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Comparative Performance Evaluation of Sewage Treatment Plants in Gurgaon

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Abstract: The rapid growth of the population, the technological and industrial boom has brought enormous problems and degradation of the environment. Pollution caused by sewage discharged from cities and towns is the primary cause for degradation of water resources. Hence a proper and planned sewage treatment is needed.

Gurgaon city hosts two sewage treatment plants located in Dhanwanpur village. These plants are designed and constructed with an aim to manage wastewater so as to minimize and/or remove organic matter, solids, disease-causing organisms and other pollutants, before disposal. This article evaluates and compares the actual behaviour of full-scale anaerobic and aerobic wastewater treatment plants in operation in Gurgaon, providing information on the performance of the processes in terms of the quality of the generated effluent and the removal efficiency achieved. The observed results of effluent concentrations and removal efficiencies of the constituents TSS, BOD, COD, VSS and BOD/COD ratio have been compared with the typical expected performances as per the standards given by CPCB. The treatment technologies selected for study were anaerobic-UASB and aerobic-ASP plants. The results, confirmed by statistical tests, showed that, in general, the best performance was achieved by ASP, but closely followed by UASB reactor, when operating with any kind of post-treatment. It was revealed from the performance study that efficiency of the two treatment plants was adequate with respect to removal of TSS, BOD, COD and VSS. In UASB, TSS, BOD, COD and VSS removal efficiency was 90.2, 87.4, 86.96 and 86.4% respectively, while in ASP, TSS, BOD, COD and VSS removal efficiency was 88.8, 90.07, 84.15 and 90.5 % respectively. The order of removal efficiency was VSS < COD < BOD < TSS and COD < TSS < BOD < VSS respectively in UASB and ASP STPs. Additionally, the problems associated with the operation and maintenance of wastewater treatment plants is discussed.

Key words: ASP, BOD, COD, TSS, UASB and VSS.

Introduction

The rapid growth of population and the technological and industrial boom has brought enormous problems and degradation of the environment. Pollution caused by sewage discharged from cities and towns is the primary cause for degradation of water resources. Domestic sewage from cities and towns is the biggest source of pollution of water bodies in India. An estimate infers that every year, the wastewater discharges from domestic, industrial and agricultural practices pollute more than two-third of total available run-off through rainfall (Vigneshwaram, 2004). A large number of river stretches are severely polluted as a result of discharge of domestic sewage. In Haryana 29,000 million litres per day (MLD) of sewage is generated against the existing treatment capacity of 6000 MLD. In 20 Class I cities of Haryana, 440 MLD of sewage is generated and sewage treatment facilities are available in seven cities only having capacity of 240.1 MLD. Gurgaon has a water

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demand of about 200 MLD and approximately 160 MLD of sewage generation (CPCB, 2007). A solution to the effluent discharge not only requires bridging the ever widening gap between sewage generation and treatment capacity but also calls for development of facilities to ascertain the effluent characteristics within accepted limits.

In Haryana Class I cities, activated sludge process (ASP) is the most commonly employed technology, covering 59.5% of total installed capacity followed by Up flow Anaerobic Sludge Blanket (UASB) technology, covering 26% of total installed capacity. These two technologies are mostly used as the main treatment unit of a scheme including other primary or tertiary treatment units. Activated sludge process (ASP) technology is most suitable for large cities because it requires less space as compared to UASB technology which employs land intensive ponds in treatment schemes (CPCB, 2007). ASP requires high capital investment, excessive consumption of energy, and high maintenance costs. As a result, efforts to implement these methods in developing countries for water pollution control have been seriously impeded. Conversely, low cost treatment methods such as UASB reactor have recently been implemented in tropical countries like India. Operation of the UASB reactor is energy efficient since it produces useful energy in the form of biogas, if utilised properly. Moreover, a higher degree of organic materials and suspended solids can be removed with a short retention time. However, the residual concentration of pollutants in the UASB effluent usually exceeds the maximum permissible level prescribed by the effluent standards of most developing countries, including India. Hence post-treatment such as polishing pond is necessary.

Gurgaon city hosts three sewage treatment plants one at Behrampur with a capacity of 50 million litre per day (MLD) and two at Dhanwanpur, with a capacity of 68 MLD (under HUDA) and 30 MLD (under MCG).

The effluent from 68 MLD plant based on ASP and 30 MLD based on UASB technology is disposed off to Najafgarh drain which is diverted to Yamuna River (Figure 1). The Najafgarh drain alone contributes to more than 50% of the total wastewater being discharged into the river Yamuna. This paper evaluates the performance efficiency of ASP and UASB plants at Dhanwanpur in terms of TDS, TSS, BOD and COD and comparison of effluent parameter with standards set by CPCB.

