric organic loading rate is defined as the amount of organic matter loaded per unit volume of the reactor per unit time.

$$Lv = \frac{Q \times So}{V} \qquad \text{----------- (2.4)}$$

Where:

$Lv =$ Volumetric organic loading rate (kgCOD/m^3.d)

$Q =$ Flowrate (m^3/d)

$So =$ Influent substrate concentration (kgCOD/m^3)

$V =$ Total volume of the reactor (m^3)

Assuming certain design volumetric organic load (L_v), volume of the reactor can be calculated as:

$$V = \frac{Q \times S_O}{L_V} \quad \text{-------- (2.5)}$$

In the case of industrial effluents with a high concentration of organic matter, literature reports extremely high organic loads successfully applied to the pilot facilities (45 kg COD/m3.d), although the organic loads adopted in the design of full scale plant have been lower than 15 kg COD/m3.d **(Chernicharo, 2007)**. For high strength, volumetric organic load actually defines the reactor volume. Recommended volumetric organic loading for UASB reactors are shown in table-2.2 **(Makarand and Ghangrekar, 2005)**. The domestic sewage with relatively low concentration of organic matter (1000 mg COD/L), the volumetric organic load to be applied is much lower (2.5 to 3.5 kg COD/m3.d). Higher load can results in excessive hydraulic loads and, consequently, excessive upflow velocities.

Table-2.2: Recommended volumetric organic loading range for UASB reactors.

Category of waste water	COD (mg/L)	OLR, Kg COD/m3.d	SLR, Kg COD/kg VSS. d	HRT, hours	Liquid upflow velocity, m/h	Expected efficiency, %
Low Strength	Upto 750	1.0-3.0	0.1-0.3	6-18	0.2-0.7	70-75
Medium Strength	750–3000	2.0-5.0	0.2-0.5	6-24	0.25-0.7	80-90
High Strength	3000–10,000	5.0-10.0	0.2-0.6	6-24	0.15-0.7	75-85
Very high Strength	> 10,000	5.0-15.0	0.2-1.0	>24	--	75-80

Source:http://www.waterandwastewater.com/www_services/ask_tom_archive/toc.htm

2.3.3 Biological loading rate (Sludge loading rate)

Biological loading rate refers to the amount (mass) of organic matter loaded daily to the reactor, per unit of biomass present.

$$Ls = \frac{Q \times So}{M} \qquad \text{------------ (2.6)}$$

Where:

$Ls =$ biological or sludge lodging rate (kg COD/kg VS.d)

$Q =$ average influent flowrate (m^3/d)

$So =$ influent substrate concentration (kg COD/m^3)

$M =$ mass of microbes present in the reactor (kg VS/m^3)

Literature recommends that the initial biological loading rate during start-up should be in the range of 0.05 to 0.15 kg COD/kg VS.d **(Chernicharo, 2007)**, depending on the type of the effluent being treated. These loads should be gradually increased, according to the efficiency of the system. The maximum allowed biological loading rate depends on the methanogenic activity of the sludge. For domestic sewage, the methanogenic activity usually ranges from 0.3 to 0.4 kg COD/VS.d. **(Chernicharo, 2007)**

2.3.4 Upflow velocity and reactor height

The upflow velocity of the liquid is calculated from the relation between the influent flowrate and the cross section of the reactor, as follows:

$$v = \frac{Q}{A} \qquad \text{------------ (2.7)}$$

Where:

$v =$ Upflow velocity (m/hour)

$Q =$ Flow (m^3/hour)

$A =$ Cross section area of the reactor (m^3)

Alternatively, from the ratio between the height and the HDT:

$$v = \frac{Q \times H}{V} = \frac{H}{t} \qquad \text{----------- (2.8)}$$

Where:

$H =$ Height of the reactor (m)

Maximum upflow velocity allowed in the reactor depends on the type of the sludge present and the load applied. Table-2.3 gives recommended upflow velocities for UASB reactors treating domestic sewage **(Chernicharo, 2007)**. For a reactor operating with flocculent sludge and the organic loading rates ranging from 5 to 6 kg COD/m3.d, the average upflow velocities should be 0.5 to 0.7 m/hr, with temporary peaks up to 1.5 to 2.0 m/hr being tolerated for 2 to 4 hr duration. For reactors operating with granular sludge, the upflow velocities can be significantly higher (e.g upto 10 m/hr).

Table-2.3: Recommended upflow velocities for design of UASB reactors treating domestic sewages.

Influent flowrate	**Upflow velocity (m/hr)**
Average flow	0.5 to 0.7
Maximum flow	<0.9to 1.1
Temporary peak flow	<1.5

Source: Chernicharo, 2007 (adapted from Lettinga and Hulshoff Pol,1995)

2.3.5 UASB reactor efficiencies

Efficiencies of the UASB reactors are estimated mainly by means of empirical relations. IWA task group developed models for efficiency estimations using operational results of 16 reactors treating domestic sewage under tropical conditions **(Batstone.et.al, 2002)**. The COD and BOD removal efficiency are substantially affected by the hydraulic detention time of the system, ranging from 40 to 70% for COD removal and 45-90% for BOD removal.

$$E_{COD} = 100 \times \left(1 - 0.68 \times t^{-0.35}\right) \qquad \text{----- (2.9)}$$

Where:

$E_{COD} =$ Efficiency of the UASB reactor in terms of COD removal (%)

$t =$ Hydraulic detention time (hour)

$0.68 =$ Empirical constant

$0.35 =$ Empirical constant

$$E_{BOD} = 100 \times \left(1 - 0.70 \times t^{-0.50}\right) \qquad \text{------ (3.0)}$$

Where:

$E_{BOD} =$ Efficiency of the UASB reactor of BOD removal (%)

$t =$ Hydraulic detention (hour)

$0.70 =$ Empirical constant

$0.50 =$ Empirical constant

From the efficiency expected for the system, the COD and BOD concentration in the final effluent can be estimated as below:

$$Ceff = So - \frac{E \times So}{100} \qquad \text{-------- (3.1)}$$

Where:

$Ceff =$ effluents total COD and BOD concentration (mg/L)

$So =$ influent total COD and BOD concentration (mg/L)

$E =$ COD and BOD removal efficiency (%)

2.3.6 Biogas production

The biogas production can be evaluated from the influent COD load to the reactor by knowing the portion of COD converted into methane. The portion of COD converted into methane gas can be determined by:

$$COD_{CH4} = Q \times (S_O - S) - Y_{obs} \times Q \times S_O \qquad \text{----- (3.2)}$$

Where:

$COD_{CH4} =$ COD load converted in to methane (Kg COD_{CH4}/d)

$Q =$ average influent flow (m^3/d)

$S_O =$ influent COD concentration (kg COD/m^3)

$S =$ effluent COD concentration (kg COD/m^3)

$Y_{obs} =$ Coefficient of solid production in the system, in term of COD (0.11 to 0.23 kg COD sludge/kg COD applied)

The methane mass (Kg COD_{CH4}/d) can be converted into volumetric production

(m^3CH_4/d) by using the following equation:

$$Q_{CH4} = \frac{COD_{CH4}}{K(t)} \quad \text{----------- (3.3)}$$

Where,

Q_{CH4} = volumetric methane production (m^3/d)

$K(t)$ = correction factor for the operational temperature of the reactor (kg COD/m^3)

$$K(t) = \frac{P \times K_{COD}}{R \times (273 + T)} \quad \text{------------ (3.4)}$$

Where,

P = atmospheric pressure (1atm)

K_{COD} = COD corresponding to 1mole of CH4 (64gCOD/mol)

R = gas constant (0.08206 atm.L/mole.K)

T = operational temperature of the reactor (°C)

The total biogas production can be estimated from the expected methane content. For the domestic sewage, the CH_4 fraction in the biogas is usually in the range of 70-80%.

2.3.7 Sludge production

Estimation of the mass of sludge produced in UASB reactors can be done by:

$$P_S = Y \times COD_{app} \quad \text{------- (3.5)}$$

Where:

$P_S =$ production of solids in the system (kg TSS/d)

$Y =$ yield or solids production coefficient (kg TSS/kg COD_{app})

$COD_{app} =$ COD load applied to the system (kg COD/d)

Values of Y reported for the anaerobic treatment of domestic sewage are in order of 0.10to0.20 kg TSS/kg COD_{app}.

Volumetric sludge production can be estimated by:

$$V_S = \frac{P_S}{\gamma \times (C_S 100)} \qquad \text{-------- (3.6)}$$

Where:

$V_S =$ volumetric sludge production (m^3/d)

$\gamma =$ sludge density (usually in order of 1020 to 1040 kg/m^3)

$C_S =$ solid concentration in the sludge (%)

2.4 Design principles of facultative ponds

The design of facultative ponds focuses on BOD removal. **Mara (1997)** describes how the design of facultative ponds is currently based on rational and empirical approaches. The empirical design approach is based on correlating performance data of existing WSP. The rational design approach models the ponds performance by using kinetic theories of biochemical reactions in association with the hydraulic flow regime.

2.4.1 Surface BOD loading ((kg BOD/ha/d)

The surface BOD loading method is the recommended approach for designing facultative ponds. According to the US Environmental Protection Agency (1983) for every climate there is an appropriate value of surface BOD loading λs (kg BOD/ha/day) which can be applied to a pond for a given removal efficiency. The facultative pond area is calculated by using following equation;

$$A_f = \frac{10 L_i Q}{\lambda_S} \qquad \text{------ (3.7)}$$

Where

L_i = influent BOD (kg BOD_5/d)

Q = flow rate (m^3/d)

A_f = Area of facultative pond (m^2)

λ_S = surface BOD loading (kg BOD/ha/d)

Design value of λs increases with temperature. An empirical equation proposed by **Mara (1997)**, correlate the surface loading rate λs with temperature T, this equation has global applicability and is given below:

$$\lambda s = 350 \times (1.107 - 0.002 \times T)^{(T-25)} \qquad \text{------- (3.8)}$$

Where T is mean temperature in the coldest month (°C).

Removal rate of organic matter is calculated as following:

$\lambda r = 0.725\ \lambda_s + 10.75$ ------- (3.9)

$\lambda r = 0.79\ \lambda_s + 2$ ------- (3.10)

$\lambda r = 0.83679\ \lambda_s - 4.86$ -------- (3.11)

$\lambda r = 0.956\ \lambda_s - 1.31$ -------- (3.12)

Hydraulic retention time (t) of facultative ponds is then calculated as and matched with the observed retention times.

$$t = \frac{A_f H}{Q_{avg}} \qquad \text{------- (3.13)}$$

Where;

H = pond depth (usually 1.5m)

Q = average flow, (m^3.d)

A_f = Area of facultative pond (m^2)

2.4.2 Coliform removal

It can be estimated using following equation:

$$\frac{N_e}{N_O} = \frac{1}{(1 + k_b t)} \qquad \text{---- (3.14)}$$

Where:

N_O = coliform conc. in influent (org/100ml)

N_e = coliform conc. in effluent (org/100ml

t = hydraulic retention time of facultative pond

k_b = coliform die–off coefficient

$$k_{bT} = k_{b20}\theta^{(T-20)} \qquad \text{------ (3.15)}$$

Where:

k_{b20} = Coliform die–off coefficient at 20°C, taken as2.6**(Marais, 1974)**

T = Temperature (°C)

θ = Temperature coefficient, taken as 1.19 **(Marais, 1974)**

2.4.3 Ammonical nitrogen removal

Expected ammonical nitrogen removal can be calculated using following equations:

When temperature is below 20°C

$$C_e = \frac{C_o}{1+\left[(A/Q).(0.0038+0.000134.T).e^{(1.041+0.044T).(pH-6.6)}\right]} \quad \text{------ (3.16)}$$

When temperature is more than 20°C

$$C_e = \frac{C_o}{1+\left[5.035\times10^{-3}.(A/Q).e^{(1.540\times(pH-6.6))}\right]} \quad \text{--------- (3.17)}$$

Where;

C_e = ammonical nitrogen concentration in pond effluent, (mg N/L)

C_o = ammonical nitrogen concentration in pond influent, (mg N/L)

A = pond surface area, (m^2)

Q = wastewater flow rate, (m^3/d)

T = temperature, (°C)

pH = 7.3exp (0.0005A)

[Where A = influent alkalinity (mg $CaCO_3$/L)]

2.4.4 Total nitrogen removal

For estimating total nitrogen removal following equation is used in case of facultative and maturation ponds:

$$C_e = C_o \exp\{-[0.0064(1.039)^{T-20}][t + 60.6(pH - 6.6)]\} \quad \text{--------} \quad (3.18)$$

Where;

C_e = total nitrogen concentration in the pond effluent, (mg N/L)

C_o = total nitrogen concentration in the pond influent, (mg N/L)

T = temperature, (°C; range: 1-28°C)

t = retention time, (days; range: 5-231days)

pH = 7.3exp (0.0005A) [where A = influent alkalinity (mg $CaCO_3$/L)

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CHAPTER – 3

METHODOLOGY

3.1 Introduction

In this chapter the methods followed for the study are discussed. For achieving the objectives of the study, the work was planned on the following work elements:

- Getting background information on the STPs.
- Monitoring
- Performance evaluation

3.2 Getting background information of the STPs

The STPs in question were visited, surveyed and the people working there were consulted for understanding the scheme of treatment and for obtaining dimensional, capacity and other details. Sampling locations, parameters to be analyzed at each of the sampling locations were also decided on the basis of the survey.

3.3 Monitoring

Monitoring was done to understand the performance evaluation of the STPs. For facilitating this, the sampling locations were identified and the parameters for which the samples should be analysed were decided. The monitoring involved collection of grab samples on a monthly basis over twelve months (June 2009 to May 2010). Date and time of sampling, wastewater flow rate through the STPs and temperature of both ambient air and wastewater (at inlet and outlet) were recorded at the time of sampling. Even pH of the collected samples was measured on site. The samples were collected in three containers of which one is a sterilized grass bottle (meant for MPN test). The collected samples were brought to the Environmental Laboratory of the Thapar University within a few hours of collection, and analysed for the parameters indicated in table-3.1. Until the analysis was over the samples were stored in a deep freeze. Samples were collected from both the inlet and the outlet of the STP, for all the six STPs. In case of Jalandhar and Jamalpur STP over two months time samples were collected from two more locations and even UASB , sludge samples were collected. Methods followed for the analysis are indicated in table-3.2.

