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Modelling and Life Cycle Assessment of Sewage Treatment Plant (STP) in Lucknow City

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Abstract: The implementation of wastewater treatment plants has been a challenge for most countries. Economic resources, political will, institutional strength, and cultural background are important factors that define the trajectory of pollution control in many countries. Technology is sometimes mentioned as one of the reasons hindering further development. Therefore, a key objective of this research is to evaluate the performance of a plant based on the 345 MLD Upflow Anaerobic Sludge Blanket (UASB) technology by analyzing the physical and chemical parameters of the water treated by UASB to evaluate the performance of the plant located. at Bharwara Tech from Gomti Nagar Lucknow. In this study, the performance of the wastewater treatment plant and the UASB reactor was calculated. Wastewater is mixed with domestic wastewater, so the concentration of BOD and COD is relatively low. The amount of biogas produced by the UASB reactor is also less than its design value. All STP inlet and outlet water concentration results are displayed graphically.

I. INTRODUCTION

The Wastewater Treatment Plant is a wastewater treatment plant designed to remove pollutants from wastewater. Wastewater includes household wastewater and industrial wastewater that may be pre-treated. In the past two decades, UASB technology has been adopted by many developing countries, especially in Southeast Asia, including India. The anaerobic wastewater treatment system, especially the upflow anaerobic sludge jacketed reactor (UASB), has matured. Due to its favorable temperature conditions, it occupies a prominent position in several tropical countries. Its acceptance has changed from a stage of disbelief that lasted until the early 1980s to a stage that is currently widely accepted. However, this wide acceptance often leads to serious conceptual problems in the implementation of project development and treatment plants. In this sense, the following research aims to provide information related to the principle, design, operation and performance of anaerobic wastewater treatment systems, with an emphasis on the upflow anaerobic sludge mantle reactor. In principle, all organic compounds can be degraded through an anaerobic process, which is more efficient and economical when the waste is easily biodegradable. Anaerobic digestion tanks have been widely used in the treatment of solid waste, including agricultural waste, animal manure, sewage treatment plant sludge and municipal waste. It is estimated that millions of anaerobic digestion tanks have been built around the world. The UASB reactor was initially inoculated with a sufficient amount of anaerobic sludge and started to feed at low speed in an upflow mode shortly after the room. This initial stage is called system startup and is the most important stage in reactor operation. According to the success of the system response, the feed rate of the reactor must be gradually increased. After several months of operation, a highly concentrated sludge bed was formed near the bottom of the reactor. The mud is very dense and has excellent settlement characteristics. Depending on the nature of the seed sludge, the characteristics of the wastewater and the operating conditions of the reactor, sludge particles (from 1 to 5 mm in diameter) may be produced. A more dispersed area of bacterial growth, called the mud layer, develops on the mud bed, and the solids show a lower concentration and sedimentation rate. The sludge concentration in this area is usually between 1% and 3%. The system automatically mixes by the upward movement of biological bubbles and the flow of liquid through the reactor. During system startup, when biogas production is generally low, some form of additional mixing may be required, such as gas or effluent recirculation. The entire bed and the base in the mud layer are removed, although the removal is more pronounced in the mud layer. The sludge is transported by the upward movement of bubbles, and a three-phase separator (gas, solid, and liquid) needs to be installed on the upper part of the reactor to allow the sludge to be retained and returned. There is a sedimentation chamber around and above the three-phase separator, where the heavier sludge is removed from the liquid material and returned to the digestion chamber, while the lighter particles leave the system with the final effluent. The installation of the gas-solid-liquid separator ensures the turnover of the sludge and the high retention capacity of a large amount of highly active biomass without any type of packing medium. Therefore, the UASB reactor exhibits a high time (sludge age), which is much higher than the hydraulic stop time, which is a characteristic of high-speed anaerobic systems. The age of the sludge in the UASB reactor is usually more than 30 days, thus stabilizing the remaining sludge removed from the system. The UASB reactor can withstand high organic load rate. Compared with other reactors of the same generation, the biggest difference lies in its simple structure and low operating cost.

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II. SITE ANALYSIS

The focus of this study is the Bharwara 345 MLD Gomti nagar Wastewater Treatment Plant in Lucknow. The latitude and longitude of the plant extend to 26.85°N and 80.92°E, including the location of the UASB Bharwara Gomti Nagar wastewater treatment plant in Lucknow. The factory receives wastewater from the entire Trans Gomti side, including the Gomti Nagar, Indira Nagar, and Sitapur highway areas that carry wastewater, which are approved for the second phase of the Gomti Action Plan. The plant's capacity is 345 MLD. The total length of the trunk sewer line and the sewer branch is approximately 860 kilometers. The entire sewer pipeline network in Lucknow includes 26 main drainage pipes. Before the appearance of these STPs, these drain pipes were used to discharge raw sewage directly into Gomti. Of these 26 drainage ditches, it has been proposed that 22 lead to Bharwara STP. In this technology, wastewater is pumped from the bottom to the reactor, where the entry of suspended solids and bacterial activity and growth leads to the formation of sludge. The rising air bubbles mix the sludge without the aid of mechanical parts. Microorganisms in the sludge layer degrade organic compounds. as a result, gases are released. A gas-liquid-solid separates the gas from the treated wastewater and the sludge. Small sludge granules begin to form whose surface area is covered in 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".

The summarized detail of the plant is being given in table 1.