This paper describes the performance of the sewage treatment plants in terms of wastewater characterization to derive a comparative account between the pollution load before and after the treatment processes, besides, discerning their efficiency. The performance of the STPs in terms of percentage reduction in pollution load in each plant was carried out.

Study Area

Study area, Gurgaon is situated on south eastern part of Haryana state and has an area of 3852 sq.km. In the

Figure 1: Overview of STP and drain.

north it is bordered by the Union Territory of Delhi, in the east by Uttar Pradesh, in the North West by Jhajjar and Rewari districts of Haryana and in the west by the Alwar district of Rajasthan state and south by the Mewat district of Haryana state. The study area is largely occupied by alluvial plains, traversed by elongated ridges of quartizites. It lies in between the 27° 39′ and 28°32′25″ latitude, and 76° 39′ 30″ and 77° 20′ 45″ longitude.

A rapidly growing population alongside with urbanization and industrialization is one of the reasons for severe water-related problems, such as water pollution and water shortage. Both problems are closely linked as shortage of water is caused due to contamination of ground and surface water by domestic and industrial effluents. A predominant cause of discharge of a large amount of untreated sewage into the water bodies is the lack of sufficient sewerage and sewage treatment plants (STPs). Figure 2 shows the population rise in Gurgaon in the past decade.

Methodology

Data on unit operation, facilities and layout were collected from UASB and ASP plants located within Gurgaon city. The sampling and analysis of sewage quality of the plants were conducted.

Process Description

Upflow Anaerobic Sludge Blanket (UASB)

The 30 MLD Sewage Treatment Plant based on UASB technology maintained by public health and engineering department (PHED) was established in January 2001. The plant receives sewage from all the non-sector areas of Gurgaon and few industries.

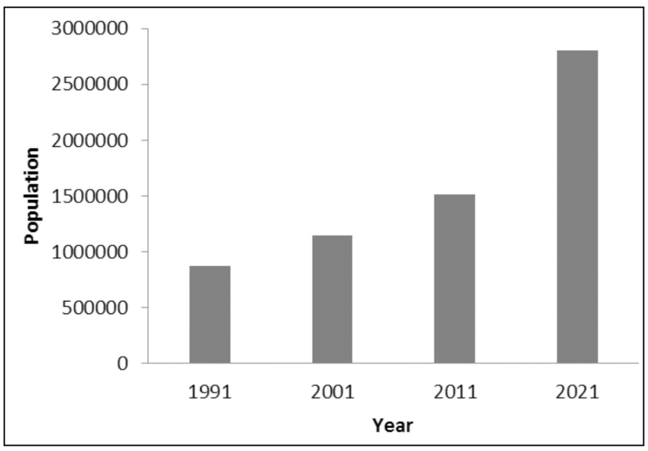


Figure 2: Population of Gurgaon (Source: Census).

A screen and grit chamber are the typical components that are installed before a UASB reactor. Raw sewage flows through the screen and grit chamber to the UASB reactor. The UASB generally requires post-treatment because the effluent usually exceeds the maximum permissible level defined by the effluent standards of most developing countries, including India. Polishing pond called as final polishing units (FPU) are implemented in this plant. The gas is taken to gas holder and is utilized for power generation in combination with diesel for running the plant. From reactor the sludge is pumped to the drying beds. The effluent from treatment plant is taken through drains to main Najafgarh drain. Figure 3 describes the process.

UASB uses an anaerobic process whilst forming a blanket of granular sludge and suspended in the tank. Wastewater flows upwards through the blanket and is processed by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. The blanket begins to reach maturity at around three months. Small sludge granules begin to form and their surface area is covered with aggregations of bacteria. In the absence of any support matrix, the flow conditions create a selective environment in which only those microorganisms, capable of attaching to each other, survive and proliferate. Eventually the aggregates form into dense compact biofilms referred to as “granules”.

Activated Sludge Process (ASP)

The 68 MLD STP with conventional activated sludge process has been constructed by HUDA in the year 2001 to cater to HUDA areas including industrial areas. Plant is being maintained in good condition. Here preliminary treatment includes mechanical screening with scrapers and grit chamber. Waste water is taken into primary sedimentation tanks and then for aeration, two tanks are provided where an aerobic bacterial culture is maintained in suspension. Here, the bacterial culture carries out the conversion of the organic matter. The aerobic environment in the tank is achieved by the use of eight mechanical aerators. From there it is taken to secondary settling tank and sludge pumped into digester and gas taken to gas flaring unit. The effluent from treatment plant is taken through drains to main Najafgarh drain. Primary and secondary sludge undergo anaerobic treatment in two digestion tanks where the sludge is digested and disposed off after drying in specifically created drying beds. At present 100% of the gas produced is flared in a gas burning facility. Implementation of a component of power generation