Table-3.1: Parameters to be characterized at different sampling points:

Parameter	Sampling points				
	Inlet (P1)	UASB Outlet (P2)	Pre-aeration Outlet (P3)	Outlet (P4)	Sludge (P5)
pH	✓	✓	-	✓	-
Temp.	✓	✓	-	✓	-
BOD	✓	✓	-	✓	-
COD	✓	✓	-	✓	-
MPN	✓	✓	✓	✓	-
TSS	✓	✓	-	✓	-
TDS	✓	✓	-	✓	-
TKN	✓	✓	-	✓	✓
Nitrate+Nitrite	✓	✓	-	✓	-
Total-P	✓	✓	-	✓	✓
Chloride	✓	-	-	✓	-
Sulphate	✓	-	-	-	-
Sulfide	-	✓	✓	✓	-
Alkalinity	✓	✓	-	✓	-
VSS	-	-	-	-	✓

Table-3.2: Analytical techniques for testing of wastewater parameters:

Sr. No.	Parameter	Method	References
1	Ph	Electrometric method	APHA (4500-h+ : B)
2	Temperature	Laboratory and field methods	APHA (1999) "manual standard method" 20th edition (2550: B)
3	Chemical Oxygen Demand (COD)	Closed reflux method	APHA (1999) "manual standard method" 20th edition (5220: B)
4	Biochemical Oxygen Demand (BOD)	5 day BOD test	APHA (1999) "manual standard method" 20th edition (5210: B)
5	Alkalinity	Titration method	APHA (1999) "manual standard method" 20th edition (2320: B)
6	TSS	Total suspended solids dried at 103-105°C.	APHA (1999) "manual standard method" 20th edition (2540: D)
7	TDS	Total dissolved dried at 180°C.	APHA (1999) "manual standard method" 20th edition (2540: C)
8	TS	Total solids dried at 103-105°C.	APHA (1999) "manual standard method" 20th edition (2540: B)
9	Ammonical nitrogen	Preliminary distillation step, titrimetric method.	APHA (1999) "manual standard method" 20th edition (4500-NH3: B, E)
10	Organic nitrogen	Macro kjeldahl method.	APHA (1999) "manual standard method" 20th edition (4550- org: B)
11	Nitrate nitrogen	Cadmium reduction method	APHA (1999) "manual standard method" 20th edition (4500-No3: E)
12	Nitrite nitrogen	Colorimetric method	APHA (1999) "manual standard method" 20th edition (45000-No2: B)
13	Total phosphorous	Stannous chloride method	APHA (1999) "manual standard method" 20th edition (4500-P: B, D)
14	MPN	Serial dilution method	APHA (1999) "manual standard method" 20th edition (9221:B,C)
15	Sulphates	Gravimetric method	APHA (1999) "manual standard method" 20th edition (4500-SO_4^{2-}: D)

16	Sulfide	Iodometric Method	APHA(1999) "manual standard method" 20th edition (4500-S^{2-}:E)
17	Chlorides	Argentometric method	APHA (1999) "manual standard method" 20th edition (4500-Cl^-: B)
18	VSS	TSS dried at 550°C	APHA (1999) "manual standard method" 20th edition (2540: G)

3.4 Performance evaluation

Using the monitoring data both at whole plant level and at the individual treatment units level, performance evaluation of the STPs was done. Performances of the individual units were assessed against the parameters for which the units were designed and used. Performance evaluation was also done for the coincidental removal of pollutants from the wastewater. By knowing the inlet and outlet concentration of different parameters, plants removal efficiencies for various parameters were calculated. The performance evaluation also involved comparison of the actual performance against the design performance and estimated performance. Individual evaluation of UASB and polishing pond has been done for suspended solids, BOD, COD, nutrients and pathogens removal.

3.5 Sewage Treatment Plants being studied

UASB & Polishing pond based STPs, installed and commissioned in **Jamalpur, Balloke, Bhattian, Jalandhar, Kapurthala, Phagwara** by Punjab Water Supply and Sewerage Board under the Satluj River Action Plan were studied. Schematic diagram of the STPs are given in **figure-.** All the treatment plants included the following units and facilities:

- Bar screen
- Sewage collection sump
- Raw sewage pumps
- Bar screen
- Grit chambers/channels (both manual/mechanical)

- UASB reactor
- Pre-aeration tank
- Polishing pond
- Chlorination unit (may or may not be commissioned)
- Sludge drying bed
- Biogas storage, handling and flaring system

Generally in STP the wastewater conveyed is collected into a raw sewage sump through mechanically cleaned bar screens, and from there, it is pumped with the help of number raw sewage pumps and passed through different units of the STP. The pumped raw sewage is metered with the help of an online flow meter. The pumped wastewater is first passed through a screen then degritted in both mechanical grit chambers and manual grit channels. The degritted sewage is passed through division boxes and uniformly distributed among distribution boxes. From the distribution boxes the wastewater is loaded to the UASB cells at the bottom through distribution tube for getting uniform upflow velocity in the UASB reactor. In the UASB primary treatment of the wastewater occurs. Suspended biodegradable and non-biodegradable solids are removed and stabilized anaerobically producing biogas. Wastewater from the UASB is allowed flow under gravity into the polishing pond through pre-aeration tank (where toxic and inhibitory gases are removed by air stripping). Secondary treatment of the wastewater occurs in the polishing pond. Algal photosynthesis and surface re-aeration provide the needed dissolved oxygen. Algal cells live the pond in symbiotic association with the heterotrophic bacteria bio-oxidizing the soluble biodegradable organic matter. Facultative have bottom anaerobic, middle facultative and top aerobic zones. Treated wastewater from the facultative pond is allowed to come out as treated effluent. This treated effluent is supposed to be chlorinated for pathogen removal prior to discharge. Sludge accumulated in the UASB reactor as and when needed is drained and loaded on the sludge drying beds for dewatering and drying. Biogas produced in the UASB reactor after mist elimination is collected into a floating gas dome and excess biogas is metered and flared.

3.5.1. STP at Bhattian (Ludhiana)

STP at Bhattian has a design capacity of 111 MLD & receives sewage which includes wastewater from dairy farms and also industrial effluents. Dimensional and capacity details of various units and facilities of the STP are given in table 3.3 and process flow diagram of STP is schematically shown in figure 3.1.

Table-3.3: Dimensional and capacity details of various units and facilities of the STP at Bhattian:

Units	**Dimensions**
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 40mm spacing. Mechanical reciprocating type of screen
Sumps	2 sumps both are interconnected.
Raw sewage Pumps	12 pumps, 10 of 140 hp capacity and 2 to 20 hp capacity.
Grit chambers/channels (both manual and mechanically)	Mechanically operated grit chamber with scraper.
UASB reactor	9 cells of UASB each of 30m length, 32m width, 5.06m liquid depth and 0.80m freeboard with 3 division box and 10 distribution box
Pre-aeration tank	Single unit having size of 12m length, 20m width, 3.5m depth
Polishing pond	Single pond having dimensions of 630m length, 270m width, 1.8m of liquid depth and 0.2m freeboard. Two baffles at distance of 90 m along the width.
Chlorination unit	Not yet commissioned
Sludge drying beds	72 beds each of 256m^3 and depth of 0.25m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 16m diameter, 1000m^3 of capacity

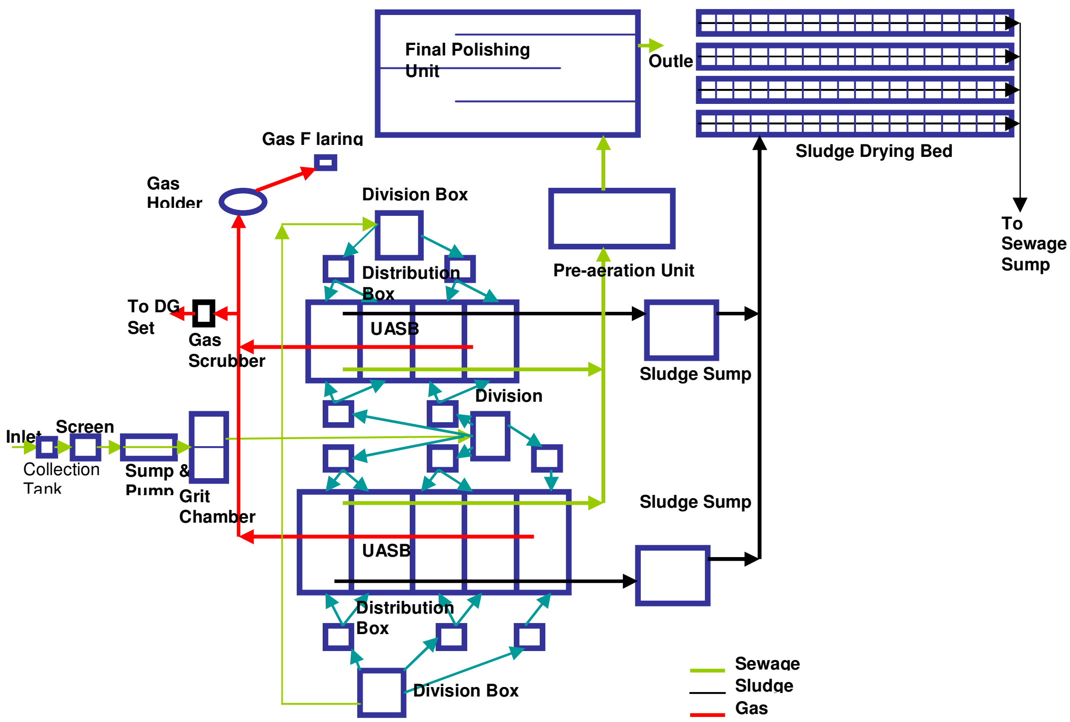


Figure-3.1: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Bhattian

3.5.2. STP at Kapurthala

STP at Kapurthala has a design capacity of 25 MLD & receives municipal sewage for city. For the dimensional and capacity details of various units and facilities see table 3.4 and process flow diagram of STP is schematically shown in figure 3.2.

Table-3.4: Dimensional and capacity details of various units and facilities of the STP at Kapurthala

Units	**Dimensions**
Inlet Chamber	Single unit having size of 4.6m length, 2.3m width, 5m depth
Screens Channels	4 Screen Channels each of 6m length, 1m width, 1m depth.
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 20mm spacing. 2 mechanical reciprocating type of screen.
Raw sewage Pumps	7 pumps (2 pumps of capacity 50 hp, 2 pumps of 30 hp, 3 pumps of capacity of 25 hp).
Grit Channel	4 grit channel each of 10.4m length, 2.5m width and 0.70m depth.
UASB reactor	2 cells of UASB each of 19m length, 58m width, 6m liquid depth and 0.52m freeboard with 1 division box & 4 distribution box
Pre-aeration tank	Single unit having size of 10.9m length, 3.6m width, 2.5m depth
Polishing pond	2 polishing pond having dimensions of 146.2m length, 57m width, 1.50m of liquid depth and 0.30m freeboard. Each has two baffles at distance of 60m along the width.
Chlorination unit	Commissioned in the month of February 2010.
Sludge Sump	Single sludge sump having dimension of 6.3m length and 3.2m width.
Sludge drying beds	18 beds each of 16m length and 16m width and depth of 2.5m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 32m diameter, 900m^3 of capacity

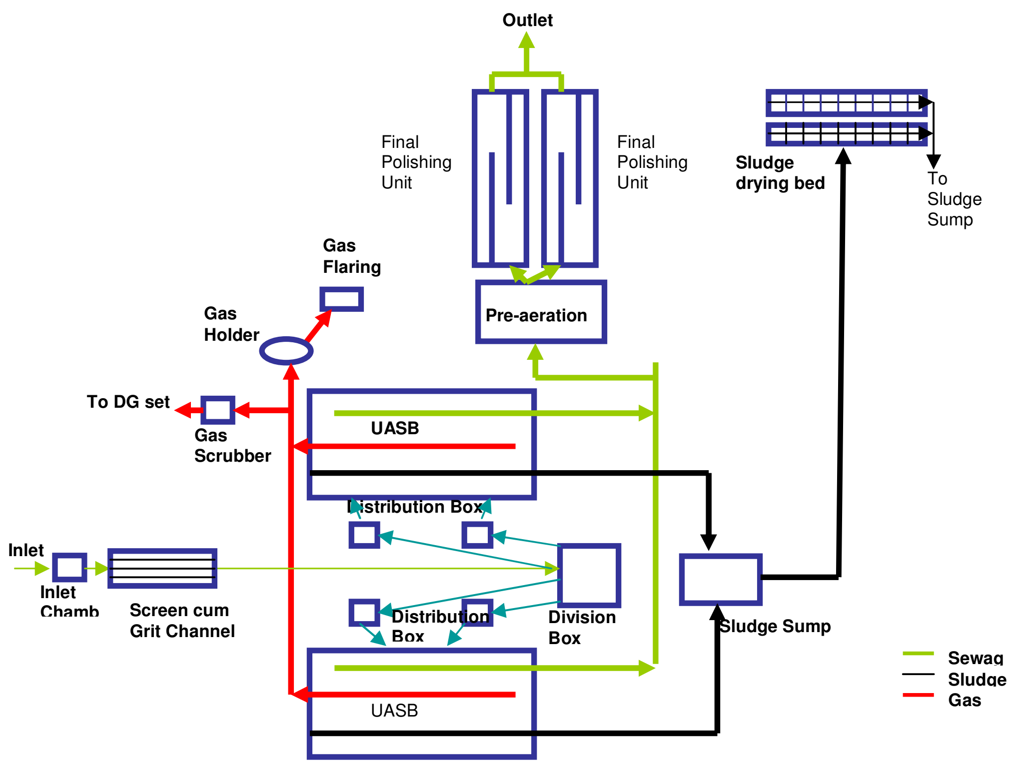


Figure-3.2: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Kapurthala

3.5.3. STP at Phagwara

STP at Phagwara has a design capacity of 20 MLD & receives sewage which includes wastewater from cities & from sugar industry. Dimensional and capacity details of various units and facilities of the STP are given in table 3.5 and process flow diagram of STP is schematically shown in figure 3.3.

Table-3.5: Dimensional and capacity details of various units and facilities of the STP at Phagwara

Units	**Dimensions**
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 25mm spacing. Mechanical reciprocating type of screen.
Screen Chamber	2 screen chamber each of 6.5m length, 2m width, 6.3m depth.
Sumps	2 sumps both are interconnected.
Raw sewage Pumps	6 pumps of capacity 30 hp.
Grit Channel	3 grit channel each of 14m length, 1.8 m width and 0.86m depth.
UASB reactor	2 cells of UASB each of 28m length, 30m width, 5.65m liquid depth and 0.50m freeboard with 1 division box & 4 distribution box
Pre-aeration tank	Single unit having size of 6.80m length, 6.80 m width, 3.60m depth
Polishing pond	2 polishing pond having dimensions of 124m length, 54m width, 1.50m of liquid depth and 0.30m freeboard. Each has two baffles at distance of 30m along the width.
Chlorination unit	Not yet commissioned
Sludge drying beds	6 beds each of 27.65m length and 21m width and depth of 2m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 30.4m diameter, $1000m^3$ of capacity

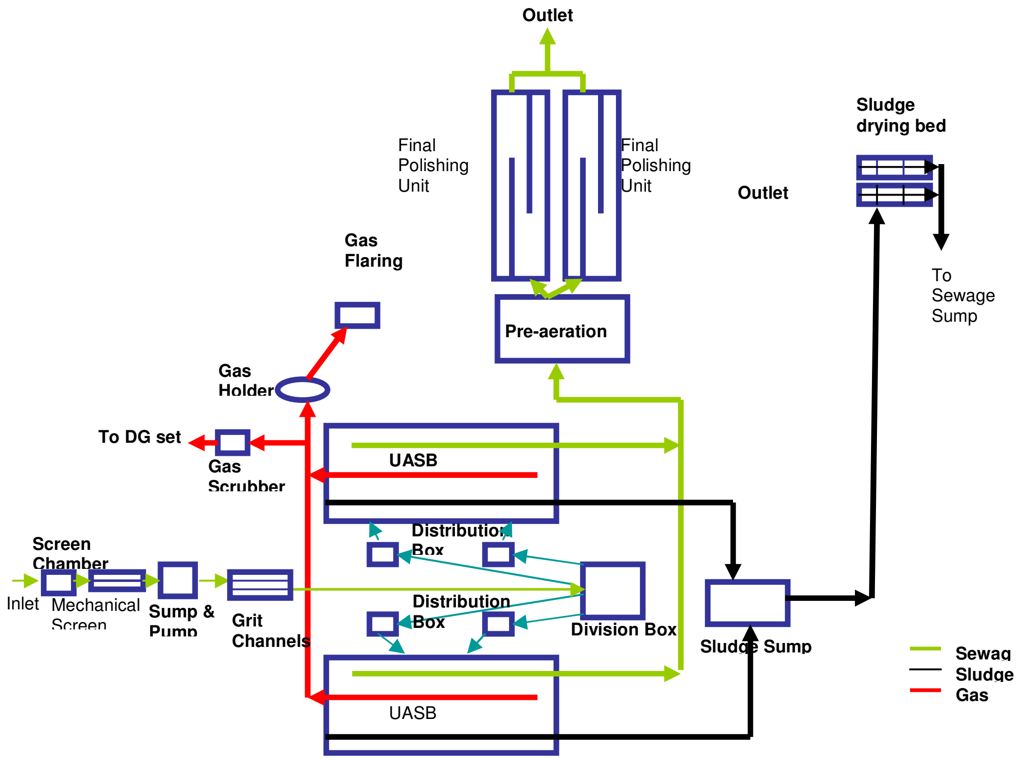


Figure-3.3: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Phagwara

3.5.4. STP at Jalandhar

STP at Jalandhar has a design capacity of 100 MLD & receives municipal sewage from the city. For the dimensional and capacity details of various units and facilities of the STP see table 3.6 and for the process flow diagram of STP is schematically shown in figure 3.4.