S.No	UNITS	NO.	DIMENSION
1.	Inlet Chamber	1	20mx9mx4m SWD
2	No. of stream proposed	3	115 mld capacity each
3	Distribution Chamber	3	8.8mx7.5mx2m SWD
4	Screen (mechanical)	6	2 Nos for each stream+1 standby
		+3 standby	6mx1.8mx1m SWD
	(Manual standby)	3	1 no. for each stream 6mx2.8mx8m SWD
5	Grit chamber(mechanical)	6	2nos working for each stream
	(Manual standby 50%)	3	1 no for each stream divided in 2 channels of 9.5mx4.6mx7m SWD
6	Parshall Flume	3no	1 for each stream 10mx1.5mx1.5m SWD
7	Division box	3no	12.8mx2.5mx2.25m SWD
8	Division Box 2A	12no	4 no for each stream 6.85mx2mx2.25m SWD
	Division Box 2B	60no	20 nos for each stream 3.6mx1.5mx1m SWD
9	No. of UASB reactor 11.50 mld capacity each	30nos	32mx28mx4.6m SWD (2 sets of 5 reactor in each stream)
10	Feed pipe(75 mm dia) HDPE	6720 pipes	224 pipes/reactor(4 sqm. Per pipe)
11	HRT at average flow		8.5 hrs
12	HRT at peak flow		5.6 hrs
13	SRT		35 days
14	Gas holder	3.Nos	17.5m SWD & 3.50m SWD
15A	Pre aeration tank	3 nos	29.6x13.5x3 SWD
B	Surface aerators in pre aeration tank	6nos	2nos of 30 HP in each stream(fixed type)
16A	Polishing pond compartment	3 nos	1 no for each stream140mx140mx3m SWD
B	Floating aerator for compartment no. 1	18 Nos	6 nos surface aerator of 50 HP for each stream
17	Polishing pond compartment no 2	3 nos	550mx140mx1.5m SWD
18	Chlorine contact tank	3 nos	60mx20mx2m SWD
19	Chlorination	3 nos	50kg/hr Booster pump 20 m3/hr@6kg/cm2
20	Sludge Concentration		65 kg/m3
21	Total sludge generation(wet)		1780m3/day
22	Total sludge generation (dry)		100 tonnes/day
23	Sludge sump	3 nos	1no. for each stream 9.85mx6.80mx1.0m SWD
24	Sludge pump	18 nos (9W+9S)	68m3/hr at 35m head
25	Sludge drying beds	106 nos	27mx27m
26	Sludge cycle		10 days
27	Filtrate water sump	2 nos	10mx7.5mx1.0m SWD
28	Filtrate water pump	4 nos	40m3/hr.18m head
29	Total power requirement of		STP 1500 KVA
30	Effluent pipe	1500m	2400mm dia RCC Pipe
31	Dual fuel engine for bio gas utilization	2 nos	850 KVA each
32	Gas flaring system	2 nos	Aspiration type pre mixing burner 6 m above GL.

Table 1: Summarized details of the Bharwara UASB plant

III. REVIEW OF LITERATURE

An extensive literature review was carried out by referring standard journals, reference books and conference proceedings. The major work carried out by different researchers can summarized as follows:

Jin wang et al (2020)[1] studied the Dynamic modeling of the biomass gasification process in a fixed bed reactor by using artificial neural network (ANN). For dynamic modeling, ANN model were used and the predicted results showed that the decreases in the data recording frequency, increases the prediction error. By expanding the training dataset, reduce discrepancies between predicted and measured results.

Fatih Tufaner et al (2020)[2] studied the prediction of biogas production rate from anaerobic hybrid reactor by ANN and nonlinear regressions models. Both model are trained and tested for the future prediction. The results showed that the proposed ANNs and nonlinear regression models performed well in predicting the biogas production rate.

Tanja beltramo et al (2019)[3] studied the Prediction of the biogas production using GA and ACO input features selection method for ANN model. The results showed that they identified significant process variables , reduced the model and improved the prediction capacity of ANN models.

Ryan T Greenham (2019)[4] studied the Removal efficiencies of top-used pharmaceuticals at sewage treatment plants with various technologies. In this study, removal efficiency of various technologies calculated for the sewage treatment plant. Compare all the technologies on the basis of removal efficiency and the results showed that the aerated lagoons are most effective technology with 98.1% removal efficiency.

Philip Antwi et al (2016)[5] studied the estimation of biogas and methane yields in an UASB treating potato starch processing wastewater with backpropagation artificial neural network. in the study for estimate the biogas and methane yield in UASB ,three layer feedforward backpropagation ANN and multipal nonlinear regression MnLR models were developed . compare with the BP-ANN model and MnLR model demonstrated significant performance , suggesting possible control of the anaerobic digestion process with the BP-ANN model.

Hina Rizvi et al (2015)[6] studied the upflow anaerobic sludge blanket reactors seeded with cow dung manure (UASBCD) and activated sludge of a dairy wastewater treatment plant (UASBASDIT) to treat raw domestic wastewater of medium strength. The study found that the overall performance of both reactors was optimum at sludge age ranging from 120 to 150 days and temperature varying between 25 and 30^0C. The UASBCD reactor required a period of 120 days to start up and UASBASDIT reactor, sludge bed was stabilized in a period of 80 days.

Carlos Mendes et al (2015)[7] studied the artificial neural network modeling for predicting organic matter in a full scale up-flow anaerobic sludge blanket (UASB) reactor. in this study artificial neural network models are used to evaluating the performance of UASB reactor based on the application of two method for the selection of the ANN topology- the static split method SSM and the dynamic division method DDM. The two methods are applied to predict the amount of OM in UASB reactor and compared. The comparisons disclose that the DDM accurately selects the best model and reliably assesses its quality.