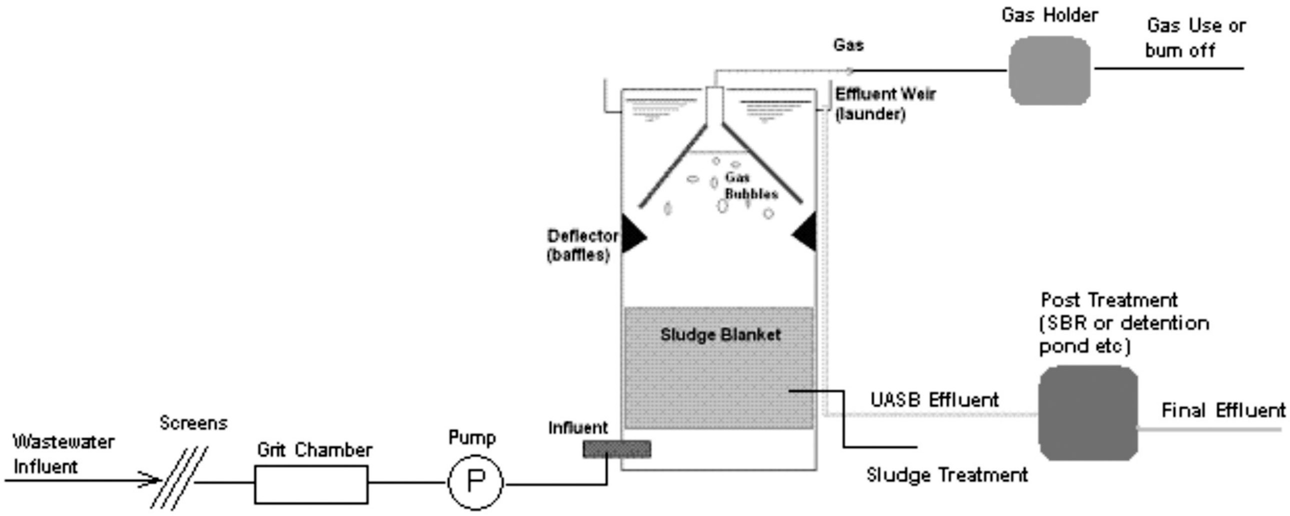


Figure 3: Schematic layout of UASB.

from biogas is at planning stage. The dried sludge is further utilized in agriculture. Some portion of the effluent is being used for land application within the STP compound and in nearby fields. Table 1 shows the machinery details of the ASP plant and Figure 4 describes the process.

Sampling and Analysis

Samples from both the treatment plants were collected in summer season (Figures 5 and 6). The influent samples were collected from the inlet chamber constructed to hold the water after pumping the sewage from drain to sewerage system and treated effluent were collected after the secondary sedimentation tank. The physico-chemical analysis was done as per the standard methods (APHA). The parameters included pH, total dissolved solids, total suspended solids, BOD_5, COD and the ratio of COD to BOD_5.

Results and Discussion

Procedures as per standard methods for water and wastewater testing (Standard methods for examination of water and wastewater, 21st edition, APHA/AWWA/WEF) have been adopted for analysis of the following physico-chemical parameters:

1. pH
2. Total suspended solids
3. Bio-chemical oxygen demand
4. Chemical oxygen demand

Table 1: 68 MLD sewage treatment plant at Dhanwapur

Treatment unit	*Machinery details*
Inlet system	Penstock gate – 3 Nos
Bar screen	Mechanical screen with motor and gear box (2 Nos)
Grit chamber	Grit chamber with scraper and MS Bridge (2 Nos)
Parshall flume	1 No
Distribution chamber 1	Penstock gate – 3 Nos
Primary settling tank	MS Bridge 42 m dia with motor and gear box
Raw sludge pump house	4 × 15 HP motor with sludge pump
Aeration tank	8 × 50 HP motor with gear box
Final settling tank	MS Bridge 38 m dia with motor and gear box
Return sludge pump house	4 × 50 HP motor with sludge pump
Return sludge pump house dimension	8 m × 4 m
Sludge Digester	2 × 60 HP motor with screw pump
Gas holder	19.2 m dia M S cell
Filtrate pump house	2 × 5 HP motor with sludge pump
Sludge drying bed	30 m × 20 m × 20 m
Gas burner	Gas burner – set 1