Table-3.6: Dimensional and capacity details of various units and facilities of the STP at Jalandhar:

Units	**Dimensions**
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 25mm spacing. Mechanical reciprocating type of screen
Sumps	2 sumps both are interconnected.
Raw sewage Pumps	10 pumps of capacity 135 hp
Grit chambers/channels (both manual and mechanically)	Mechanically operated grit chamber with scraper.
UASB reactor	8 cells of UASB each of 32m length, 28m width, 5.6 m liquid depth and 0.80m freeboard with 1 division box & 4 distribution box
Pre-aeration tank	Single unit having size of 15.25m length, 15.25m width, 3m depth
Polishing pond	Single pond having dimensions of 650m length, 250m width, 1.5m of liquid depth and 0.2m freeboard. Two baffles at distance of 95m along the width.
Chlorination unit	Commissioned
Sludge drying beds	40 beds each of 250m^3 and depth of 1.2m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 18m diameter, 1100m^3 of capacity

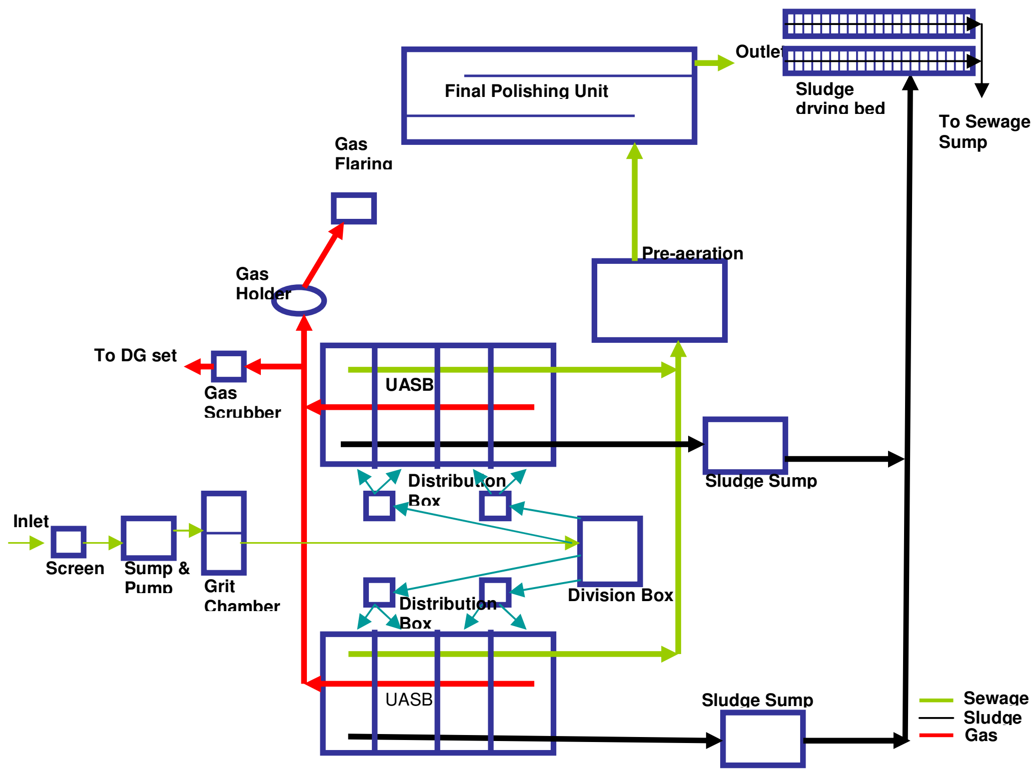


Figure-3.4: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Jalandhar

3.4.5. STP at Jamalpur (Ludhiana)

STP at Jamalpur (Ludhiana) has a design capacity of 48 MLD & receives wastewater which is not purely municipal sewage. Significant portion of it is industrial wastewater. About 25% of the effluent is domestic sewage & the rest comes from textile processing & metal finishing industries. Dimensional and capacity details of various units and facilities are given in table 3.7 and process flow diagram of STP is given in figure 3.5.

Table-3.7: Dimensional and capacity details of various units and facilities of the STP at Jamalpur

Units	**Dimensions**
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 50mm spacing. Mechanical reciprocating type of screen
Sumps	2 sumps both are interconnected.
Raw sewage Pumps	6 pumps of 120 hp capacity
Grit chambers/channels (both manual and mechanically)	Mechanically operated grit chamber with scraper.
UASB reactor	4 cells of UASB each of 30m length, 28m width, 5.06m liquid depth and 0.80m freeboard with 2 division box & 4 distribution box
Pre-aeration tank	Single unit having size of 12m length, 20m width, 3.5m depth
Polishing pond	Single pond having dimensions of 600m length, 200m width, 1.5m of liquid depth and 0.2m freeboard. Two baffles at distance of 90m along the width.
Chlorination unit	Not yet commissioned
Sludge drying beds	32 beds each of 200m^3 area and depth of 0.20m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 16m diameter, 1000m^3 of capacity

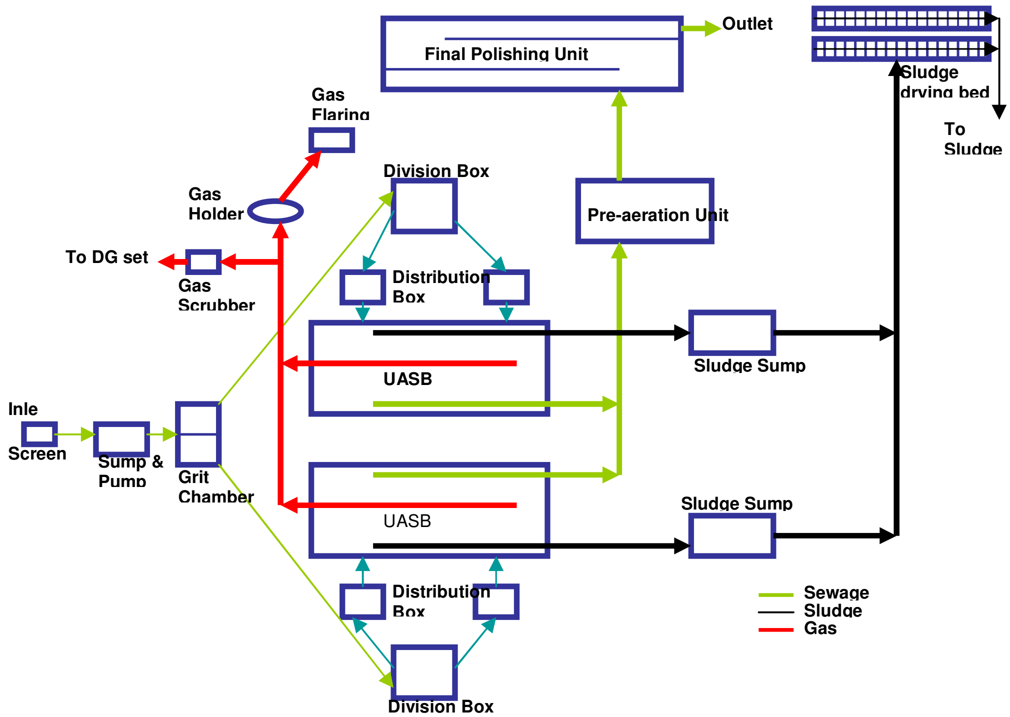


Figure-3.5: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Jamalpur

3.5.6. STP at Balloke (Ludhiana)

STP at Balloke has a design capacity of 152 MLD & receives wastewater from the city and also from dairy. For the dimensional and capacity details of various units and facilities see table 3.8 and for the process flow diagram see figure 3.6

Table-3.8: Dimensional and capacity details of various units and facilities of the STP at Balloke

Units	**Dimensions**
Bar screen (both manual and mechanically)	Manual bar screen of 6mm thick bars with 20mm spacing. 2 mechanical reciprocating type of screen.
Sumps	1 sump
Raw sewage Pumps	16 pumps (10 pumps of capacity 150 hp, 6 pumps of 20 hp)
Grit chambers/channels	2 Mechanically operated grit chamber with scrapers
UASB reactor	12 cells of UASB each of 32m length, 38m width, 5.06m liquid depth and 0.52m freeboard with 6 division box & 24 distribution box
Pre-aeration tank	Single unit having size of 15m length, 25m width, 3.5m depth
Polishing pond	3 polishing pond having dimensions of 280m length, 100m width, 1.5m of liquid depth and 0.20m freeboard.
Chlorination unit	Not yet commissioned
Sludge drying beds	96 beds each of $250m^3$ and depth of 0.30m.
Biogas storage, handling and flaring system	Gas stored in gas holder of 20m diameter, $1100m^3$ of capacity

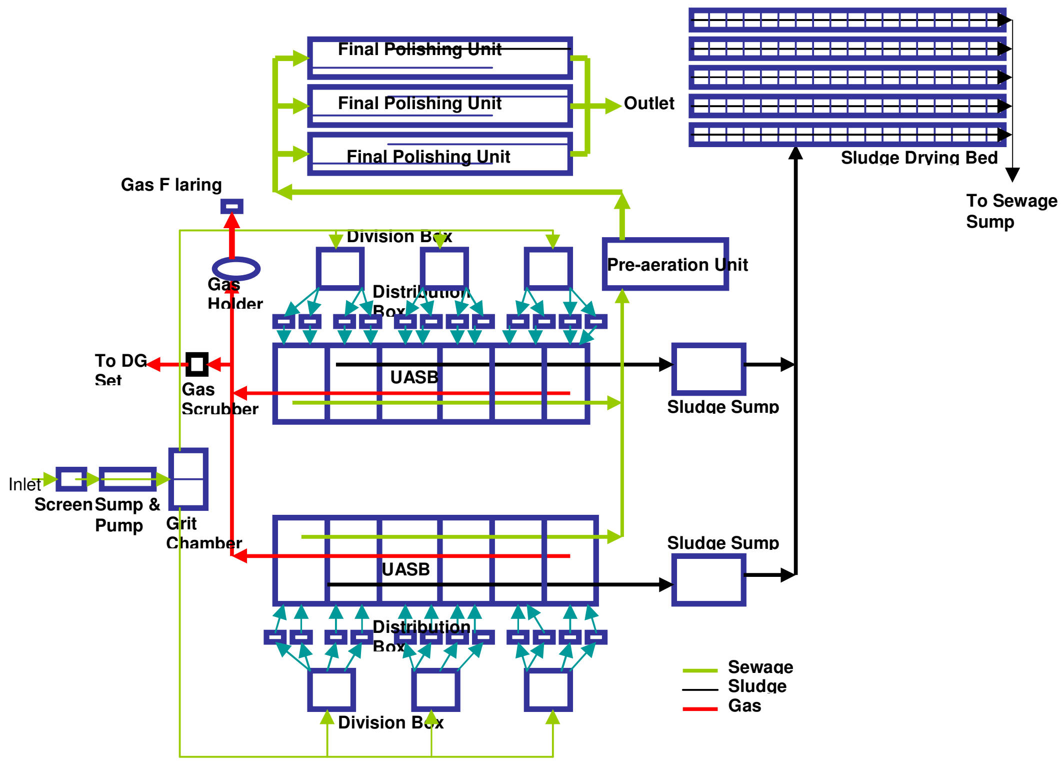


Figure-3.6: Schematic Process Flow diagram of UASB + Polishing Pond based STP at Balloke

CHAPTER - 4

RESULTS AND DISCUSSION

4.1 Introduction

Results obtained from the monitoring of the STPs over an year, from June 2009 to May 2010 and overall plant level performance evaluation of the six STP at (Bhattia, Balloke, Jalandhar, Jamalpur, Kapurthala & Phagwara) are presented in this chapter. The monitoring data is given in annexure-1 to annexure-6. Individual unit level performance evaluation results for the two STPs (one at Jalandhar and the other at Jamalpur) monitored over four months (Feb to May 2010) are also presented and discussed in this chapter. Please see annexure-7 and annexure-8 for the monitoring results. Sludges drained out from UASB was also characterized and given in annexure-9.

The STP are designed, commissioned and operated mainly for the removal or reduction of total suspended solids, BOD, COD and coliform count from the sewage being treated. In these STPs even nutrients get coincidentally removed. Hence the performance evaluation has been carried out against these parameters and given in this chapter. The performance evaluation also involved comparison of the actual performance against the design performance and estimated performance.

UASB is used in the STP for the removal of suspended solids and their anaerobic stabilization and for the BOD, COD removal from wastewater. In these treatment units removal of nutrients and pathogens is coincidental. Performance evaluation of the UASB was thus been carried out in the light of the above. Similarly, polishing ponds are designed for the removal of BOD. Removal of nutrients and pathogens are coincidental. Hence performance evaluation of the polishing ponds focused mainly on BOD, nutrients and pathogens.

4.2 Performance analysis of STPs

4.2.1 BOD, COD removal

Performance of the six STPs was evaluated in terms of BOD and COD removal. BOD and/or COD are the design parameters for the STP. TSS, MPN and nutrients are also removed in the treatment process but not by design. The extent of removal of these pollution parameters had also been evaluated in order to know how the performance compares with that experienced else where.

Average BOD and COD removals (over one year period and over the six STPs) were 79% and 69% respectively. See table 4.1 and 4.2 for details. There were variations among the six plants in this regards. For the STP at Jalandhar, these removals were 82% and 75% respectively. For the STP at Phagwara, the BOD removal was just 67% and the COD removal was the lowest (60%) for the STP at Kapurthala. The BOD and COD removal efficiencies have been relatively lower than those reported in literature (ref.). In fact the treated effluents were mostly not complying with the effluent standards prescribed under the EP Rules, 1986 for BOD (42.3mg/l against the standard of 30mg/L). Main cause for this appears to be high TSS in the treated effluent (94mg/l) which is coming out from the polishing pond (a facultative pond!). Since most of this TSS is algal cells that contribute both BOD and COD to the treated effluent, the overall performance of the STPs might have been brought down. This is evident even from the influent BOD and COD values. Higher influent BOD values had not resulted in higher effluent BOD values. Instead higher influent BOD and COD values were increasing the BOD and COD removal efficiencies.

It appears that capacity utilization and variations in sewage flow rates apparently have very little influence on the performance of the STPs. STP at Bhattian, where the capacity utilization was just 28%, and of the STP at Kapurthala, where the capacity utilization was as high as 95%, both were showing almost the same level of performance. Flow variations were quite high for the STPs at Phagwara and at Jalandhar, but the effluent BOD and COD values for these plants were not found much different from those of the other STPs. BOD of the effluent for these plants was

47.1 and 35mg/l respectively, while the average effluent BOD for all the six STPs was 42.3mg/l. Similarly, the effluent COD values for these plants were 134 and 116mg/l respectively for these plants while average effluent COD for the six STPs was 123mg/l. If only soluble BOD and COD of the effluent were considered then the STPs performance might have been observed as much higher.

BOD removal efficiencies calculated for the design flows, while taking the annual average sewage characteristics into consideration, have been much higher than the actual removal efficiencies observed. BOD removal efficiencies calculated for the design flows were 94% while actual removal efficiencies were 79%. If BOD contributed by the algal cells, in the treated effluent, is excluded then the actual removal efficiencies may become comparable to those for design flows.

BOD removal efficiencies calculated for the actual flows and actual average sewage characteristics for the four of the six STPS, for which data is available, are comparable to those obtained for the design flows. However, in case of the STP at Bhattian, Ludhiana, efficiencies calculated for actual flows were found unrealistically very high. Main reasons for this could be underutilization of the capacity (28% of the design capacity) and use of empirical formulas in the calculations.