Z. A. Bhatti, F. Maqbool et al (2014)[8] studied to shorten the start-up time of up-flow anaerobic sludge blanket (UASB) reactor. In this study two different nutrients were used during the UASB start-up period, which was designed to decrease the hydraulic retention time (HRT) from 48 to 24 and 12 to 6 hrs at average temperatures of 25-34 0C. In the first stage, start-up was with glucose for 14 days and then the reactor was also fed with macro- and micronutrients as a synthetic nutrient influent (SNI) from 15 to 45 days as the second stage. The removal efficiencies of the chemical oxygen demand (COD) were 80% and 98% on the 6th and 32nd day of the first and second stage, respectively.

K.Kaviyarasan (2014)[9] studied the performance of UASB (Upflow Anaerobic Sludge Blanket) reactor for treating various industrial and domestic wastewaters at various operating conditions. The study found that the UASB reactors can be conveniently used for the treatment of tannery, distillery, food processing, metal mining, dairy, domestic wastewater etc. The performance of the reactor mainly depends on the OLR and HRT.

Abid Ali Khan et al (2014)[10] studied up flow anaerobic sludge blanket (UASB) based sewage treatment plants (STPs) of different cities of India. The study highlighted that presently 37 UASB based STPs were under operation and about 06 UASB based STPs are under construction and commissioning phase at different towns. The nature of sewage significantly varied at each STP.

Massimo Raboni et al (2014)[11] conducted an experimental process designed for the treatment of the sewage generated by a rural community located in the north-east of Brazil. The process consists of a preliminary mechanical treatment adopting coarse screens and grit traps, followed by a biological treatment in a UASB reactor and a sub-surface horizontal flow phytodepuration step. The use of a UASB reactor equipped with a top cover, as well as of the phytodepuration process employing a porous medium, showed to present important health advantages..

Mrunalini M. Powar et al (2013)[12] study found that UASB reactor is feasible for treating variety of wastewater and performance of UASB reactor gets affected by pH, HRT, OLR, temperature and volatile fatty acids (VFA) to alkalinity ratio. The study recommended that proper HRT should be provided to give sufficient contact time between wastewater and bacteria. For avoiding VFA accumulation in UASB reactor and for getting effective biogas production sodium bicarbonate alkalinity should be provided. VFA to alkalinity ratio should maintained between 0.5 - 0.8 for good performance of UASB reactor.

Kaan Yetilmezsoy et al (2013)[13] studied to development of ANN based model to predict biogas and methane productions in anaerobic treatment of molasses wastewater. In this study two three layer ANN models were developed and eight process related variables such as operating temperature, OLR, influent and effluent pH , influent and effluent alkalinity, effluent COD and VFA concentrations were selected. The result show that the proposed ANN based model produced smaller deviations and exhibited superior predictive accuracy for the forecasts of biogas and methane production rates.

Mansi Tripathi and S. K. Singal (2013)[14] conducted a study to evaluate the performance of existing sewage treatment plants (STPs) in Lucknow City of India. In this study two approaches, evaluating the treatability performance and Life-Cycle Assessment (LCA) have been used to determine the plants efficiencies in the study. All the results have been interpreted graphically. The results of this study concluded that the UASB reactor is better than the FAB, however in terms of LCA the FAB seems to be more reliable.

Gangesh Kumar Kasaudhan et al (2013)[15] work is concerned with the detailed study of Asia's largest sewage treatment plant of 345 MLD capacity (based on Up flow Anaerobic Sludge Blanket reactor), installed at Bharwara, Lucknow, Uttar Pradesh, India. The design analysis of the sewage treatment plant has been carried out to comment on the adequacy of design and capacity.

R.N. Uma et al (2012)[16] studied the different treatment for waste water. The study designed a hybrid UASB rector involving both suspended and attached growth process by changing retention time in day for particular organic loading rate. The study found that this method effectively removed the BOD, COD and other parameters because of both suspended and attached growth process.

E.R.N. Gunawardena et al (2011)[17] carried out a study to evaluate the performances of eight STPs representing different locations and management organizations such as government, private sector and community and to investigate the reasons for their performance. The methodology included a checklist survey with 109 performance criteria under five categories such as general, technical, physical, personnel and operational and maintenance, complemented by focus group discussion, formal and informal discussion and stakeholder interviews. The results showed that only two out of eight STPs studied performed well.

Takahashi M. et al (2011)[18] investigated the treatment characteristics and sludge properties of an upflow anaerobic sludge blanket (UASB) process using a pilot-scale 1.15 m3reactor. In this study the UASB, inoculated with digester sludge, was operated at a hydraulic retention time of 8 h at sewage with temperatures ranging from 10.6 to 27.70C for more than 1100 days. The study observed that the stable removal efficiencies for total COD Cr and SS were 63± 13% and 66 ± 20%, respectively.

S.A. Habeeb et al (2011)[19] studied the up-flow anaerobic sludge bed UASB operation as well as the main parts of the reactor. The study specifically explained the correlations and compositions of sludge granule and believed that the extracellular polymer (ECP) is totally responsible of bacterial cell correlations and the formation of bacterial communities in the form of granules.

A K Mittal et al (2008)[20] studied the overall implications of UASB technology in India. In this study institutional and technical aspects with special reference to the Yamuna Action Plan (YAP) were presented. It also presents the potential of UASB technology in other developing countries with its future within India as well based on the evaluation of life cycle cost (LCC).

P. Sankar Ganesh et al (2007)[21] studied the suitability of UASB reactors in treating low-strength (< 2000 mg/L COD) industrial wastewaters in general and dairy industry wash water in particular. The study found that the consistency of reactor performance even when COD loading is changed quickly over a wide range of values indicates the robustness of the system. The reactors appear capable of treating the wash waters with a high degree of consistency even when the influent strength may vary due to across-the-week flow variations and shock loads.