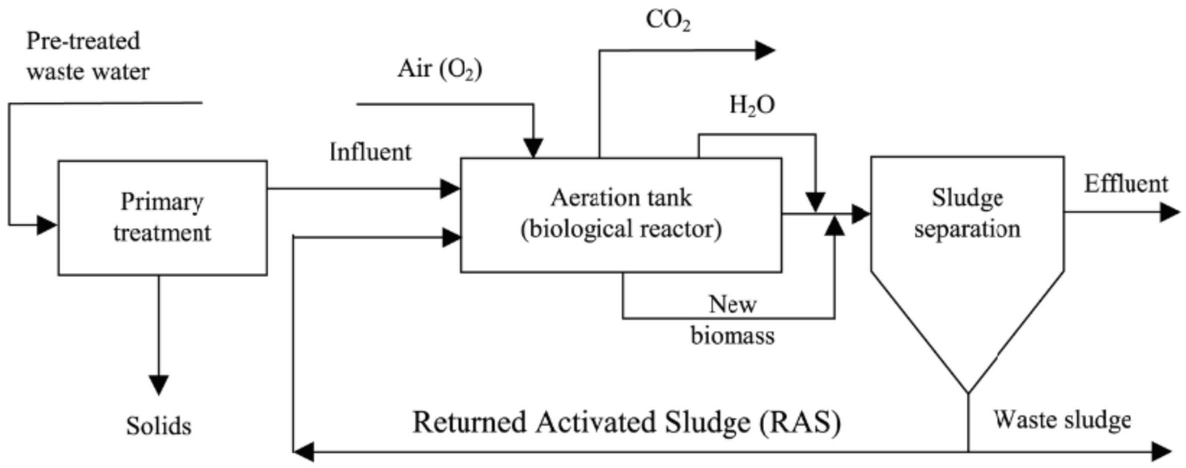
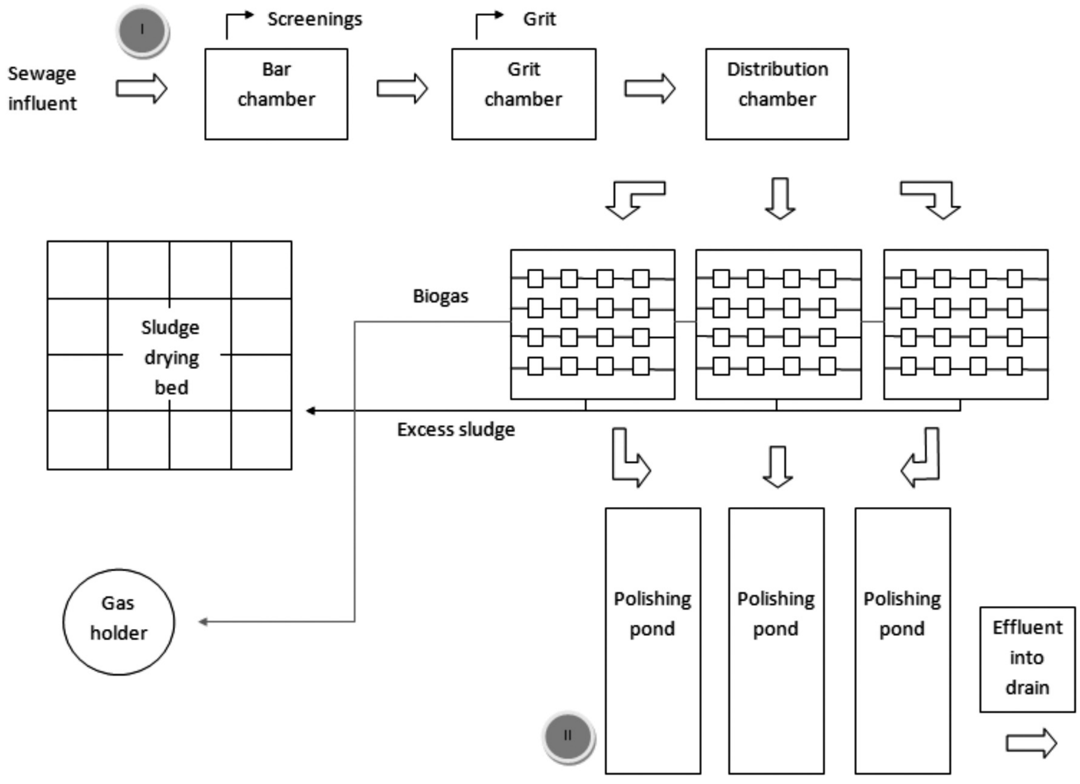
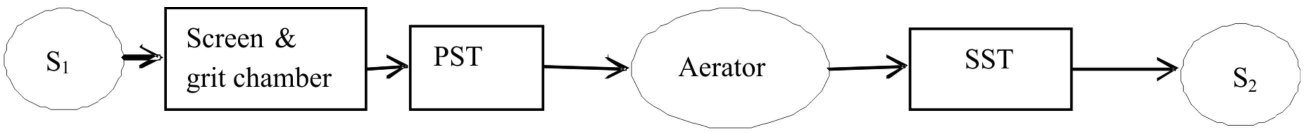


Figure 4: Schematic layout of ASP.