Table-4.1: BOD, COD, TSS mean and standard deviations of UASB-Polishing pond based STPs

STP	BOD			COD			TSS		Capacity Utilization	
	Inlet (mg/l)	Outlet (mg/l)	Removal Efficiency	Inlet (mg/l)	Outlet (mg/l)	Removal Efficiency	Outlet (mg/l)	Removal Efficiency		
BHATTIAN									**Capacity**	111000
Mean	232.10	39.2	80%	450.0	111.30	70%	95.9	60%	**Capacity Utilization**	28%
Stdev	±58.42	±14.92	±5%	±162.14	±54.84	±8%	±53.35	±22%	**Variation in flow**	18.50%
KAPURTHALA									**Capacity**	25000
Mean	220	55.3	80%	423.6	153.5	60%	84.5	80%	**Capacity Utilization**	95%
Stdev	±47.42	±17.17	±4%	±141.65	±60.06	±11%	±44.03	±11%	**Variation in flow**	32.60%
PHAGWARA									**Capacity**	20000
Mean	153.9	47.1	67%	414.3	133.7	65%	125.6	58%	**Capacity Utilization**	85%
Stdev	±64.06	±12.80	±9%	±160.3	±30.19	±11%	±90.89	±40%	**Variation in flow**	43.30%
JALANDHAR									**Capacity**	100000
Mean	200	35	82%	498.18	116.36	75%	64.27	79%	**Capacity Utilization**	94%
Stdev	±66.08	±18.20	±8%	±206.58	±63.64	±11%	±33.03	±12%	**Variation in flow**	44.35%
JAMALPUR									**Capacity**	48000
Mean	156	38.56	76%	457.78	112	75%	85.44	63%	**Capacity Utilization**	NA
Stdev	±37.16	±18.81	±9%	±106.04	±35.10	±9%	±52.74	±27%	**Variation in flow**	NA
BALLOKE									**Capacity**	152000
Mean	181.67	38.89	76%	406.67	113.78	71%	112	66%	**Capacity Utilization**	NA
Stdev	±88.23	±12.81	±10%	±135.65	±43.41	±11%	±55.28	±30%	**Variation in flow**	NA
Average Removal										
Mean	-	-	79%	-	-	69%	-	68%	-	-
Stdev	-	-	±2%	-	-	±6%	-	±10%	-	-

NA: Not Available

Table-4.2: BOD, COD removal efficiencies of STPs

STP	BOD	COD	TSS
Bhattian			
Actual performance	80% ±5%	70% ±8%	60% ±22%
Designed performance	93%	-	77%
Estimated performance	101% ±12%*1	-	87% ±9%*1
Kapurthala			
Actual performance	80% ±4%	60% ±11%	80% ±11%
Designed performance	94%	-	82%
Estimated performance	95% ±5%*2	-	80% ±5%*2
Phagwara			
Actual performance	67% ±9%	65% ±11%	58% ±40%
Designed performance	94%	-	78%
Estimated performance	86% ±5%*3	-	79% ±9%*3
Jalandhar			
Actual performance	82% ±8%	75% ±11%	79% ±12%
Designed performance	93%	-	77%
Estimated performance	91% ±4%*4	-	77% ±16%*4
Jamalpur			
Actual performance	76% ±9%	75% ±9%	63% ±27%
Designed performance	94%	-	67%
Estimated performance	*5	-	*5
Balloke			
Actual performance	76% ±10%	71% ±11%	66% ±30%
Designed performance	94%	-	81%
Estimated performance	*6	-	*6

*1: Based on 4 months flowrate

*2: Based on 7 months flowrate

*3: Based on 6 months flowrate

*4: Based on84 months flowrate

*5: No flowrate are available

*6: No flowrate are available

4.2.2 Nitrogen removal

Raw wastewater received by the STPs has been taken to have negligible concentration of nitrate and nitrite nitrogen and all the nitrogen present is in the form of TKN. In the UASB reactor, except for a small fraction of the nitrogen lost in the stabilized sludge being wasted, the TKN loaded will remain unaffected and come out in the treated effluent. The amount of nitrogen lost in the wasted stabilized sludge has been taken as that present in the biosolids being synthesized. This assumption may hold true only if the TSS in the treated effluent of the UASB is within the range estimated by the expression [102*(HRT in days)**(-0.24)]. The nitrogen removal efficiencies for the UASB thus must be higher if the TSS of the effluent is lower. In the facultative ponds (polishing pond), significant amounts of ammonical nitrogen and total nitrogen are removed. A few empirical models are available for estimating ammonical and total nitrogen removals in the facultative (polishing) ponds. Depending on the level of DO in the aerobic zone, some of the ammonical nitrogen of the wastewater may be converted into nitrite and nitrate nitrogen.

Total nitrogen removals observed for the six STPs have been only moderate (12.8%) and there have been wide variations in the removal efficiencies among the plants. See table-4.3 for detail. For the STPs at Jamalpur no net nitrogen removal was observed, while for Kapurthala it is highest at 26.8%. Low inlet TKN levels and high TSS levels in the final effluent are apparently closely related with the low nitrogen removal efficiencies. Nitrogen from the STP must be getting lost as organic nitrogen in the algal cells being washed out in the effluent. Performance evaluation based on grab samples may not be appropriate and composite sampling of the inlet and the outlet over 3 days period or over the HRT of the STP may prove more appropriate.

Design nitrogen removal efficiencies estimated based on certain assumptions while using empirical models available from literature are given in table-4.4. The removal efficiency expected has been much higher than what is actually getting removed. Estimated removal for design flow is 64% and it is varying between 34% and 76%. The actual removal efficiencies observed have been 12.8% and varying between -4.8% and +26%. Surprisingly the removal efficiency has been lowest for Jamalpur in both the cases. The performance evaluation is based on grab samples; composite sampling over the retention time of the STP might have given more reliable results. Still the empirical models used for the performance assessment and for the assumption made may need a fresh took for their use for Punjab condition where industrial wastewater fraction of the sewage is higher. Further, wastewater contribution by dairy and animal keeping is also high.

Table-4.3: Actual removal values and removal efficiency of organic, ammonical, total nitrogen , nitrite-nitrate and TSS.

STP	Inlet			Outlet					TSS		Capacity Utilization	
	Org-N (mg/l)	NH4-N (mg/l)	Total-N (mg/l)	Org-N (mg/l)	NH_4-N (mg/l)	NO_2+NO_3-N (mg/l)	Total (mg/l)	Removal efficiency	Inlet (mg/l)	Outlet (mg/l)		
BHATTIAN											**Capacity**	111000
Mean	2.78	25.56	28.34	2.91	23.65	1.52	27.99	1.24%	286.8	95.9	**Capacity Utilization**	28%
Stdev	±1.75	±9.79	±9.10	±3.38	±11.11	±1.61	±11.35		±80.69	53.35±	**Variation in flow**	18.50%
KAPURTHALA											**Capacity**	25000
Mean	2.7	23.5	26.1	2.1	15.9	1.03	19.1	26.80%	336.7	84.5	**Capacity Utilization**	95%
Stdev	±2.59	±9.11	±9.25	±1.85	±8.80	±0.83	±8.31		±66.87	±44.03	**Variation in flow**	32.60%
PHAGWARA											**Capacity**	20000
Mean	3.89	20.97	24.9	5.14	14.11	2	21	15.70%	306	125.6	**Capacity Utilization**	85%
Stdev	±3.79	±8.46	±12.02	±8.30	±6.42	±1.57	±7.14		±97.08	±90.89	**Variation in flow**	43.30%
JALANDHAR											**Capacity**	100000
Mean	2.48	25.82	28.3	1.82	18.11	1.59	21.53	23.90%	367.5	64.27	**Capacity Utilization**	94%
Stdev	±2.09	±6.83	±7.46	±1.51	±8.05	±1.36	±8.58		±173.9	±33.03	**Variation in flow**	44.35%
JAMALPUR											**Capacity**	48000
Mean	3.63	8.75	12.38	2.1	9.28	2	12.98	-4.80%	331.2	85.4	**Capacity Utilization**	NA
Stdev	±4.07	±4.39	±7.18	±3.25	±4.59	±1.07	±7.18		±206.4	±52.7	**Variation in flow**	NA
BALLOKE											**Capacity**	152000
Mean	5	27.05	32.05	2.6	24.87	2	29.91	6.70%	485.66	112	**Capacity Utilization**	NA
Stdev	±4.09	±8.43	±9.46	±2.00	±7.48	±1.68	±7.91		±264.58	±55.28	**Variation in flow**	NA
Average Removal												
Mean	3.41	21.94	25.35	2.78	17.65	1.69	22.09	0.13	352.31	94.61	-	-
Stdev	±0.95	±6.80	±6.80	±1.22	±5.89	±0.39	±6.15		±70.90	±21.78	-	-

NA: Not Available

Table-4.4: Design removal values and removal efficiency of nitrogen.

STP		Total Inlet-N (mg/l)	Removal of N in UASB (mg/l)	Removal of N in Polishing pond (mg/l)	Outlet-N (mg/l)	Removal efficiency
BHATTIAN	***Mean***	28.34	1.49	15.61	11.24	60%
	Stdev	9.10	0.37	6.27	3.67	
KAPURTHALA	***Mean***	26.14	1.49	18.31	6.34	76%
	Stdev	9.25	0.32	7.12	3.44	
PHAGWARA	***Mean***	24.85	1.03	15.78	8.04	68%
	Stdev	12.02	0.43	6.89	5.57	
JALANDHAR	***Mean***	28.30	1.27	15.45	11.59	59%
	Stdev	7.46	0.42	4.91	3.17	
JAMALPUR	***Mean***	12.38	0.97	3.25	8.16	34%
	Stdev	7.07	0.23	2.20	6.00	
BALLOKE	***Mean***	32.05	1.21	20.98	9.86	69%
	Stdev	9.46	0.59	6.96	4.33	
	Average Mean	25.34	1.24	14.90	9.20	64%
	Average Stdev	1.76	0.12	1.91	1.17	

4.2.3 Coliform removal

Total coliform numbers and fecal coliform numbers monitored at both the inlet and outlet of the STPs indicate 1.92 log units removal of coliform bacteria. This is very close to the expected removal of 1.85 log units found from the empirical models (for completely mixed flow conditions) available from literature for the design flows. See table 4.5 and table 4.6 for detail. For the STPs at Balloke and at Kapurthala actual removal are relatively lower than the expected removals. For the other STPs actual removals are higher than the expected. This is along the expected lives; the STPs were run at design capacity.

In case of STP at Kapurthala the treated sewage was chlorinated prior to disposal since March, 2010 but it did not significantly reduce the coliform count of the treated effluent. Instead the coliform count was higher after the start of chlorination. Geometric mean of coliform count for the months June, 09 to Jan 2010 was 2.6×10^6 (when the effluent was chlorinated). This indicates the chlorination though done was not proper. This is evident from the ammonical nitrogen concentration in the treated effluent. For the months Feb to May 2010 its value was 14.4mg/l while annual average was 15.4mg/l.

Table-4.5: Actual and calculated removal of total coliform.

STP	Inlet values in geomean	Outlet				Capacity Utilization	
		Actual value in geomean	Actual removal in LOG	Calculated value in geomean	Calculated removal in LOG		
Bhattian						**Capacity**	111000
	4.5×10^7	3.0×10^5	2.18	3.5×10^5	2.11	**Capacity Utilization**	28%
						Variation in flow	18.50%
Kapurthala						**Capacity**	25000
	6.3×10^7	3.3×10^6	1.28	1.7×10^6	1.57	**Capacity Utilization**	95%
						Variation in flow	32.60%
Phagwara						**Capacity**	20000
	7.3×10^7	1.1×10^6	1.82	2.4×10^6	1.48	**Capacity Utilization**	85%
						Variation in flow	43.30%
Jalandhar						**Capacity**	100000
	4.4×10^7	3.3×10^5	2.12	6.5×10^5	1.83	**Capacity Utilization**	94%
						Variation in flow	44.35%
Jamalpur						**Capacity**	48000
	2.3×10^7	1.2×10^5	2.28	1.9×10^5	2.08	**Capacity Utilization**	NA
						Variation in flow	NA
Balloke						**Capacity**	152000
	3.8×10^7	5.1×10^5	1.87	3.4×10^5	2.85	**Capacity Utilization**	NA
						Variation in flow	NA
Average (LOG)	-	-	1.92	-	1.85	-	-
Stdev(LOG)	-	-	0.36	-	0.27	-	-

NA- Not Available

Table-4.6: Actual and calculated removal of fecal coliform.

STP	Inlet values in geomean	Outlet				Capacity Utilization	
		Actual values in geomean	Actual removal in LOG	Calculated values in geomean	Calculated removal in LOG		
BHATTIAN						**Capacity**	111000
	1.1×10^{7}	5.7×10^{4}	2.29	9.1×10^{4}	2.08	**Capacity Utilization**	28%
						Variation in flow	18.50%
KAPURTHALA						**Capacity**	25000
	3.2×10^{7}	6.3×10^{5}	1.71	8.9×10^{5}	1.56	**Capacity Utilization**	95%
						Variation in flow	32.60%
PHAGWARA						**Capacity**	20000
	9.8×10^{6}	2.4×10^{5}	1.61	3.3×10^{5}	1.47	**Capacity Utilization**	85%
						Variation in flow	43.30%
JALANDHAR						**Capacity**	100000
	5.0×10^{6}	8.1×10^{4}	1.79	7.5×10^{4}	1.82	**Capacity Utilization**	94%
						Variation in flow	44.35%
JAMALPUR						**Capacity**	48000
	5.3×10^{6}	3.6×10^{4}	2.17	4.4×10^{4}	2.08	**Capacity Utilization**	
						Variation in flow	
BALLOKE						**Capacity**	152000
	1.0×10^{7}	1.7×10^{5}	1.77	2.0×10^{4}	2.7	**Capacity Utilization**	
						Variation in flow	
Average (LOG)			1.89		1.95		
Stdev(LOG)			0.27		0.45		

NA:NotAvilable

CHAPTER – 5
CONCLUSION

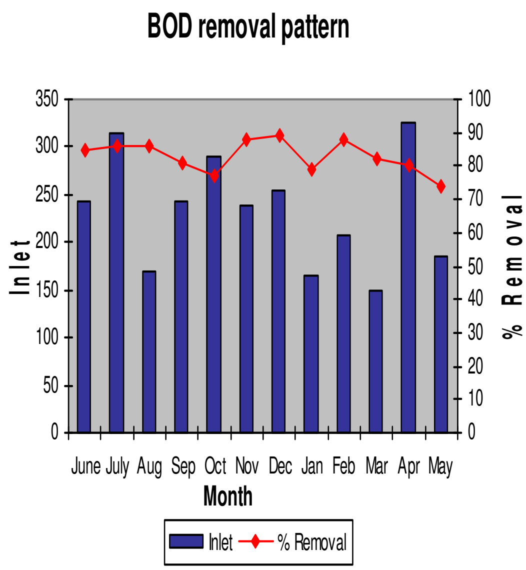
Monitoring and performance evaluation of Upflow Anaerobic Sludge Blanket Reactor and Polishing Pond based sewage treatment plants was carried out in order to evaluate performance of the STPs and its key constituent units and also involved comparison of the performance against the design performance and estimated performance. Average BOD, COD, TSS and MPN (over one month year period and over the six STPs) of the treated effluent were 42.3mg/l, 94.6mg/l, 94.6mg/l and 1.92 log unit respectively. The treated effluent is not complying with the effluent standards prescribed for BOD and COD due to high TSS in the treated effluent which is mainly contributed by algal cells. Overall total nitrogen removal observed for six STPs has been moderate (12.8%) and there are wide variations in the removal efficiencies among the plants. Low nitrogen removal efficiency may be due to high TSS contributed by algal cells resulting in the loss of greater amount of nitrogen in the effluent. Excepting for MPN, if not for the role played by the algal cells in the treated effluent, the treatment process is satisfactory indicating that plants are working properly. Reduction of coliform count was not satisfactory as expected and effluent from the polishing pond needs further treatment. Chlorination has been commissioned in some of the plants but MPN reduction was not occurring as desired. Higher algal cell concentration and ammonical nitrogen concentration in the treated effluent could be responsible. The performance evaluation was based on grab samples. But during the study need for composite samples was very much felt. Further inclusion of parameters like soluble BOD and COD, residual chlorine in the treated effluent was also felt needed. Instead of instantaneous sewage flow rates, flow rates cumulated over a month period might have made the performance evaluation more meaningful.