A. Mirsepasi et al (2006)[22] studied two full-scale UASB reactors were investigated. Volume of each reactor was 420 m3. Conventional parameters such as pH, temperature and efficiency of COD, BOD, TOC removal in each reactor were investigated. Also several initial parameters in designing and operating of UASB reactors, such as upflow velocity, organic loading rate (OLR) and hydraulic retention time were investigated.

M. Zamanzadeh et al (2004)[23] studied UASB reactor for treating waste water in tropical regions. In this study two different temperatures of waste water were carried out at ambient temperature. It was observed that in colder period BOD5, COD and TSS removal efficiency were 54, 46, 53% respectively and in warmer period it is about 71, 63 and 65% respectively.

Ezzat A. Hassanienc et al (2003)[24] studied the prediction of wastewater treatment plant performance using artificial neural networks. In this studied ANN model used to predict the performance of WWTP in Greater Cairo district, Egypt based on past information. 10 month daily records of suspended solids (SS) and biochemical oxygen demand (BOD) concentration are obtain from the laboratory of the plant. To evaluate data dependence and detect the data relationships, exploratory data analysis was used. For prediction of SS and BOD concentration in plant effluent, two ANN-based models are used. Through several steps of training and testing of the model, the architecture of the neural network models was determines. The ANN models were found to provide a robust tool for prediction of WWTPs performance.

IV. METHODOLOGY

To evaluate the performance of UASB plant physic-chemical parameters of pH, temperature, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and total suspended solids (TSS) at the inlet and outlet points of the treatment units were selected and analyzed in plant laboratory. Consequently, the design analysis of Organic loading rate (OLR), Volumetric hydraulic loading (VHL), Up flow velocity, hydraulic retention time and removal efficiencies of biochemical oxygen demand (BOD5), chemical oxygen demand (COD) and biogas production through empirical equations were calculated to compare the values obtained to check for variation in the actual values obtained through tests. The biogas and methane production rate through equations were also calculated.

V. DATA COLLECTION AND ANALYSIS

The samples were collected at inlet and outlet points of the treatment units and analyzed as outlined in the standard methods for the examination of water and wastewater (APHA, 1999). The plastic sample bottles of 500 ml each were used to collect the samples and rinsed with the effluent water at the sampling points. Inlet samples consisted of raw waste water entering the UASB plant through the inlet chamber while the outlet water consisted of treated water from the plant which is being released into the Gomti River. Both wastewater temperature and ambient air temperature of the sewage were recorded at the time of sampling. The samples were mostly collected between 10:00 AM and 11:00 AM. The parameters of influent and effluent were monitored every week (Monday) for over a period of four months i.e. from February 2021 to May 2021.

A. pH

The waste water reaches the inlet chamber with pH between 7.0 and 7.46. A significant drop in pH was observed in the streams at outlet is between 7.32 and 7.65, due to the formation of acetate, with consequent release of hydrogen. The average pH at inlet and outlet of the plant is 7.28 and 7.52.

B. Temperature

The maximal and minimal recorded temperatures of the influent water were 31.5^{0}C and 26.3°C respectively. While the effluent maximal and minimal recorded temperatures were 31.9^{0}C and 29.9°C. Thus the recorded temperatures of the influent and effluent were between 26.3°C to 31.9°C which was found optimal for the growth of bacteria and optimal anaerobic digestion. The temperature of the raw sewage is typical of the local tropical climate value is maintained quite well during the whole treatment process.

C. Dissolved Oxygen(Do)

Dissolved oxygen is a relative measure of the amount of oxygen dissolved in water. The oxygen content of water will decrease when there is an increase in nutrients and organic materials from industrial wastewater, sewage discharge, and runoff from the land. The dissolved oxygen range in the final effluent is always greater than 4.

D. Total Suspended Solids (TSS)

The maximal and minimal recorded TSS of the influent water were 296 mg/l and 160 mg/l, respectively. While the effluent maximal and minimal recorded TSS were 47 mg/l and 37 mg/l. The average TSS at inlet and outlet of the plant is 216.44 mg/l and 42.77.

E. Chemical Oxygen Demand (COD)

The maximal and minimal recorded COD of the influent water were 368 mg/l and 149 mg/l, respectively. While the effluent maximal and minimal recorded COD were 88 mg/l and 60 mg/l. The average COD at inlet and outlet of the plant is 270.94 mg/l and 74.

F. Biochemical Oxygen Demand(BOD5)

The maximal and minimal recorded BOD5 of the influent water were 160 mg/l and 120 mg/l, respectively. While the effluent maximal and minimal recorded BOD5 were 34 mg/l and 19 mg/l. the average BOD5 at inlet and outlet of the plant is 138.88 mg/l and 24.77.

DATE	INLET						OUTLET					
	Ph	TEMP (^{0}C)	DO	TSS (mg/l)	COD(mg/l)	BOD(mg/l)	pH	TEMP(^{0}C)	DO	TSS (mg/l)	COD (mg/l)	BOD (mg/l)
01-Feb	7.33	26.3	0	216	320	160	7.52	26.9	4.6	42	72	25
08-Feb	7.15	26.5	0	241	352	150	7.65	27.0	4.2	41	80	21
15-Feb	7.32	26.4	0	296	368	155	7.60	26.8	4.5	45	80	25
22-Feb	7.22	26.7	0	203	312	145	7.61	27.2	4.5	46	80	28
01-Mar	7.35	27.0	0	215	248	135	7.63	27.7	4.2	42	60	34
08-Mar	7.31	27.2	0	202	256	145	7.61	27.8	4.3	47	80	19
15-Mar	7.5	27.9	0	224	149	130	7.60	28.6	4.5	47	72	26
22-Mar	7.32	27.7	0	239	256	125	7.52	28.5	4.5	37	72	21
29-Mar	7.31	28.1	0	274	240	125	7.45	28.9	4.4	47	64	19
05-Apr	7.29	28.4	0	211	280	140	7.60	29.4	4.3	42	80	26
12-Apr	7.19	28.2	0	201	272	135	7.38	29.1	4.2	40	80	27
19-Apr	7.25	28.8	0	219	264	145	7.42	29.7	4.2	39	60	24
26-Apr	7.2	28.7	0	210	256	150	7.62	29.9	4.1	42	72	25
03-May	7.46	28.8	0	160	224	120	7.46	30.1	4.5	46	76	25
10-May	7.46	29.5	0	216	280	140	7.46	30.6	4.2	39	80	26
17-May	7.05	30.2	0	183	264	135	7.32	31.3	4.3	40	64	24
24-May	7	31.5	0	200	264	130	7.42	32.1	4.4	47	88	27
31-May	7.4	31.0	0	186	272	135	7.61	31.9	4.4	41	72	24