S_1 = Sampling point for influent (sump); S_2 = Sampling point for effluent (before FPU); FPU = Final polishing unit

Figure 5: Sampling points for UASB.



S1 = Sampling point for influent (sump)

S2 = Sampling point for effluent (after SST)

PST = Primary settling tank

SST = Secondary settling tank

Figure 6: Sampling collection points for ASP.

pH

To ensure an optimal growth of bacteria, requirements concerning environmental conditions, such as temperature and pH, must be met. pH is an indicator of the alkalinity of the sewage. The determination of pH is important because of the fact that efficiency of certain treatment methods depends upon the availability of suitable pH value. Fresh sewage is generally alkaline in nature. It can be seen that in both plants the pH increases during the process. Furthermore, the pH of the raw sewage as well as the pH for the effluent is higher for the ASP plant compared to the UASB plant. The average pH value of influent in ASP was 7.05 and UASB is 7.2. As time passes pH tends to fall due to production of acid by bacterial actions in an anaerobic process. The pH however rises upon treatment of sewage. The average effluent pH in ASP was 7.9 and in UASB was 7.25. The rise in pH was more in ASP than in UASB as there is no anaerobic condition prevailing throughout the process in ASP. The pH variation in ASP and UASB is shown in Figure 7.

Total Suspended Solids (TSS)

Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. As levels of TSS increases water begin to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight which increases water temperature and subsequently increases level of dissolved oxygen. TSS can destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed.

The TSS variation is shown in Figure 8 and reveals that ASP receives more turbid influent as compared to UASB.

The comparison of effluent TSS of both the plants with the BIS standards, IS-2490 and EPA Rules is shown in Figure 9. The level of TSS in both the plants is well below the standards set by IS-2490 and EPA whereas it is slightly above BIS.

Bio-chemical Oxygen Demand (BOD)

Biochemical oxygen demand of sewage directly gives the amount of biologically active organic matter present in sewage. It constitutes the most important test for wastewater. If sufficient oxygen is available in waste water, the useful aerobic bacteria will flourish and cause the anaerobic biological decomposition of wastewater, which will continue until oxidation is completed. The amount of oxygen consumed in this process is BOD. Polluted waters will continue to absorb oxygen for many more months and it is not practically feasible to determine the ultimate oxygen demand. BOD of water during five days at 20°C is generally taken as the standard demand and is about 68% of the total demand. The variation of BOD shown in Figure 10 shows that ASP receives higher BOD influent than UASB.

The comparison of effluent BOD of both the plants with the BIS standards, IS-2490 and EPA Rules is shown in Figure 11. The level of BOD in both the plants is well below the standards set by IS-2490 and EPA whereas it is slightly above BIS.

Chemical Oxygen Demand (COD)

Chemical oxygen demand is a measure of the oxygen equivalent of the organic material in waste water that

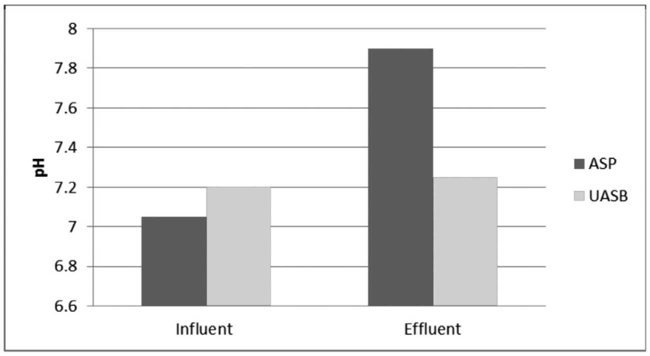


Figure 7: Variation of pH in the plants.

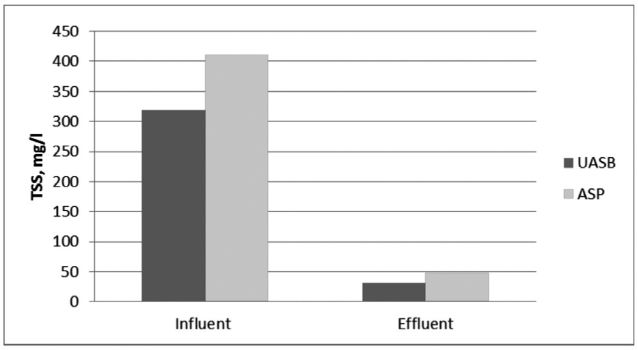


Figure 8: Variation of TSS in the plants.