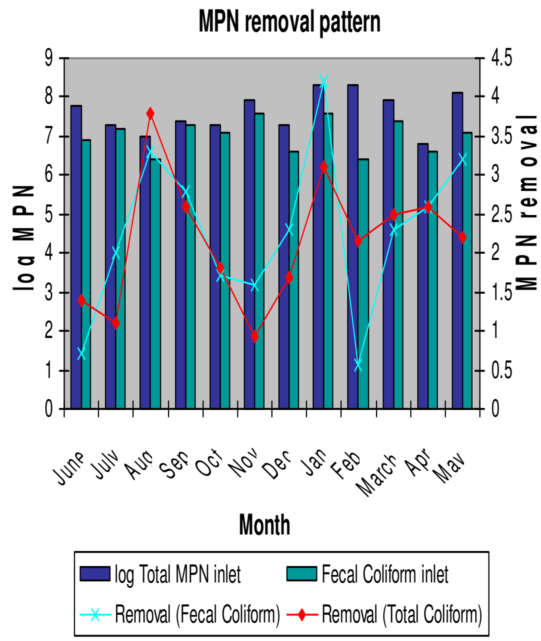
Performance Monitoring Data for the STP at Bhattian.

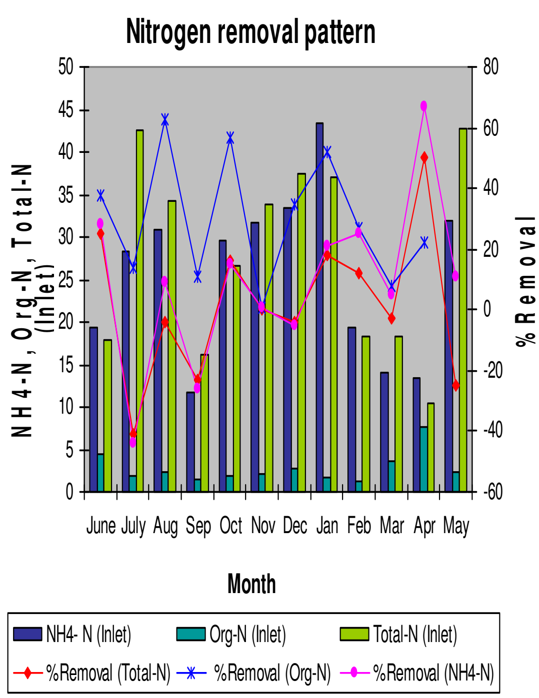
Annexure-1a: Performance efficiencies

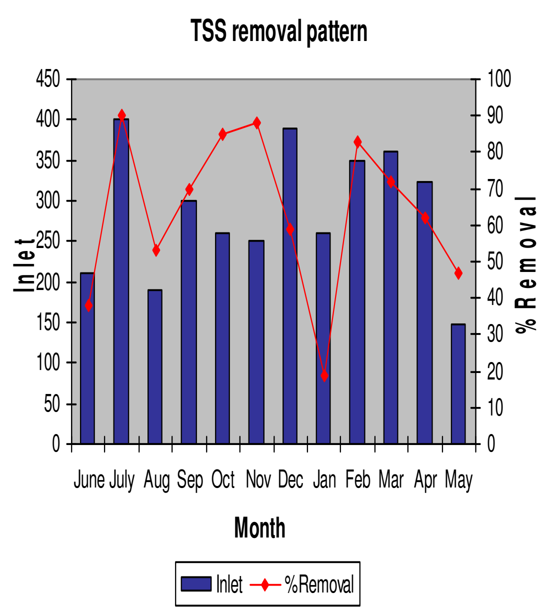
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	242.5	36 (85%)	520	96 (82%)	210	130 (38%)
July, 09	315.0	43 (86%)	600	176 (71%)	400	40 (90%)
Aug, 09	170.0	23 (86%)	640	192 (70%)	190	90 (53%)
Sep, 09	242.5	45 (81%)	280	80 (71%)	300	90 (70%)
Oct, 09	290.0	68 (77%)	480	112 (77%)	260	40 (85%)
Nov, 09	237.5	29 (88%)	560	80 (86%)	250	30 (88%)
Dec, 09	255.0	28 (89%)	600	80 (87%)	390	160(59%)
Jan, 10	165.0	34 (79%)	360	64 (82%)	260	210 (19%)
Feb, 10	207.5	25 (88%)	240	56 (77%)	350	60 (83%)
Mar, 10	150.0	27 (82%)	260	80 (60%)	360	100 (72%)
Apr, 10	325.0	64 (80%)	620	224(64%)	323	123 (62%)
May, 10	185.0	48 (74%)	240	96 (60%)	148	78 (47%)
St.deviation	58.42	14.92 (5%)	162.14	54.84 (8%)	80.69	53.35 (22%)
Average	232.1	39.2 (80%)	450.0	111.3 (70%)	286.8	95.9 (60%)
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	4.48	2.8 (38%)	19.32	14 (28%)	23.80	17.91 (25%)
July, 09	1.96	1.68 (14%)	28.28	40.68 (-44%)	30.24	42.5 (-41%)
Aug, 09	2.30	0.84 (63%)	30.80	27.92 (9%)	33.10	34.32 (-4%)
Sep, 09	1.54	1.37 (11%)	11.62	14.59 (-26%)	13.16	16.15 (-23%)
Oct, 09	1.96	0.84 (57%)	29.50	25.2 (15%)	31.46	26.57 (16%)
Nov, 09	2.07	2.04 (1%)	31.64	31.36 (1%)	33.71	33.87 (0%)
Dec, 09	2.66	1.74 (35%)	33.32	35 (-5%)	35.98	37.52 (-4%)
Jan, 10	1.62	0.78 (52%)	43.40	34.16 (21%)	45.02	37.06 (18%)
Feb, 10	1.29	0.94 (27%)	19.32	14.56 (25%)	20.61	18.22 (12%)
Mar, 10	3.67	3.36 (8%)	14.14	13.5 (5%)	17.81	18.32 (-3%)
Apr, 10	7.56	5.88 (22%)	13.50	4.5 (67%)	21.06	10.53 (50%)
May, 10	2.24	12.6 (-463%)	31.92	28.28 (11%)	34.16	42.86 (-25%)
St. deviation	1.759	3.38 (144%)	9.79	11.11 (28%)	9.10	11.35 (25%)
Average	2.78	2.91 (-11%)	25.56	23.65 (10%)	28.34	27.99 (2%)
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	8.0×10^6	1.3×10^6	0.79	7.0×10^7	2.3×10^6	1.48
July, 09	1.7×10^7	1.7×10^5	2	2.4×10^7	1.7×10^6	1.15
Aug, 09	3.0×10^6	1.2×10^3	3.40	1.1×10^7	1.7×10^3	3.81
Sep, 09	2.2×10^7	3.4×10^4	2.81	2.8×10^7	7.0×10^4	2.6
Oct, 09	1.3×10^7	2.3×10^5	1.75	2.3×10^7	3.5×10^5	1.82
Nov, 09	5.0×10^7	1.1×10^6	1.66	8.0×10^7	9×10^6	0.95
Dec, 09	4.0×10^6	2.0×10^4	2.30	2.4×10^7	5.0×10^5	1.68
Jan, 10	5.0×10^7	3.0×10^3	4.22	2.2×10^8	1.7×10^5	3.11
Feb, 10	3.0×10^6	8.0×10^5	0.57	2.4×10^8	1.7×10^6	2.15
Mar, 10	3.0×10^7	1.3×10^5	2.36	8.0×10^7	2.2×10^5	2.56
Apr, 10	5.0×10^6	1.1×10^4	2.66	7.0×10^7	1.7×10^4	2.61
May, 10	1.3×10^7	8.0×10^3	3.21	1.3×10^8	8.0×10^5	2.21
Geo.mean	1.1×10^7	5.7×10^5	2.03	4.5×10^7	3.0×10^5	2.03

Annexure-1b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Bhattian









Annexure-1c: Other monitoring data fir the STP at Bhattian

Sampling time range: 11:06am – 01:10pm

Month	Date of sampling	Flowrate (m3/sec)	pH		Temp, (^{0}C)	
			Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	8/6/2009	0.011833	7.75	8.51	32	30 (38.4)
July, 09	14/7/09	0.0949	7.77	7.57	31	31 (35.8)
Aug, 09	14/8/09	NA	7.30	7.69	34	35 (33)
Sep, 09	17/9/09	N.A	7.86	8.59	31	32 (32)
Oct, 09	13/10/09	N.A	7.48	7.58	27	32 (32)
Nov, 09	13/11/09	1.38888	7.26	7.95	24	21 (24)
Dec, 09	15/12/09	0.04052	8.24	8.29	24	19 (15)
Jan, 10	14/1/10	N.A	8.38	8.99	21	18 (11)
Feb, 10	9/2/2010	N.A	8.34	8.56	22	20 (19)
Mar, 10	14/3/10	N.A	6.85	7.30	28	26 (26)
Apr, 10	15/4/10	N.A	7.15	7.33	32	34 (36)
May, 10	13/5/10	N.A	6.82	7.23	30	29 (35)

Month	TDS, mg/l		Chloride, mg/l	NO_2+NO_3-N, mg/l	Total-P, mg/l
	Inlet	Outlet	Outlet	Outlet	Outlet
June, 09	820	1020	290.7	1.11	1.07
July, 09	910	840	165.9	0.14	0.89
Aug, 09	930	950	217.0	5.56	2.20
Sep, 09	1360	950	209.2	0.19	1.31
Oct, 09	910	950	198.5	0.53	0.20
Nov, 09	820	920	163.1	0.47	1.82
Dec, 09	800	970	203.3	0.78	2.95
Jan, 10	760	990	193.8	2.12	0.87
Feb, 10	820	1040	205.6	2.72	1.07
Mar, 10	1340	1410	234.0	1.46	0.65
Apr, 10	1080	1230	189.7	0.15	0.72
May, 10	1170	1112	2.39.3	2.98	0.69
Average	976.67	1031.83	206.44	1.52	1.20

* Chlorination has not been started.

ANNEXURE-2

Performance Monitoring Data for the STP at Kapurthala

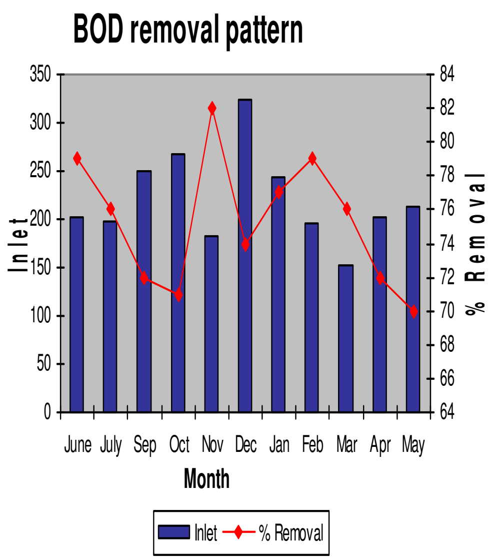
Annexure-2a: Performance efficiencies

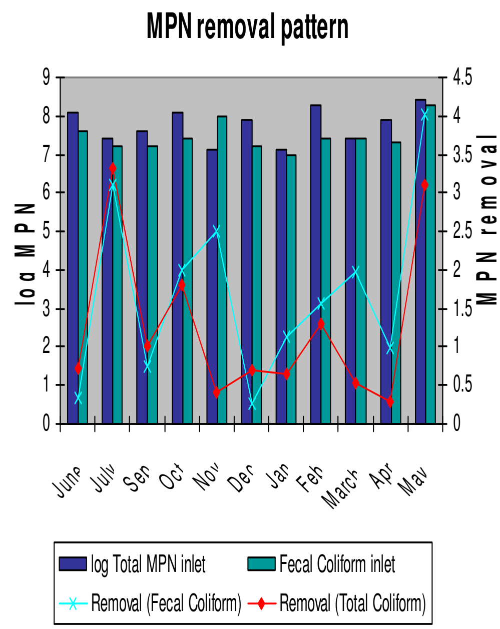
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	202.5	43 (79%)	480	144 (70%)	260	50 (81%)
July, 09	197.5	47 (76%)	480	184 (62%)	360	40 (89%)
Sep, 09	250	71 (72%)	320	112 (65%)	390	80 (79%)
Oct, 09	267.5	78 (71%)	480	112 (77%)	340	40 (88%)
Nov, 09	182.5	32 (82%)	240	128 (47%)	240	60 (75%)
Dec, 09	325.0	84 (74%)	560	288 (49%)	350	100 (71%)
Jan, 10	242.5	56 (77%)	640	128 (80%)	320	150 (53%)
Feb, 10	195.0	41 (79%)	200	96 (52%)	420	160 (62%)
Mar, 10	152.2	37 (76%)	380	136 (64%)	410	75 (82%)
Apr, 10	202.5	56 (72%)	560	240 (57%)	383	128 (67%)
May, 10	212.5	63 (70%)	320	120 (63%)	231	47 (80%)
STDEV	47.42	17.17 (4%)	141.65	60.06 (11%)	66.87	44.03 (11%)
Average	220.9	55.3 (80%)	423.6	153.5 (60%)	336.7	84.5 (80%)

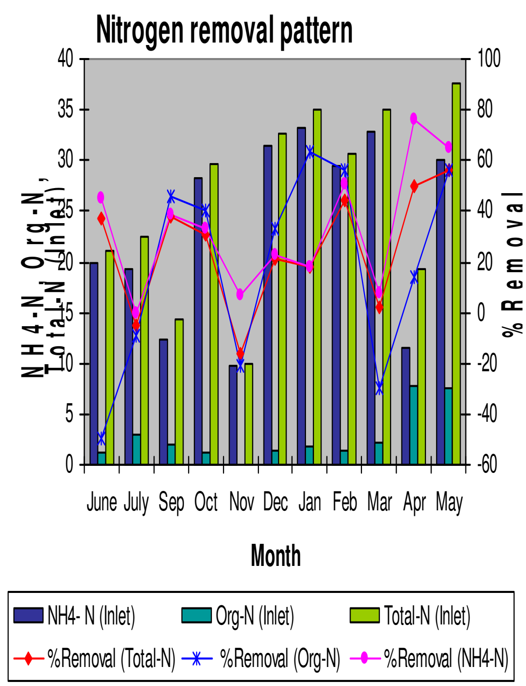
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	1.12	1.68 (-50%)	19.88	10.92 (45%)	21.00	13.24 (37%)
July, 09	3.08	3.36 (-9%)	19.32	19.32 (0%)	22.40	23.52 (-5%)
Sep, 09	1.93	1.04 (46%)	12.38	7.5 (39%)	14.31	8.87 (38%)
Oct, 09	1.29	0.78 (40%)	28.28	19.04 (33%)	29.57	20.45 (31%)
Nov, 09	0.07	1.54 (2100%)	9.80	9.07 (7%)	9.87	11.4 (-16%)
Dec, 09	1.34	0.9 (33%)	31.36	24.08 (23%)	32.70	25.91 (21%)
Jan, 10	1.74	0.64 (63%)	33.32	27.44 (18%)	35.06	28.82 (18%)
Feb, 10	1.34	0.59 (56%)	29.40	14.28 (51%)	30.74	17.22 (44%)
Mar, 10	2.25	2.92 (-30%)	32.75	30.24 (8%)	35.00	34.29 (2%)
Apr, 10	7.84	6.72 (14%)	11.50	2.8 (76%)	19.34	9.65 (50%)
May, 10	7.56	3.3 (56%)	29.96	10.36 (65%)	37.52	16.53 (56%)
STDEV	2.59	1.85 (64%)	9.11	8.80 (25%)	9.25	8.31 (23%)
Average	2.7	2.1 (22%)	23.5	15.9 (33%)	26.1	19.1 (30%)