Table 2: Results of wastewater quality parameters for the 18 weeks collected at Bharwara UASB plant

The inlet and outlet concentration of STP pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) are shown graphically.

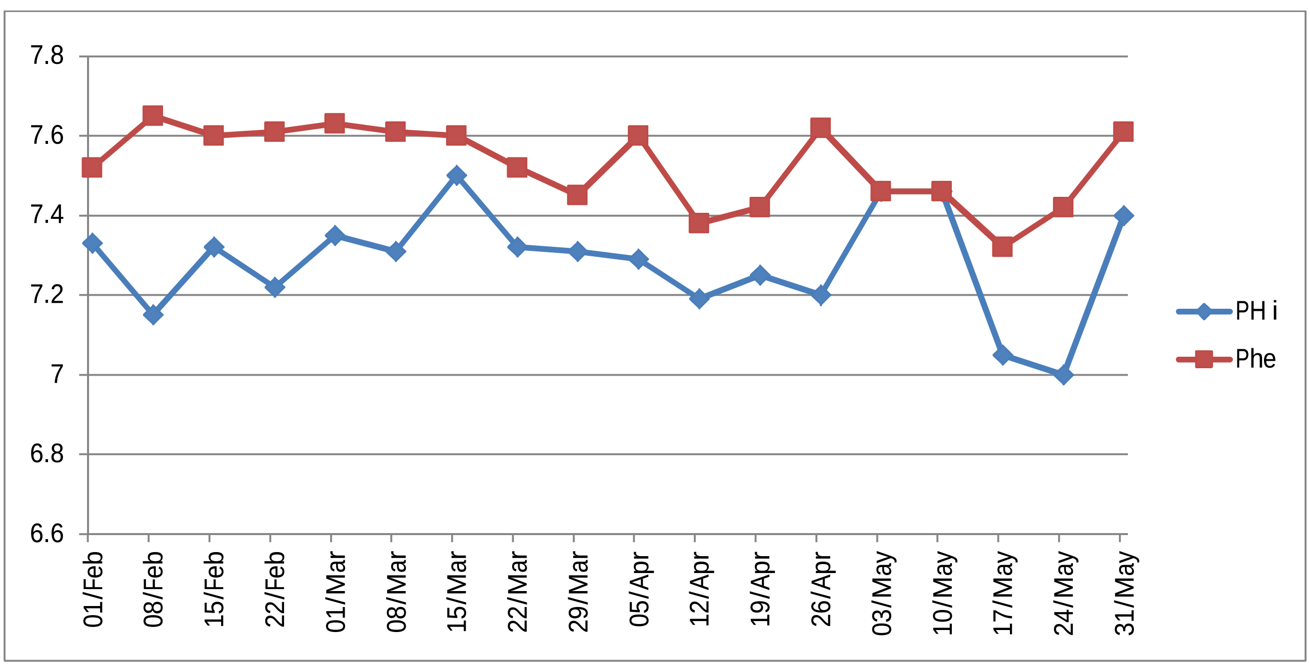

Fig. 1: pH Variation b/w influent and effluent of the Bharwara UASB plant

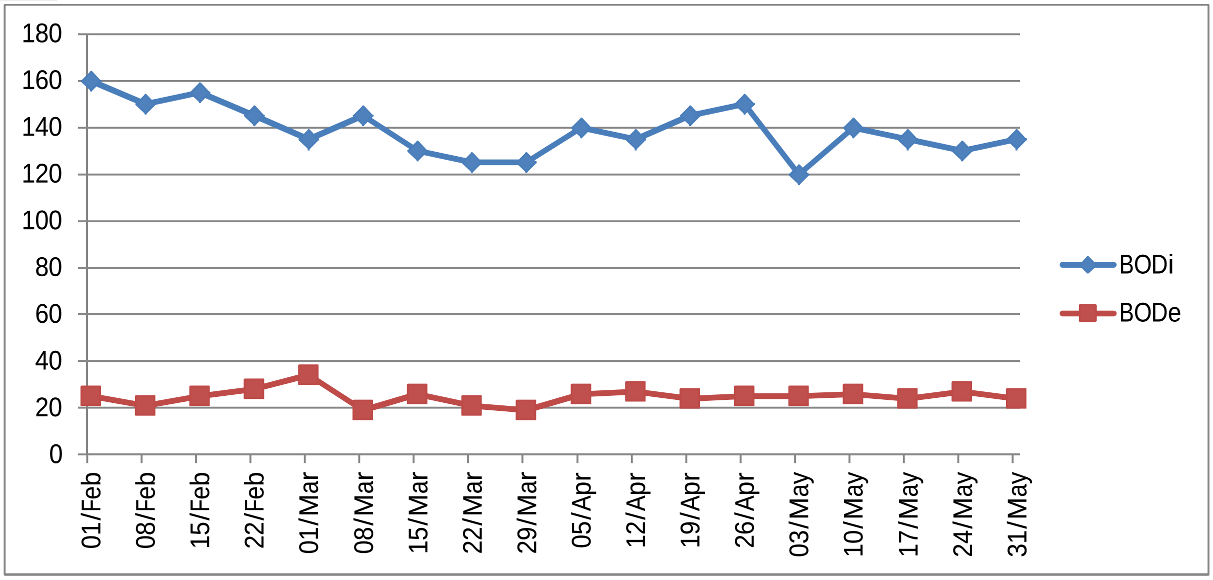

Fig. 2: BOD Variation b/w influent and effluent of the Bharwara UASB plant

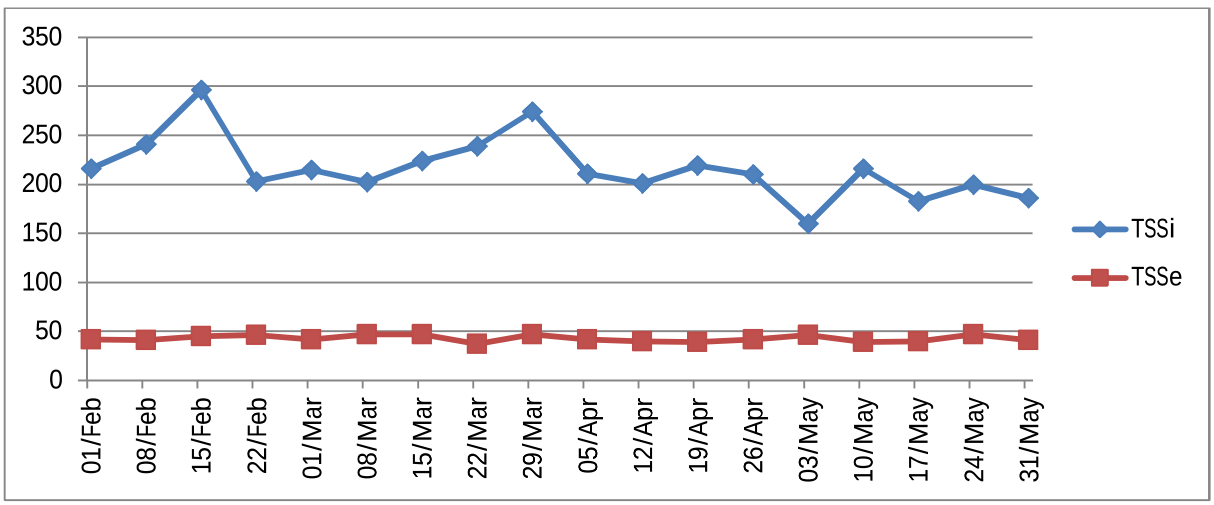

Fig. 3: TSS Variation b/w influent and effluent of the Bharwara UASB plant

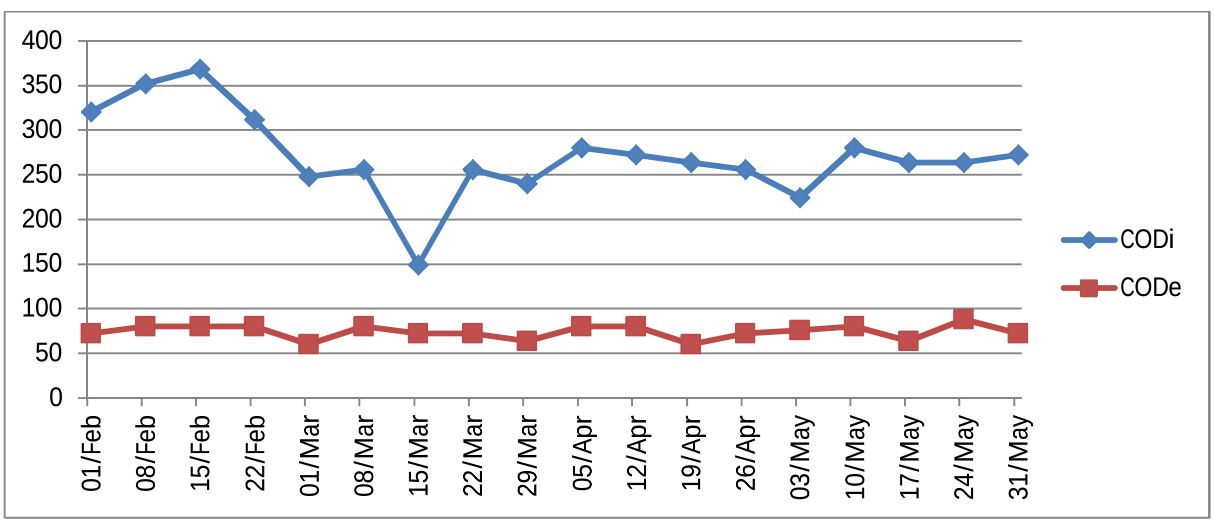

Fig. 4: COD Variation b/w influent and effluent of the Bharwara UASB plant

VI. DESIGN ANALYSIS

The design analysis of the UASB reactor was done against commonly used design equations and empirical formulas. The design equations and the typical values against which the design analysis was carried out according to Metcalf and Eddy,(2003)[25], Chernicharo,(2007)[26] and Marcos Von Sperling, (2007)[27]. The standard design considerations the design analysis of UASB is determined by the following steps:

A. *Volumetric Hydraulic Load And Hydraulic Detention Time*

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

$$VHL = Q/V$$

Where:

VHL = volumetric hydraulic load ($m^3/m^3 \cdot d$)

Q = Flow rate (m^3/d)

V = total volume of the reactor (m3)

$$t = 1/VHL$$

Where:

t = hydraulic detention time (d) or

$$t = V / Q$$

Experimental studies demonstrated that the volumetric hydraulic load should not exceed the value of 5.0 $m^3/m^3 \cdot d$, which is equivalent to a minimum hydraulic detention time of 4.8 hours.