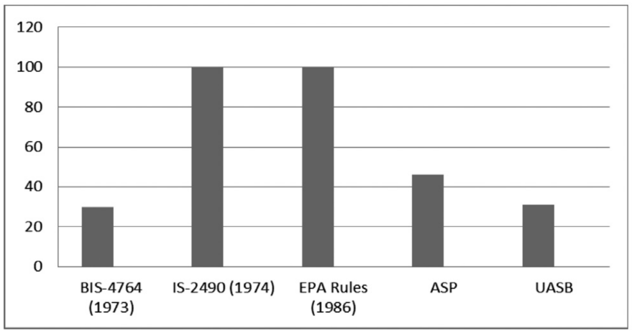


Figure 9: Comparison of effluent TSS with standards.

can be oxidized chemically. COD does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements take five days. COD test predicts the oxygen requirement of the effluent and is used for monitoring and control of discharges and for assessing treatment plant performance. COD variation shown in Figure 12 shows that UASB receives high strength COD influent; may be because the plant receives waste from few industries also.

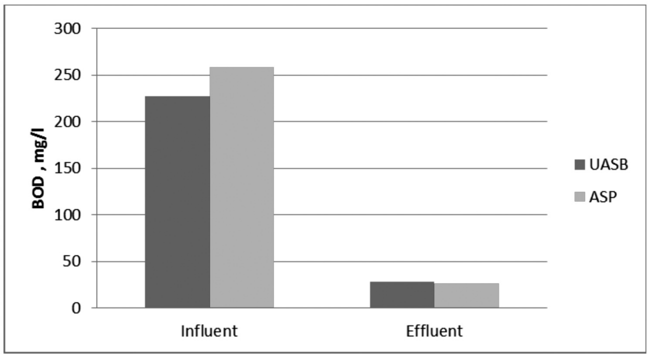


Figure 10: Variation of BOD in the plants.

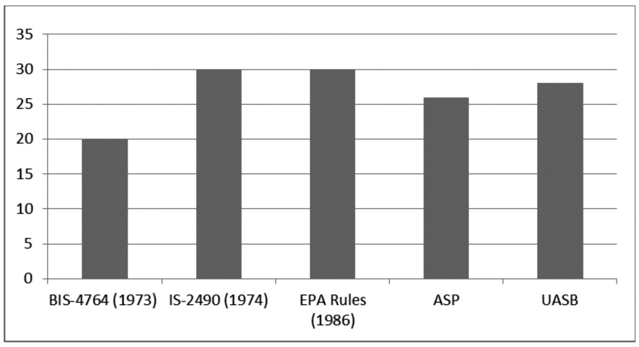


Figure 11: Comparison of effluent BOD with standards.

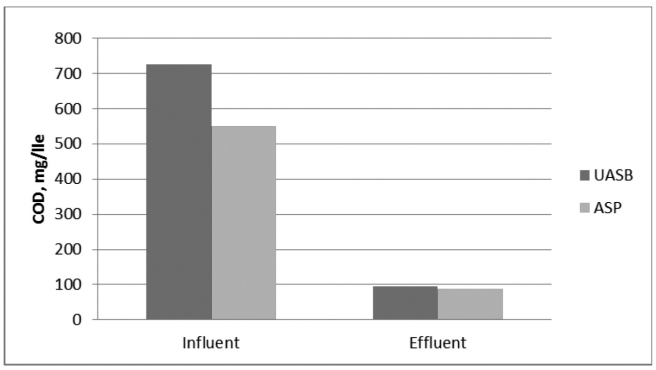


Figure 12: variation of COD in the plants.

The effluent COD of ASP and UASB plant in comparison with the various standards is shown in Figure 13. The COD of effluents from both the plants are well below the standards and efficiency for COD removal of ASP is better than UASB.

BOD to COD Ratio

The difference between BOD and COD represents the quantum of non-biodegradable organics (NBO's) present in waste water. Since BOD (ASP) is about 68% of BOD (UASB). BOD_5/COD ratio for fully biodegradable waste water may be between 0.63 and 0.68. Any waste water having BOD/COD ratio more than 0.63 can be considered to be quite amenable to biological treatment since it does not contain non-biodegradable organics. For ASP plant, BOD to COD ratio is 1.075 and for UASB, BOD to COD ratio is 1.01 (as shown in Figure 14). In both the cases BOD/COD ratio is more than 0.63 and hence it does not contain any non-biodegradable organics.