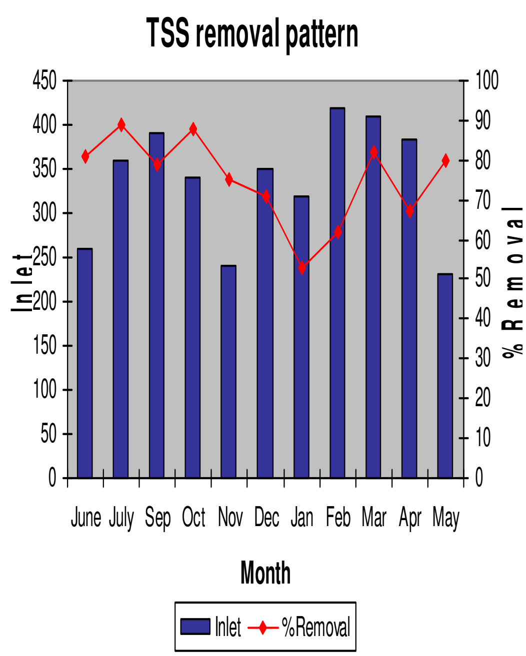
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	5.0×10^{7}	2.3×10^{7}	0.34	1.3×10^{8}	2.4×10^{7}	0.73
July, 09	1.7×10^{7}	1.1×10^{4}	3.19	3.0×10^{7}	1.4×10^{4}	3.33
Sep, 09	1.7×10^{7}	3.0×10^{6}	0.75	5.0×10^{7}	5.0×10^{6}	1
Oct, 09	3.0×10^{7}	3.0×10^{5}	2	1.4×10^{8}	2.2×10^{6}	1.80
Nov, 09	1.1×10^{8}	3.0×10^{5}	2.56	1.3×10^{7}	5.0×10^{6}	0.41
Dec, 09	1.7×10^{7}	9.0×10^{6}	0.28	8.0×10^{7}	1.6×10^{7}	0.70
Jan, 10	1.1×10^{7}	8.0×10^{5}	1.14	1.3×10^{7}	2.8×10^{6}	0.67
Feb, 10	3.0×10^{7}	8.0×10^{5}	1.57	2.2×10^{8}	9.0×10^{6}	1.39
Mar, 10	2.8×10^{7}	3.0×10^{5}	1.97	3.0×10^{7}	9.0×10^{6}	0.52
Apr, 10	2.3×10^{7}	2.4×10^{6}	0.98	9.3×10^{7}	4.6×10^{7}	0.31
May, 10	2.4×10^{8}	2.2×10^{4}	4.04	3.0×10^{8}	2.2×10^{4}	0.13
Geomean	3.2×10^{7}	6.3×10^{5}	1.3	6.3×10^{7}	3.3×10^{6}	0.7

Annexure-2b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Kapurthala.









Plant was not in operation during the month of August 2009

Annexure-2c: Other monitoring data for STP at Kapurthala

Sampling time range: 10:44am – 12:05pm

Month	Date of sampling	Flowrate (m3/sec)	pH		Temp (^{0}C)	
			Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	9/6/2009	18.84	7.80	7.81	30	28 (36)
July, 09	15/7/09	NA	7.59	8.01	30	31 (37.2)
Sep, 09	18/9/09	NA	7.10	7.61	27	26 (34)
Oct, 09	14/10/09	13.0208	7.58	7.79	27	25 (33)
Nov, 09	14/11/09	6.481	7.66	8.06	20	19 (16)
Dec, 09	16/12/09	0.2265	7.87	8.25	22	20 (22)
Jan, 10	15/1/10	0.137	7.98	8.70	15	20 (16)
Feb, 10	10/2/2010	NA	7.67	7.72	20	18 (19)
Mar, 10	15/3/10	0.34278	7.28	7.36	27	23 (27)
Apr, 10	16/4/10	NA	7.70	7.22	30	29 (42)
May, 10	14/5/10	NA	7.43	6.96	30	25 (34)

Month	TDS, mg/l		Chloride, mg/l	NO_2+NO_3-N, mg/l	Total-P, mg/l
	Inlet	Outlet	Outlet	Outlet	Outlet
June, 09	680	540	97.5	0.64	0.63
July, 09	550	410	39.7	0.84	1.17
Sep, 09	490	460	40.6	0.33	0.21
Oct, 09	520	570	42.5	0.63	1.56
Nov, 09	590	510	47.9	0.79	3.42
Dec, 09	530	540	40.2	0.93	4.18
Jan, 10	500	540	52.0	0.74	1.51
Feb, 10	560	490	58.5	2.35	0.66
Mar, 10	610	580	56.7	1.13	0.87
Apr, 10	710	670	47.8	0.13	0.61
May, 10	690	635	93.9	2.87	0.76
Average	584.55	540.45	56.12	1.03	1.42

* Plant was not in operation when we went for sampling during the month of August, 2009.

* Chlorination started in the month of February 2010.

Performance Monitoring Data for the STP at Phagwara

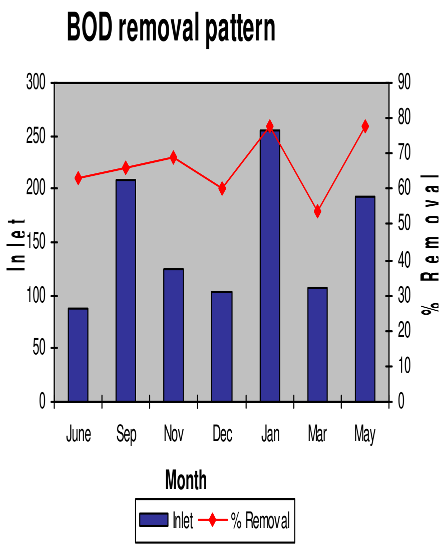
Annexure-3a: Performance efficiencies

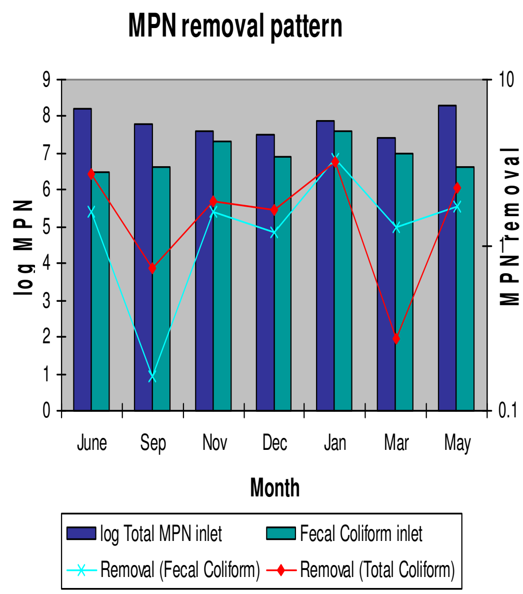
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	87.5	32 (63%)	240	112 (53%)	220	30 (86%)
Sep, 09	207.5	70 (66%)	440	144 (67%)	270	80 (70%)
Nov, 09	125.0	39 (69%)	400	160 (60%)	230	140 (39%)
Dec, 09	102.5	41 (60%)	560	176 (69%)	390	150 (62%)
Jan, 10	255.0	57 (78%)	680	104 (85%)	400	290 (28%)
Mar, 10	107.5	49 (54%)	300	144 (52%)	430	160 (63%)
May, 10	192.5	42 (78%)	280	96 (66%)	202	29 (86%)
STDEV	64.06	12.8 (9%)	160.30	30.19 (11%)	97.08	90.89 (21%)
Average	153.9	47.1 (67%)	414.3	133.7 (65%)	306.0	125.6 (58%)

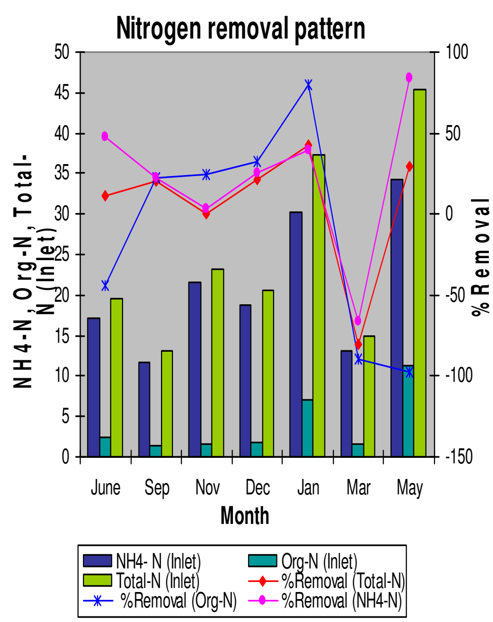
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	2.52	3.64 (-44%)	17.08	8.96 (48%)	19.60	17.49 (11%)
Sep, 09	1.43	1.12 (22%)	11.7	9.18 (22%)	13.13	10.53 (20%)
Nov, 09	1.57	1.2 (24%)	21.56	21 (3%)	23.13	23.05 (0%)
Dec, 09	1.74	1.18 (32%)	18.76	14 (25%)	20.50	16.21 (21%)
Jan, 10	7.06	1.43 (80%)	30.24	18.2 (40%)	37.30	21.19 (43%)
Mar, 10	1.68	3.64 (-177%)	13.16	21.84 (-66%)	14.84	26.69 (-80%)
May, 10	11.20	23.8 (-113%)	34.26	5.6 (84%)	45.46	32.17 (29%)
STDEV	3.79	8.30 (76%)	8.46	6.42 (46%)	12.02	7.14 (40%)
Average	3.89	5.14 (-17%)	20.97	14.11 (22%)	24.9	21 (6%)

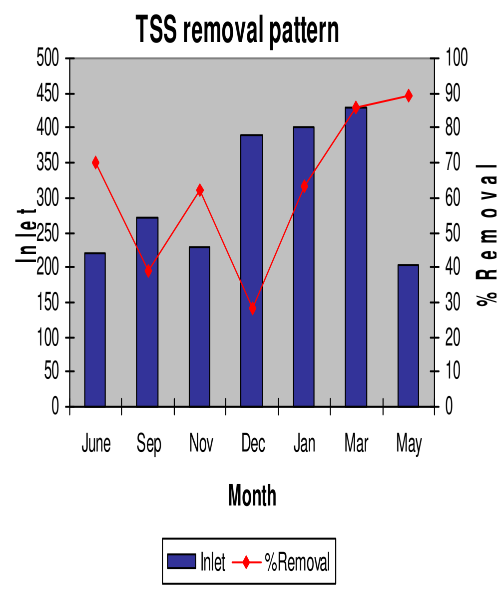
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	3.3×10^6	8.0×10^4	1.62	1.6×10^8	3.0×10^5	2.73
Sep, 09	5.0×10^6	3.4×10^6	0.17	7.0×10^7	1.3×10^7	0.73
Nov, 09	2.4×10^7	5.0×10^5	1.68	5.0×10^7	7.0×10^5	1.85
Dec, 09	8.0×10^6	5.0×10^5	1.20	3.5×10^7	8.0×10^5	1.64
Jan, 10	5.0×10^7	2.2×10^4	3.36	8.0×10^7	5.0×10^4	3.20
Mar, 10	1.1×10^7	5.0×10^5	1.34	3.0×10^7	1.6×10^7	0.27
May, 10	5.0×10^6	8.0×10^4	1.80	2.4×10^8	1.3×10^6	2.27
Geomean	9.8×10^6	2.4×10^5	1.24	7.3×10^7	1.1×10^6	1.42

Annexure-3b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Phagwara.









Plant was not in operation during the month of July 09, Aug 09, Oct 09, Feb 10 and April 10

Annexure-6: Other monitoring data for the STP at Phagwara

Sampling time range: 9:22am – 10:30am

Month	Date of sampling	Time	Flowrate (m3/sec)	pH		Temp(^{0}C)	
				Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	9/6/2009	9:30am	0.214	8.60	8.83	33	28 (34.9)
Sep, 09	18/9/09	9:47am	NA	7.82	8.29	25	29 (30)
Nov, 09	14/11/09	10:07am	1.615	7.21	7.00	14	17 (12)
Dec, 09	16/12/09	1:00pm	0.095	8.56	8.68	22	18 (22)
Jan, 10	15/1/10	10:30am	0.091	7.99	8.98	22	15 (10)
Mar, 10	15/3/10	9:51am	0.238	7.24	7.87	27	25 (26)
May, 10	14/5/10	9:22am	0.268	6.93	7.67	29	28 (34)

Month	TDS, mg/l		Chloride, mg/l	NO_2+NO_3-N, mg/l	Total-P, mg/l
	Inlet	Outlet	Outlet	Outlet	Outlet
June, 09	1150	1020	242.8	4.89	4.61
Sep, 09	890	1170	179	0.23	1.00
Nov, 09	960	900	190.0	0.85	1.83
Dec, 09	1030	1190	220.0	1.03	4.36
Jan, 10	1110	1050	163.0	1.56	2.13
Mar, 10	1260	1310	245.0	1.21	0.32
May, 10	1130	1200	211.0	2.77	0.66
Average	1076	1120	207	2	2

* Plant was not in operation when we went for sampling during the month of Jul 09y, August 09, October 09, February and April 2010.

* Chlorination has not been commissioned. .