B. *Organic Loading Rate*

The volumetric organic load is defined as the amount (mass) of organic matter applied daily to the reactor, per volume unit:

$$Lv = Q \times S_0 / V$$

Where:

Lv = volumetric organic loading rate (kg $COD/m^3 \cdot d$)

Q = flow rate (m^3/d)

S_0 = influent substrate concentration (kg COD/m^3)

V = total volume of the reactor (m^3)

C. *Upflow Velocity And Reactor Height*

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

$$v = Q / A$$

Where:

v = upflow velocity (m/hour)

Q = flow (m^3/hour)

A = area of the cross section of the reactor, in this case the surface area (m2) or alternatively, from the ratio between the height and the HDT:

$$v = Q \times H / V = H \times t$$

Where:

H=height of the reactor (m)

D. *Efficiency Of The Uasb Reactors*

Efficiencies of the UASB reactors by empirical relations were estimated as:

$$E\ COD = 100 \times (1 - 0.68 \times t^{-0.35})$$

Where:

E = efficiency of UASB reactor in term of COD removal (%)

t = hydraulic detention time (hr.)

0.68 = empirical constant
0.35 = empirical constant

$$E\ BOD = 100 \times (1 - 0.70 \times t^{-0.50})$$

Where:
E = efficiency of UASB reactor in term of BOD removal (%)
t = hydraulic detention time (hr.)
0.70 = empirical constant
0.50 = empirical constant

E. Evaluation Of The Biogas Production

The biogas production can be evaluated from the estimated influent COD load to the reactor that is converted into methane gas. In a simplified manner, the portion of COD converted into methane gas can be determined as follows:

$$COD_{CH4} = Q \times (S_0 - S) - Y_{obs} \times Q \times S_0$$

Where:
COD_{CH4} = COD load converted into methane (kg $CODCH_4$/d)
Q = average influent flow (m^3/d)
S_0 = influent COD concentration (kg COD/m^3)
S = effluent COD concentration (kg COD/m^3)
Y_{obs} = co-efficient of solids production in the system, in terms of COD (0.11 to 0.23 kg CODsludge/kg CODappl).
The methane mass (kg$CODCH_4$/d) can be converted in to volumetric production (m^3CH_4/d) by using the following equations:

$$Q_{CH4} = COD_{CH4} / K(t)$$

Where:
Q_{CH4} = volumetric methane production (m^3/d)
K(t) = correction factor for the operational temperature of the reactor (kgCOD/m^3)

$$K(t) = P \times K_{COD} / [R \times (273+T)]$$

Where:
P = atmospheric pressure (1 atm)
K_{COD} = COD corresponding to one mole of CH4 (64 gCOD/moL)
R = gas constant (0.08206 atm·L/mole·K)
T = operational temperature of the reactor (◦C)

Once the theoretical methane production is obtained, the total biogas production can be estimated from the expected methane content. For the treatment of domestic sewage, the methane fraction in the biogas usually ranges from 70 to 80%.
The value of volumetric hydraulic loading, volumetric organic loading, upflow velocity and HRT was calculated and shown in the table 3. The volumetric hydraulic loading rates were range between 2.86 and 3.00 m^3/day.$m^3$for the UASB reactor. The upflow velocity was also slight varies between 0.54 – 0.57 m/hr. the hydraulic retention time are varies in range of 8.00 to 8.39 hr.

MONTHS	VOLUMETRIC HYDRAULIC LOADING (m^3/day.m^3)	VOLUMETRIC ORGANIC LOADING(kg COD/m^3.day)	UPFLOW VELOCITY (m/hr)	HRT (hr)
Feb	2.86	0.87	0.54	8.39
March	3.00	0.62	0.57	8.00
April	2.93	0.74	0.56	8.19
May	2.97	0.74	0.57	8.08

Table 3: Design analysis calculations for UASB reactor

The treatment efficiencies were observed to be lower than the expected shown in table 4. Observed efficiencies were 54.69%-64.55% for COD and 62.38%-67.71% for BOD while expected efficiencies calculated according to the empirical formula equations were 67.16-67.70% and 75.25-75.83% respectively.

MONTHS	BOD removal efficiency (%)		COD removal efficiency (%)	
	Expected	Observed	Expected	Observed
Feb	75.83	65.22	67.70	64.55
March	75.25	62.53	67.16	54.69
April	75.54	67.71	67.42	62.67
May	75.37	62.38	67.27	62.13

Table 4: Efficiencies calculation for the UASB reactor

This indicates that the equations used were slightly underestimating the COD efficiency, which may be because of the differences in the characteristics of the sewage being treated.

The biogas production can be evaluated from the estimated influent COD load to the reactor that is converted into methane gas. The evaluation of the biogas is done from the estimation of the percentage of methane in the biogas. Adopting a methane content of 75% in the total biogas generated. The average monthly production rate of biogas and methane are calculated and shown in the table 5-

Month	COD_{CH4} (kg COD/day)	Q_{CH4} (m^3/day)	Q_{BIOGAS} (m^3/day)
February	52961	20448	27264
March	31015	11974	15965
April	42717	16493	21990
May	42417	16377	21836

Table 5: Biogas production calculation for the UASB reactor

The COD_{CH4} (COD load converted into methane) maximum value are comes from the month of February is 52961 kg COD/day. The minimum value of COD_{CH4} in the month march is 31015 kg COD/day. The Q_{CH4} (volumetric methane production) is maximum in the month of February is 20448 (m^3/day) and the minimum value of Q_{CH4} is 11974 (m^3/day) in the month of March. The Q_{BIOGAS} (total biogas production) value is maximum in the month February is 27264 (m^3/day) and the minimum value is obtain in the month March is 15965 (m^3/day).