The ratio for untreated sewage is in the range 0.3-0.8. If this ratio is greater than 0.5 the waste is considered to be easily treatable by biological means. If this ratio is less than 0.3, either the waste may have some toxic

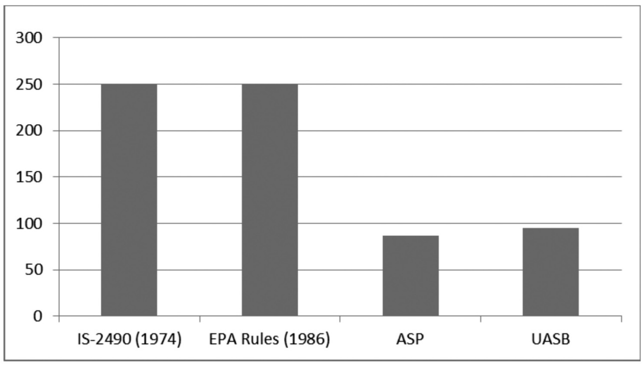


Figure 13: Comparison of effluent COD with standards.

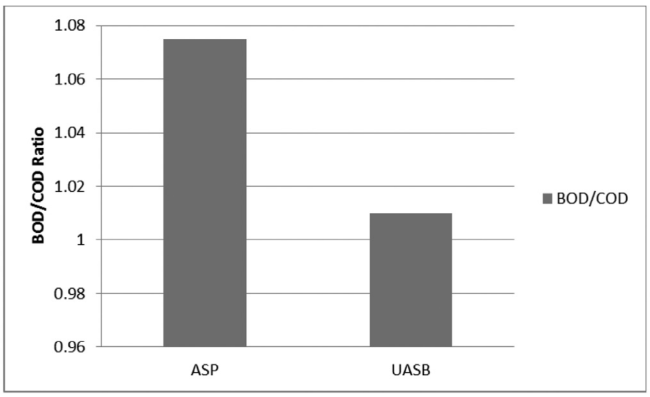


Figure 14: Comparison of effluent BOD/COD.

components or acclimated microorganisms requiring stabilization (Metcaff and Eddy, 2003). The BOD/COD ratio for untreated sewage in ASP is 0.45 and UASB is 0.3 which falls on the border line.

It can be due to the presence of certain microorganisms which require stabilization. Hence enhancement of facilities in UASB plant for removal and/or stabilization of toxic components are recommended.

Volatile Suspended Solids (VSS)

The volatile suspended solids refer to the organic content of suspended solids. The suspended organic fraction will oxidize and will be driven off as gas at temperature 550 $\pm$ 50 ^oC. In a biological treatment system, the volatile solids are often associated with the biomass and can be used as a measure of the microorganism population within the plant (Ellis, 2010). For example, an activated sludge tank would be tested for volatile suspended solids to determine the level of organic "microbial mass" that will be available to treat dissolved organic waste in incoming waste. The VSS analysis of municipal waste water is given in Table 2 (Metcalf and Eddy, 2003). The variations of VSS in both the plants are shown in Figure 15.

Table 2: Volatile suspended solids concentration

Constituent (mg/l)	*Concentration*		
	Strong	*Medium*	*Weak*
VSS	275	165	80

The influent VSS concentration in both the plants lie in the medium range and the effluent VSS concentrations is weak.

Comparison of UASB and ASP

The comparison of removal efficiency of various parameters is shown in Figure 16. It can be seen that the removal efficiency of BOD and VSS in ASP was far better than the UASB. But the COD and TSS removal was slightly better in UASB.

ASP being an aerobic plant is provided with eight aerators which fully oxidize the organic matter leading to better removal efficiency. The majority of volatile suspended solids are organic matter which is better removed under aerobic conditions as in ASP. UASB being an advanced anaerobic treatment technique is capable of removing inactive organic matter efficiently

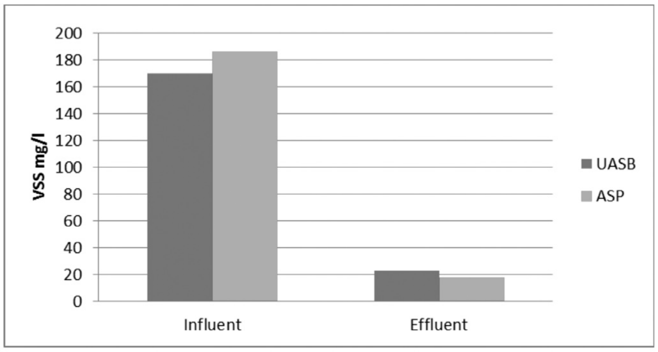


Figure 15: Variation of VSS in plants.