Performance Monitoring Data for the STP at Jalandhar

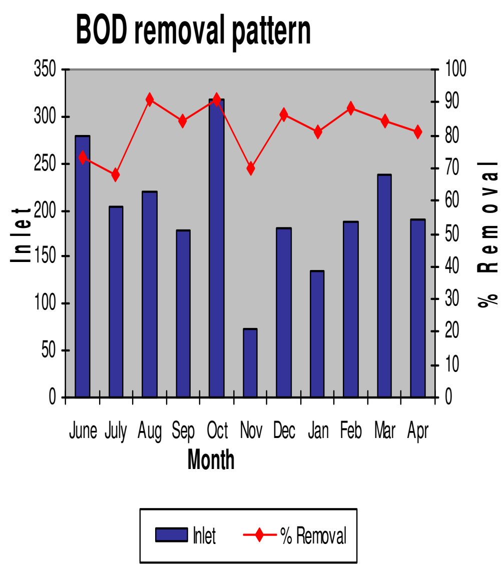
Annexure-4a: Performance efficiencies

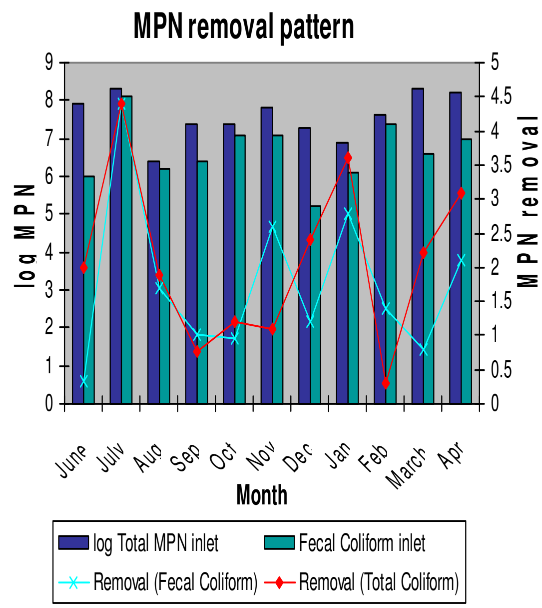
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	280	75 (73%)	560	240 (57%)	380	130 (66%)
July, 09	202.5	64 (68%)	520	224 (57%)	130	50 (62%)
Aug, 09	220	19 (91%)	1000	128 (87%)	320	70 (78%)
Sep, 09	177.5	28 (84%)	320	64 (80%)	330	100 (70%)
Oct, 09	317.5	29 (91%)	640	128 (80%)	120	30 (75%)
Nov, 09	72.5	22 (70%)	240	48 (80%)	410	10 (98%)
Dec, 09	180	25 (86%)	520	64 (88%)	300	90 (70%)
Jan, 10	135	26 (81%)	480	80 (83%)	740	60 (92%)
Feb, 10	187.5	22 (88%)	280	96 (66%)	480	50 (90%)
Mar, 10	237.5	38 (84%)	440	128 (71%)	320	60 (81%)
Apr, 10	190	37 (81%)	480	80 (83%)	513	57 (89%)
STDEV	66.08	18.20 (8%)	206.58	63.64 (11%)	173.98	33.03 (12%)
Average	200.00	35 (82%)	498.18	116.36 (75%)	367.55	64.27 (79%)

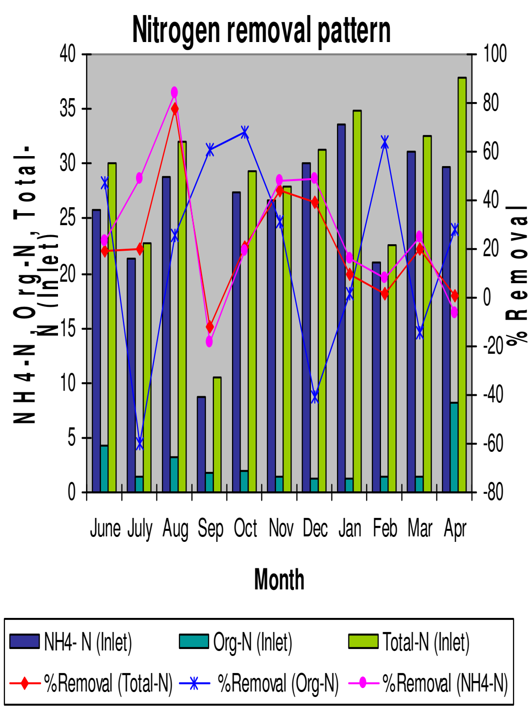
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	4.20	2.24 (47%)	25.76	19.88 (23%)	29.96	24.25 (19%)
July, 09	1.40	2.24 (-60%)	21.28	10.92 (49%)	22.68	18.22 (20%)
Aug, 09	3.16	2.35 (26%)	28.84	4.48 (84%)	32.00	7.17 (78%)
Sep, 09	1.74	0.67(61%)	8.79	10.36 (-18%)	10.53	11.84 (-12%)
Oct, 09	1.96	0.62 (68%)	27.44	22.12 (19%)	29.40	23.31 (21%)
Nov, 09	1.37	0.95 (31%)	26.60	13.92 (48%)	27.97	15.65 (44%)
Dec, 09	1.26	1.78 (-41%)	29.96	15.4 (49%)	31.22	19.19 (39%)
Jan, 10	1.20	1.18 (2%)	33.60	28.28 (16%)	34.80	31.3 (10%)
Feb, 10	1.50	0.54 (64%)	21.00	19.32 (8%)	22.50	22.16 (2%)
Mar, 10	1.40	1.59 (-14%)	31.08	23.24 (25%)	32.48	26.12 (20%)
Apr, 10	8.12	5.88 (28%)	29.68	31.34 (-6%)	37.80	37.58 (1%)
STDEV	2.09	1.51 (43%)	6.830	8.05 (29%)	7.46	8.58 (25%)
Average	2.48	1.82 (19%)	25.82	18.11 (27%)	28.30	21.53 (22%)

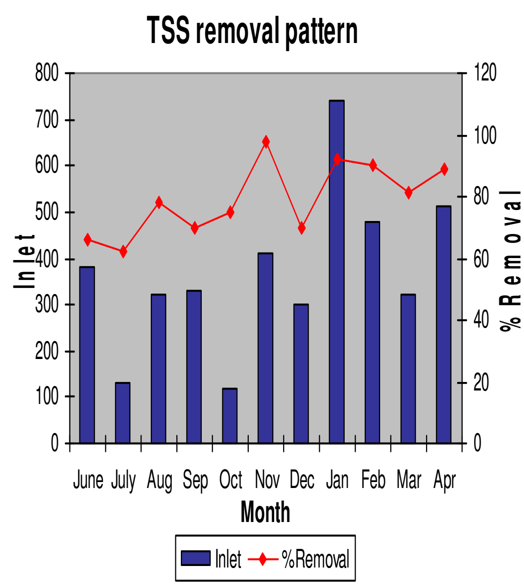
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	1.1×10^7	5.0×10^5	0.34	8.0×10^7	8.0×10^5	2
July, 09	1.3×10^7	5.0×10^3	4.41	2.2×10^8	8.0×10^3	4.44
Aug, 09	1.7×10^7	2.8×10^4	1.78	2.6×10^6	3.3×10^4	1.90
Sep, 09	3.0×10^7	3.0×10^5	1	3.0×10^7	5.0×10^6	0.78
Oct, 09	1.3×10^7	1.4×10^6	0.97	3.0×10^7	8.0×10^7	1.25
Nov, 09	1.3×10^7	2.7×10^4	2.68	7.0×10^7	5.0×10^6	1.15
Dec, 09	1.7×10^5	9.0×10^3	1.28	2.2×10^7	8.0×10^4	2.44
Jan, 10	1.5×10^7	2.1×10^3	2.85	9.3×10^6	2.3×10^3	3.61
Feb, 10	3.0×10^7	1.1×10^6	1.44	5.0×10^7	2.4×10^7	0.32
Mar, 10	5.0×10^7	8.0×10^5	0.80	2.4×10^8	1.3×10^6	2.27
Apr, 10	1.1×10^7	8.0×10^4	2.14	1.7×10^8	3.3×10^4	3.12
Geomean	5.0×10^6	8.1×10^4	1.46	4.4×10^7	3.3×10^5	1.72

Annexure-4b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Jalandhar.









Plant was not in operation during the month of May 2010

Annexure-4c: Other monitoring data for the STP at Jalandhar

Sampling time range: 11.25am – 12:11am

Month	Date of sampling	Flowrate(m3/sec)	pH		Temp (^{0}C)	
			Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	11/6/09	0.418	8.01	7.65	33	31 (38)
July, 09	12/7/09	NA	7.32	7.72	31	34 (35)
Aug, 09	13/8/09	0.539	6.95	8.1	31	32 (33)
Sep, 09	15/9/09	1.134	7.89	7.97	27	30 (32)
Oct, 09	10/11/09	1.936	7.61	7.64	26	27 (32)
Nov, 09	11/11/09	NA	7.62	7.15	21	21 (24)
Dec, 09	12/12/09	0.99	8.37	8.25	19	16 (15)
Jan, 10	12/1/10	NA	8	7.82	18	13 (11)
Feb, 10	12/2/10	0.941	7.61	7.52	21	18 (19)
Mar, 10	12/3/10	0.902	7.29	7.24	24	23 (26)
Apr, 10	13/4/10	0.941	7.71	7.16	29	29 (36)

Month	TDS, mg/l		Chloride, mg/l	NO_2+NO_3-N, mg/l	Total-P, mg/l
	Inlet	Outlet	Outlet	Outlet	Outlet
June, 09	50	540	152.4	2.13	2.03
July, 09	620	590	32.6	5.06	1.40
Aug, 09	530	450	75.2	0.34	0.45
Sep, 09	540	470	65.6	0.81	0.62
Oct, 09	590	600	67.4	0.57	0.62
Nov, 09	550	500	69.1	0.78	1.92
Dec, 09	770	610	28.5	2.01	3.89
Jan, 10	590	570	35.10	1.84	0.63
Feb, 10	510	470	42.5	2.30	1.05
Mar, 10	790	560	67.4	1.29	0.46
Apr, 10	730	800	72.7	0.36	0.36
Average	570	560	64.41	1.59	1.22

* Plant was not in operation when we went for sampling during the month of May 2010.

* Chlorination started in the month of April 2010.

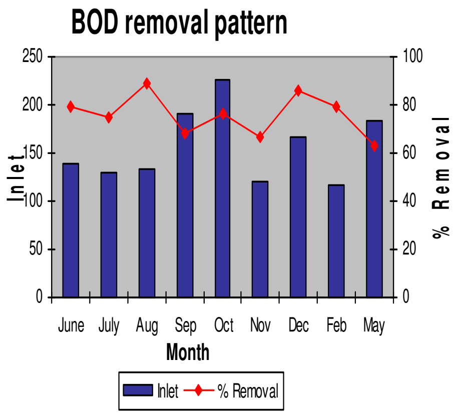
Performance Monitoring Data for the STP at Jamalpur

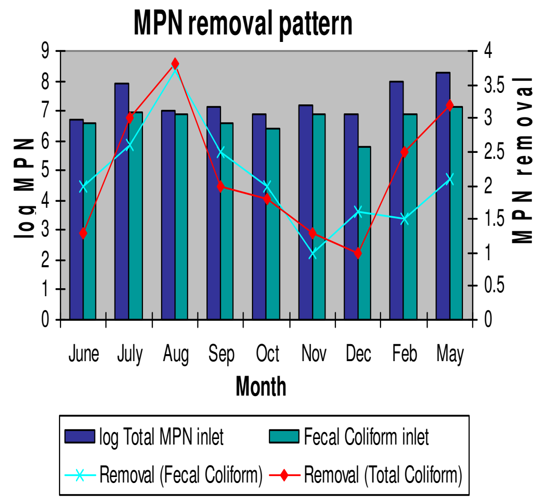
Annexure-5a: Performance efficiencies

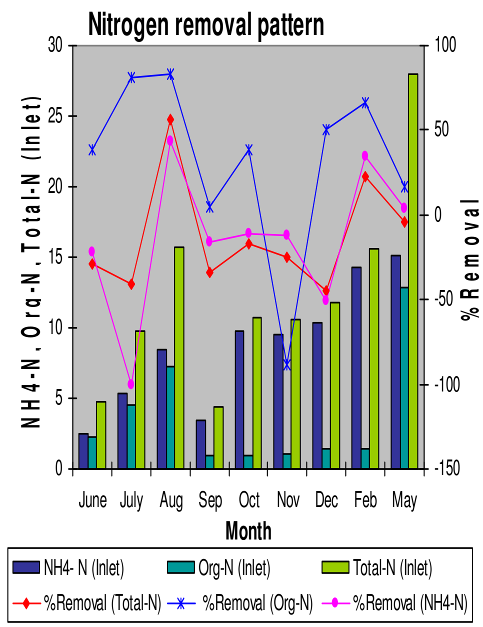
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	139	29 (79%)	320	64 (80%)	130	90 (31%)
July, 09	130	33 (75%)	400	104 (74%)	60	50 (17%)
Aug, 09	132.5	15 (89%)	560	144 (74%)	440	80 (82%)
Sep, 09	190	60 (68%)	640	112 (83%)	260	120 (54%)
Oct, 09	225	55 (76%)	360	128 (64%)	320	20 (94%)
Nov, 09	120	40 (67%)	360	144 (60%)	750	30 (96%)
Dec, 09	167.5	23 (86%)	520	88 (83%)	460	190 (59%)
Feb, 10	117.5	25 (79%)	480	64 (87%)	360	120 (67%)
May, 10	182.5	67 (63%)	480	160 (67%)	201	69 (66%)
STDEV	37.16	18.18 (9%)	106.04	35.10 (9%)	206.41	52.74 (27%)
Average	156	38.56 (76%)	457.78	112 (75%)	331.22	85.44 (63%)
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	2.24	1.4 (38%)	2.52	3.08 (-22%)	4.76	6.12 (-29%)
July, 09	4.48	0.84 (81%)	5.32	10.64 (-100%)	9.8	13.81 (-41%)
Aug, 09	7.28	1.23 (83%)	8.4	4.76 (43%)	15.68	6.94 (56%)
Sep, 09	0.95	0.90 (5%)	3.47	4.03 (-16%)	4.42	5.93 (-34%)
Oct, 09	0.90	0.56 (38%)	9.80	10.92 (-11%)	10.7	12.47 (-17%)
Nov, 09	1.10	2.07 (-88%)	9.52	10.64 (-12%)	10.62	13.3 (-25%)
Dec, 09	1.46	0.73 (50%)	10.36	15.68 (-51%)	11.82	17.09 (-45%)
Feb, 10	1.37	0.47 (66%)	14.28	9.24 (35%)	15.65	12.02 (23%)
May, 10	12.88	10.66 (17%)	15.12	14.56 (4%)	28	29.1 (-4%)
STDEV	4.07	3.25 (52%)	4.39	4.59 (43%)	7.07	7.18 (33%)
Average	3.63	2.10 (32%)	8.75	9.28 (-15%)	12.38	12.98 (-0.13%)

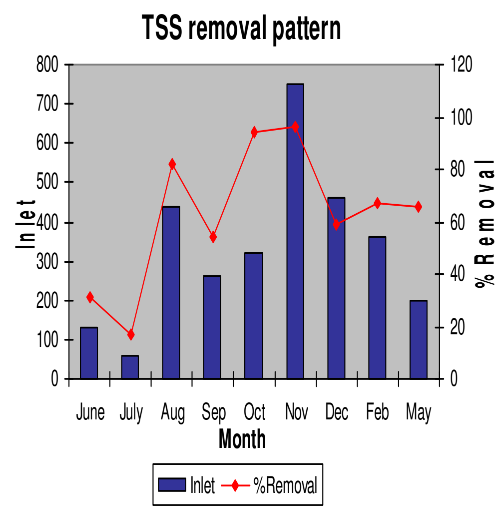
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	5.0×10^6	4.0×10^4	2.10	6.0×10^6	3.0×10^5	1.30
July, 09	9.0×10^6	2.0×10^4	2.65	8.0×10^7	8.0×10^4	3
Aug, 09	8.0×10^6	1.4×10^3	3.76	1.1×10^7	1.4×10^3	3.9
Sep, 09	5.0×10^6	1.3×10^4	2.59	1.3×10^7	1.1×10^5	2.07
Oct, 09	3.0×10^6	3.0×10^4	2	8.0×10^6	1.1×10^5	1.86
Nov, 09	8.0×10^6	7.0×10^5	1.06	1.7×10^7	7.0×10^5	1.39
Dec, 09	7.0×10^5	1.4×10^4	1.70	8.0×10^6	8.0×10^5	1
Feb, 10	8.0×10^6	2.4×10^5	1.52	1.1×10^8	3.0×10^5	2.56
May, 10	1.4×10^7	1.1×10^5	2.1	2.4×10^8	1.3×10^5	3.27
Geomean	5.3×10^6	3.6×10^4	2.04	2.3×10^7	1.2×10^5	2.06

Annexure-5b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Jamalpur.









Plant was not in operation during the month of Jan, March, April 2010

Annexure-5c: Other monitoring data for the STP at Jamalpur

Sampling time range: 8:50am – 9:20am

Month	Date of sampling	pH		Temp (^0C)	
		Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	8/6/09	7.99	8.79	37	32 (36.7)
July, 09	14/7/09	8.28	8.06	36	32 (31)
Aug, 09	14/8/09	8.08	7.91	38	35 (37.8)
Sep, 09	17/9/09	7.98	8.84	35	29 (30.6)
Oct, 09	13/10/09	7.49	7.87	33	27 (23)
Nov, 09	13/11/09	7.89	7.96	30	25 (21)
Dec, 09	15/12/09	7.26	8.38	31	24 (16)
Feb, 10	9/2/10	7.39	8.65	29	17 (16)
May, 10	13/5/10	7.24	8.32	35	29 (33)
Month	**TDS, mg/l**		**Chloride, mg/l**	**NO_2+NO_3-N, mg/l**	**Total-P, mg/l**
	Inlet	**Outlet**	**Outlet**	**Outlet**	**Outlet**
June, 09	1600	1350	551.3	1.64	1.57
July, 09	1740	1520	392.8	2.33	0.37
Aug, 09	1640	1540	430.7	0.95	1.66
Sep, 09	1880	1580	423.6	1.00	0.53
Oct, 09	1760	1510	381.1	0.99	0.67
Nov, 09	1760	1910	423.6	0.59	2.62
Dec, 09	1860	1790	538.8	0.68	0.95
Feb, 10	1660	1780	501.6	2.31	0.70
May, 10	1870	1891	529.39	3.88	0.52
Average	1752	1652	464	2	1

* Plant was not in operation when we went for sampling during the month of Jan, March and April 2010.