VII. CONCLUSION

This investigation of the working performance of UASB plant located at Bharwara, Gomti nagar Lucknow observed that the maximum BOD_5 removal efficiency was 83.72%, while the maximum COD removal efficiency was 76.92% and the maximum TSS removal efficiency was 81.80%. The BOD_5 and TSS allowance values increased with the increasing influent concentrations. The maximum BOD_5 removal efficiency was 67.71%, while the maximum COD removal efficiency was 64.55% for the UASB reactor. The BOD and COD removal efficiency are low for UASB reactor.

The lower value of removal efficiency is because of higher the value of influent wastewater then the design value. There are few observations that can be used for the identification of the fluctuations in the removal efficiency. As the pH value tended to decrease and became more acidic, decline was observed in the BOD_5 removal efficiency. The reason for the decrease in removal efficiency can be that as more organic matter was decomposed into volatile acids, the pH value dropped to be more acidic which could have obstructed the methanogenesis process.

The moderate value of the BOD_5 was observed as the pH value tended to be normal. The biogas production is depends upon the organic loading rate.

The higher the organic loading rate gives higher production rate for biogas. If the value of organic load is decrease then production rate of biogas is also decrease. The maximum biogas production rate calculated is 27264 (m^3/day). The COD_{CH4} (COD load converted into methane) maximum value is 52961 kg COD/day. Due to the inefficient sewerage network, highly diluted sewage is received at the Bharwara plant due to which there is insignificant biogas generation which could otherwise be used for power generation; hence, cost recovery.

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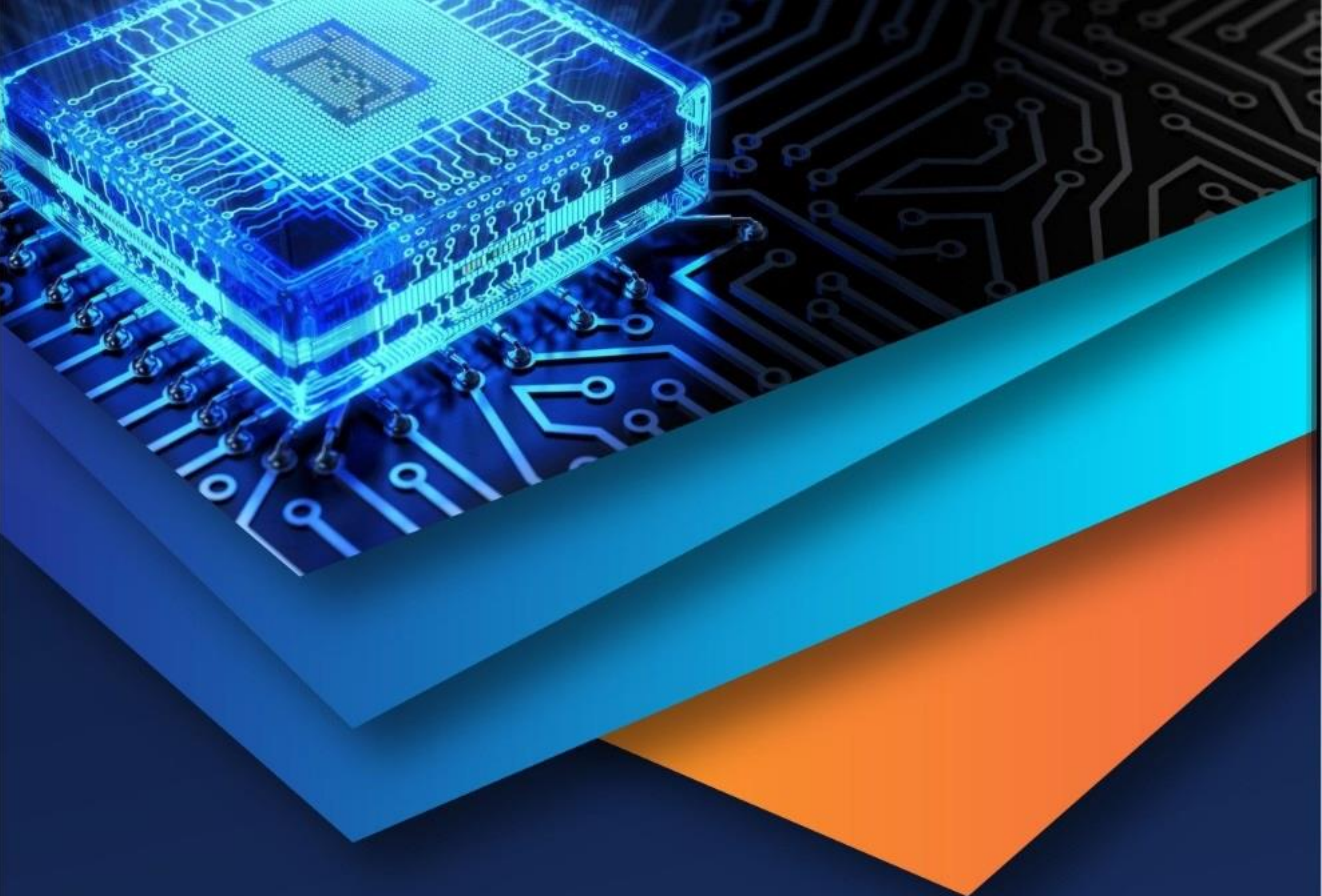

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