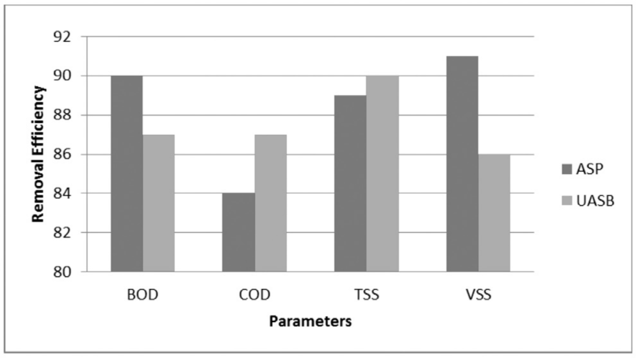


Figure 16: Comparison of efficiency.

leading to a better removal efficiency of COD. The high removal of TSS is due to proper polishing pond outlet structure.

Conclusion

1. Overall performance of both the plants is satisfactory and the plants are able to meet the prescribed norms.
2. Operation and maintenance of the plant is good.
3. UASB plant is receiving sewage of exceptionally high strength indicating mixing of industrial effluents in sewerage system.
4. Lot of solids/floating matter are found to flow along with the influent. More realistic solution of mesh screens after ordinary manual screens need to be adopted.
5. A little high TSS value in tertiary sedimentation tank of ASP plant indicates that its performance can also be improved further.
6. Plant is functioning at an overall BOD/COD removal efficiency of 60-65%.

7. Scum/algae is largely accumulated at the surface of the polishing pond and need to be removed to avoid shortening of detention time and thereby prevent deterioration of treated effluent quality.
8. Treated effluent from both the plant is discharged in Najafgarh drains. Some portion of treated effluent from ASP is being used for land application within the STP compound and in nearby fields.
9. The gas produced from reactors is utilized for power generation in combination with diesel for running the plant. The gas produced in ASP by sludge digesters is flared.

Recommendation

1. Implementation of the power generation from biogas being produced at the ASP is recommended. It is understood that projects based on generation of electric power from biogas, which is being produced as a result of digestion of sludge in STPs, are eligible for CDM (Clean Development Mechanism), as it will help in reducing and stabilizing the emissions due to methane which is a greenhouse gas. Based on the potential of biogas/power generation from STPs, expenditure on O&M can be offset by earning 'carbon credits' on recurring basis.
2. UASB reactor surfaces are mostly covered with floating layer of scum/algae which need to be regularly removed in order to improve efficiency of the plant.
3. As lot of solids/floating matter are found to flow along with the influent, fine mesh screen need to be installed along with manual screens.

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Calendar of Events

2013 International Conference on Environment Pollution and Prevention (ICEPP 2013)
5th to 6th October 2013
Melaka, Malaysia
Website: http://www.icepp.org/
Contact person: Issac Lee
Organized by: CBEES

International Conference on Water and Wastewater Management (ICWWM 2013)
8th to 10th October 2013
Kuala Lumpur, Malaysia
Website: http://icwwm.org/page/Home
Contact person: Nor

Seventeenth International Water Technology Conference
5th to 7th November 2013
Istanbul, Turkey
Website: http://iwtc.info
Contact person: Eng. Asmaa Yousef

Water 2013
12th to 13th November 2013
London, United Kingdom
Website: http://marketforce.eu.com/events/water/water-conference?utm_source=conferencealerts.com&utm_medium=event_calendar&utm_campaign=water13_conferencealerts.com_event_calendar&src=conferencealerts.com
Contact person: Robert Champion
Organized by: Marketforce Business Media Ltd

International Summit on Water Cooperation for inclusive growth 2013
15th to 16th November 2013
Yashada, Pune, Maharashtra, India
Website: http://www.seeram.org
Contact person: Mangesh Kashyap
Organized by: Society for Environment Education Research & Management.

2013 2nd International Conference on Biodiversity and Climate Change (ICBCC 2013)
17th to 18th November 2013
Abu Dhabi, United Arab Emirates
Website: http://www.icbcc.org/
Contact person: Issac Lee
Organized by: CBEES

2013 3rd International Conference on Environment and BioScience (ICEBS 2013)
23rd to 24th November 2013
Phuket, Thailand
Website: http://www.icebs.org/
Contact person: Ms. Feng
Organized by: CBEES

2nd Annual Global IWPP Summit
24th to 26th November 2013
Ras Al Khaimah, United Arab Emirates
Website: http://energy.fleminggulf.com/global-iwpp-summit
Contact person: Sobia Jameel

National Conference on Heavy Metals in the Environment
28th to 30th November 2013
Kottayam, Kerala, India
Website: http://www.hme2013.in
Contact person: Mahesh Mohan

VII World Aqua Congress
11th to 13th December 2013
New Delhi, India
Website: http://www.worldaquacongress.org
Contact person: Praggya Sharmaa
Organized by: Aqua Foundation

International Conference on Environment & Energy (ICEE 2013)
16th to 17th December 2013
Colombo, Sri Lanka
Website: http://www.enviornment3000.com
Contact person: Prabhath Patabendi
Organized by: International Center for Research & Development