* Chlorination has not yet commissioned.

Performance Monitoring Data for the STP at Balloke

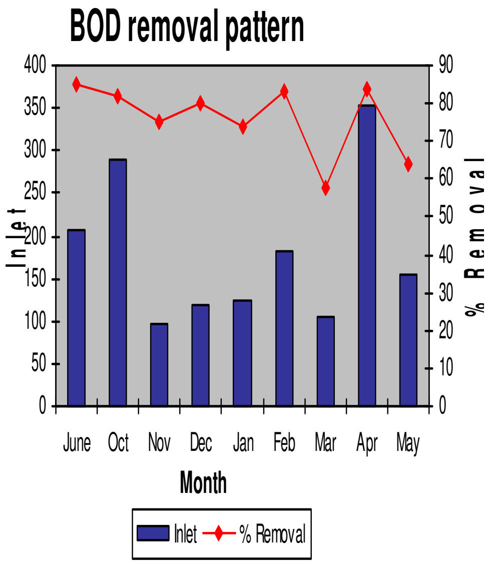
Annexure-6a: Performance efficiencies

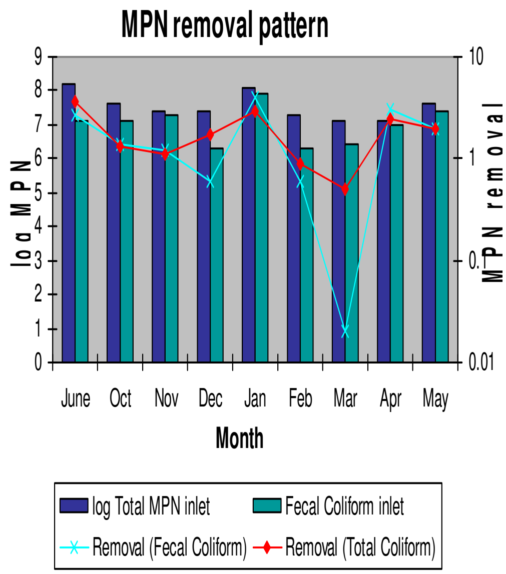
Month	BOD, mg/l		COD, mg/l		TSS, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	207.5	32 (85%)	480	128 (73%)	410	60 (85%)
Oct, 09	290.0	51 (82%)	440	96 (78%)	350	180 (49%)
Nov, 09	97.5	24 (75%)	400	80 (80%)	160	120 (25%)
Dec, 09	120.0	24(80%)	460	80 (83%)	115	101 (12%)
Jan, 10	125.0	33 (74%)	400	112 (72%)	950	210 (78%)
Feb, 10	182.5	31 (83%)	240	80 (67%)	570	50 (91%)
Mar, 10	105.0	44 (58%)	320	176 (45%)	620	110 (82%)
Apr, 10	352.5	55 (84%)	680	192 (72%)	713	123 (83%)
May, 10	155.0	56 (64%)	240	80 (67%)	483	54 (89%)
STDEV	88.23	12.81 (10%)	135.65	43.41 (11%)	264.58	55.28 (30%)
Average	181.67	38.9 (76%)	406.67	113.78 (71%)	485.66	112 (66%)

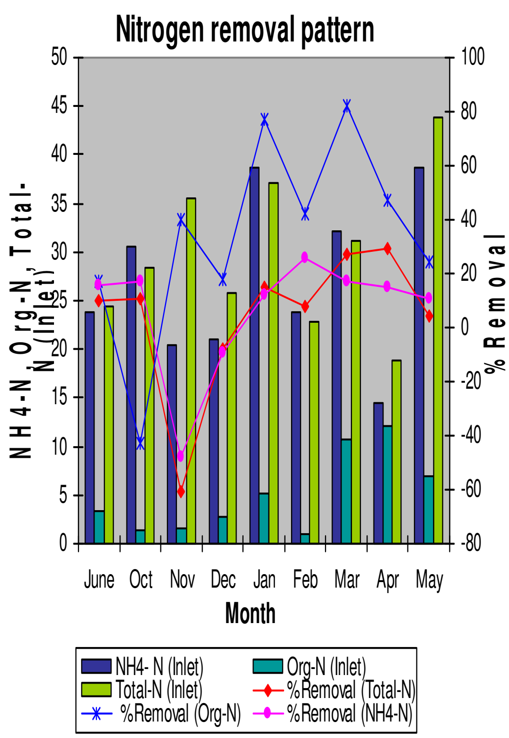
Month	Org-N, mg/l		NH_4-N, mg/l		Total-N, mg/l	
	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)	Inlet	Outlet (Performance)
June, 09	3.36	2.8 (17%)	23.80	19.88 (16%)	27.16	24.34 (10%)
Oct, 09	1.29	1.84 (-43%)	30.52	25.48 (17%)	31.81	28.45 (11%)
Nov, 09	1.62	0.98 (40%)	20.44	30.24 (-48%)	22.06	35.42 (-61%)
Dec, 09	2.82	2.3 (18%)	21.00	22.96 (-9%)	23.82	25.81 (-8%)
Jan, 10	5.24	1.18 (77%)	38.64	34.16 (12%)	43.88	37.17 (15%)
Feb, 10	1.00	0.58 (42%)	23.80	17.64 (26%)	24.80	22.9 (8%)
Mar, 10	10.64	1.96 (82%)	32.20	26.88 (17%)	42.84	31.25 (27%)
Apr, 10	12.04	6.44 (47%)	14.40	12.3 (15%)	26.44	18.89 (29%)
May, 10	7.00	5.32 (24%)	38.64	34.32 (11%)	45.64	43.89 (4%)
STDEV	4.09	2.00 (37%)	8.43	7.48 (22%)	9.46	7.91 (27%)
Average	5.00	2.6 (34%)	27.05	24.87 (6%)	32.05	29.91 (4%)

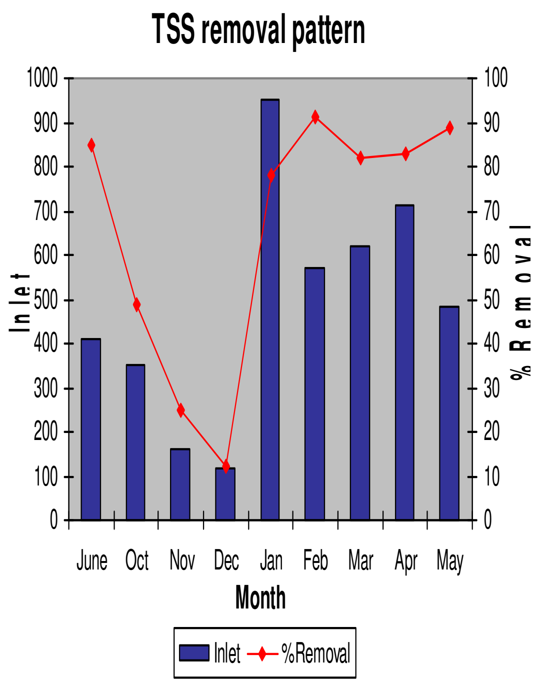
Month	Fecal, MPN/100ml			Total, MPN/100 ml		
	Inlet	Outlet	MPN removal (in log units)	Inlet	Outlet	MPN removal (in log units)
June, 09	1.4×10^{7}	2.4×10^{4}	2.77	1.7×10^{8}	2.8×10^{4}	3.78
Oct, 09	1.3×10^{7}	5.0×10^{5}	1.41	5.0×10^{7}	2.3×10^{6}	1.34
Nov, 09	2.4×10^{7}	1.3×10^{6}	1.27	3.0×10^{7}	2.3×10^{6}	1.12
Dec, 09	2.2×10^{6}	5.0×10^{5}	0.64	3.0×10^{7}	5.0×10^{5}	1.78
Jan, 10	8.0×10^{7}	8.0×10^{3}	4	1.3×10^{8}	1.4×10^{5}	2.97
Feb, 10	2.3×10^{6}	5.0×10^{5}	0.66	2.3×10^{7}	2.8×10^{6}	0.91
Mar, 10	3.0×10^{6}	2.8×10^{6}	0.03	1.3×10^{7}	3.5×10^{6}	0.57
Apr, 10	1.1×10^{7}	7.0×10^{3}	3.20	1.3×10^{7}	5.0×10^{4}	2.41
May, 10	3.0×10^{7}	3.0×10^{5}	2	5.0×10^{7}	5.0×10^{5}	2
Geomean	1.0×10^{7}	1.7×10^{5}	1	3.8×10^{7}	5.1×10^{5}	1.6

Annexure-6b: Removal pattern of BOD, MPN, Nitrogen and TSS at STP Balloke.









Plant was not in operation during the month of July, Aug and Sept 09

Annexure-6c: Other monitoring data for the STP at Balloke

Sampling time range: 9:59am – 11:35am

Month	Date of sampling	pH		Temp (^{0}C)	
		Inlet	Outlet	Inlet	Outlet (Ambient Temp)
June, 09	8/6/09	7.90	8.21	31	30 (37)
Oct, 09	13/10/09	7.20	7.60	27	25 (27)
Nov, 09	13/11/09	7.64	7.74	23	20 (24)
Dec, 09	15/12/09	7.16	7.29	21	15 (19)
Jan, 10	14/1/10	7.70	7.73	20	14 (18)
Feb, 10	9/2/10	8.03	7.75	20	17 (19)
Mar, 10	14/3/10	6.63	6.97	26	23 (27)
Apr, 10	15/4/10	7.38	6.88	38	31 (10)
May, 10	13/5/10	6.96	7.01	30	28 (35)
Month	**TDS, mg/l**		**Chloride, mg/l**	**NO_2+NO_3-N, mg/l**	**Total-P, mg/l**
	Inlet	**Outlet**	**Outlet**	**Outlet**	**Outlet**
June, 09	850	750	138.7	1.66	1.59
Oct, 09	870	710	92.2	1.13	1.503
Nov, 09	1060	710	93.9	4.20	1.4885
Dec, 09	760	750	56.7	0.55	1.08
Jan, 10	660	750	115.8	1.83	0.356
Feb, 10	640	780	95.7	4.68	0.839
Mar, 10	1510	900	102.8	2.41	0.96
Apr, 10	910	905	86.9	0.15	0.605
May, 10	907	810	141.8	4.25	0.688

Average	907	785	103	2	1

* Plant was not in operation when we went for sampling during the month of July, Aug and Sep 2009.

* Chlorination has not yet commissioned.

Performance Monitoring Data for UASB

Annexure-7a: Performance monitoring data for the UASB of the STP at Jalandhar.

Parameters	March			April		
	Inlet	UASB Outlet	Removal efficiency	Inlet	UASB Outlet	Removal efficiency
Temp (^{0}C)	24	25	*	29	27	*
pH	7.29	7	*	7.71	6.9	*
Alkalinity (mg/l)as $CaCo_3$	528	577	*	370	415	*
BOD (mg/l)	237.5	110	54%	190	66	65%
COD (mg/l)	440	169	62%	480	192	60%
TSS (mg/l)	320	174	46%	513	185	64%
Org-N (mg/l)	1.4	2.5	-79%	8.12	6.89	15%
NH_4-N (mg/l)	31.08	20.8	33%	29.68	25.60	14%
Total-P (mg/l)	2.33	1.86	20%	1.26	1.3	-3%
T.Coliform (MPN/100ml)	2.4×10^8	3.0×10^7	*	1.7×10^8	1.4×10^7	*

Annexure-7b: Performance monitoring data for the UASB of the STP at Jamalpur

Parameters	February			May		
	Inlet	UASB Outlet	Removal efficiency	Inlet	UASB Outlet	Removal efficiency
Temp (^{0}C)	29	25	*	35	31	*
pH	7.39	8.06	*	7.24	8.10	*
Alkalinity (mg/l)as $CaCo_3$	475	580	*	750	810	*
BOD (mg/l)	117.5	50	57%	182.5	80	56%
COD (mg/l)	480	170	65%	480	216	55%
TSS (mg/l)	360	200	44%	201	15.2	25%
Org-N (mg/l)	1.37	2.56	-87%	12.88	11.93	7%
NH_4-N (mg/l)	14.28	11.68	18%	15.12	15	1%
Total-P (mg/l)	1.16	1.28	-10%	0.94	1	-6%
T.Coliform (MPN/100ml)	1.1×10^8	4.6×10^7	*	2.4×10^8	5.0×10^7	*

Performance Monitoring Data for Polishing pond

Annexure-8a: Performance monitoring data for the polishing pond of the STP at Jalandhar.

Parameters	February			May		
	Polishing pond Inlet	Outlet	Removal efficiency	Polishing pond Inlet	Outlet	Removal efficiency
Temp (^{0}C)	29	17	*	35	29	*
Ph	7.39	8.65	*	7.24	8.32	*
Alkalinity (mg/l)as $CaCo_3$	475	650	*	750	810	*
BOD (mg/l)	50	25	50%	80	67	16%
COD (mg/l)	170	64	62%	216	160	26%
TSS (mg/l)	200	120	40%	150	69	54%
Org-N (mg/l)	2.56	0.47	82%	11.93	10.66	11%
NH_4-N (mg/l)	14.28	11.68	18%	15.12	15	1%
Total-P (mg/l)	0.98	0.74	24%	0.82	0.52	37%
T.Coliform (MPN/100ml)	4.6×10^7	3.0×10^5	*	5.0×10^7	1.3×10^5	*

Annexure-8b: Performance monitoring data for the Polishing pond of the STP at Jamalpur

Parameters	March			April		
	Polishing pond Inlet	Outlet	Removal efficiency	Polishing pond Inlet	Outlet	Removal efficiency
Temp (^{0}C)	24	23	*	29	29	*
pH	7.29	7.24	*	7.71	7.16	*
Alkalinity (mg/l)as $CaCo_3$	528	562	*	370	420	*
BOD (mg/l)	110	38	65%	66	37	44%
COD (mg/l)	169	128	24%	192	80	58%
TSS (mg/l)	174	60	66%	185	57	69%
Org-N (mg/l)	2.5	1.59	36%	6.89	5.88	15%
NH_4-N (mg/l)	20.8	23.24	-12%	25.6	31.34	-22%
Total-P (mg/l)	1.09	0.46	58%	1.16	0.36	69%
T.Coliform (MPN/100ml)	3.0×10^6	1.3×10^6	*	1.4×10^7	1.3×10^5	*

ANNEXURE-9

Data for Sludge drained from the UASB

Annexure-9a: Data for the sludge analysis of the STP at Jalandhar

Parameters	March		April	
	2 feet	4-5 feet	2 feet	4-5 feet
NH_4-N (mg/l)	10.26	12.32	8.6	11.26
Org-N (mg/l)	8.12	15.29	5.2	12.32
Total-P (mg/l)	0.181	0.121	0.2	0.128
VSS (mg/l)	55590	27506	39940	24515

Annexure-9b: Data for the sludge analysis of the STP at Jamalpur

Parameters	February		May	
	2 feet	4-5 feet	2 feet	4-5 feet
NH_4-N (mg/l)	4.2	20.65	20.7	40.32
Org-N (mg/l)	10.8	15.23	23.8	30.8
Total-P (mg/l)	0.206	0.131	0.382	0.296
VSS (mg/l)	29995	26341	32275	30525

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