Characterization of Sewage, Design of Laboratory Scale UASB Reactor for Its Treatment and Its Performance Evaluation

Harshan K.G[#], Gana VB[*]

[#] *Associate Professor, Dept. of Civil Engineering, *Student M. Tech (Environmental Engineering), M DIT Ulliyeri, India*

***Abstract*-The lab scale upflow anaerobic sludge blanket reactor UASB seeded with cow dung manure was used to treat the waste water from M Dasan Institute of technology having medium strength. The cow dung seed sludge required a period of 120 days for acclimatization and the sludge bed of the reactor was stabilized in a period of 20 days and the reactor was continuously working for a period of 56 days. The physicochemical and biological parameters of waste water quality are experimented and found out and design of lab scale reactor and design of proposed UASB reactor was done .pH of effluent increased with time and ranges from 4.4 to 7.62.Turbidity of effluent decreased with time and it has a percentage removal of 72.4.Conductivity of effluent decreased with time and it has a percentage removal of 84.51.TDS of effluent decreased with time and it has a percentage removal of 85.99.BOD of effluent decreased with time and it has a percentage removal of 77.95.COD of effluent decreased with time and it has a percentage removal of 82.38.Chloride of effluent decreased with time and it has a percentage removal of 81.26. All the values were within permissible limits of discharge as per E (P) rules, schedule VI part A.**

***Keywords*-UASB reactor, BOD, COD, pH, Turbidity, Conductivity**

I. INTRODUCTION

As our college, M Dasan Institute of Technology (M-DIT) Ulliyeri is newly established in 2012, no waste water treatment plant is designed for the treatment of waste water generated from our campus yet. In the beginning years, the student population was few when compared to today's scenario so that waste water generated was less and it was not considered to be a pollution. However, in the last three years, the student's population has increased drastically which results in deterioration of the environment. On a daily basis, thousands of litres of waste water is generated from our campus in which solid waste material is dumped in distant land or waste water itself discharged in pits without proper treatment which will eventually leads to a havoc. So, its high time to think and to implement a suitable waste water treatment plant for our college. Different varieties of treatment plants are available nowadays. What we need to do is to check whether the particular treatment system can be adopted in our atmospheric conditions because mainly in biological methods, microbes are used for the degradation of organic matter along with the physical chemical and biological characteristics of waste water will also use to define suitable treatment method for the waste water.

An institutional waste water contains high amount of organic and inorganic pollutants, numerous pathogenic microorganism and other nutrients and they will impose high risk to human and its environment. To diminish the environmental and health risks imposed, these contaminants and impurities need to be brought down to permissible limits for safe disposal of wastewater. The main objective of any wastewater treatment method is generally to allow human and industrial effluents to be disposed of without causing any danger to human health or damage to the natural environment which may be unacceptable. Also, removal of the organic contaminants and pathogens from wastewater is of paramount important for its reuse in different purposes.

The use of Upflow Anaerobic Sludge Blanket Reactor treatment facility that treats wastewater using anaerobic microorganisms, like the methanogens that degrades organic and inorganic materials and produces methane as a byproduct.Anaerobic digestion leads to the production of little and stabilized (i.e. non-putrescible) sludge, whereas the major part of the metabolized organic material (more than 90 percent) is converted into methane and as such becomes available as a useful energy source which can be uses. It dispensed the need of mechanical aeration required in aerobic processes and constituting an important factor in constructional and operational costs. Anaerobic process generally have higher volumetric organic loads than aerobic processes, so smaller reactor volumes and less space may be required for treatment so it has low land demand, and can be constructed underground with locally available material. Well-designed anaerobic process have a far greater treatment capacity than aerobic processes. This high treatment capacity is not due to the particularly high anaerobic sludge activity but rather to the relatively large sludge mass than can be retained in anaerobic reactors. Anaerobic sludge can be stored for long periods (months or even years) so that seasonal waste waters can be treated without major problems. Because of the energetics of anaerobic process result in lower biomass production by a factor of about 6 to 8 times of aerobic process, sludge processing and disposal cost are greatly reduced. Effluent is rich in nutrients and can be used for irrigation purposes

II. METHODOLOGY

A. Sample Collection

The experiments were carried out in the waste water samples that are collected from the campus of M-DIT Ulliyeri. The water samples were collected into a normal air tight bottle of capacity of 2 liters. A mug was used to take waste water sample. Five samples of waste water at three different times (9.00am, 12.00pm, 3.00pm) were collected and experimented from M-DIT campus. The procedure was adopted to get the average value of the required parameters of duration.

B. Chemical analysis

Physicochemical properties of samples were determined which includes Biochemical Oxygen Demand (BOD), included Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Conductivity, Turbidity, Total Dissolved Solids (TDS), Total suspended solids (TSS), chlorides, pH and microbial content.

All the parameters are determined following standard methods for the examination of wastewater.

Measurement of biochemical oxygen demand (IS 3025: part 44) .Measurement of chemical oxygen demand (IS 3025: Part 56). Measurement of dissolved oxygen (IS 3025: part 38). Measurement of conductivity (IS 3025: part 14). Measurement of pH value (IS 3025: part 11).Measurement of turbidity (IS 3025: part 10). Measurement of total suspended solids (IS 3025: part 15). Measurement of total dissolved solids (IS 3025: part 16). Sampling and Microbiological examination (IS 1622).

C. Preparation of the starter

Cow dung seed was used as the starter for the experiment because it comprised predominantly of organic matter and heavy population of microbes such as methanogens. Equal volume of cow dung and water were thoroughly mixed in a container. This mixture 9L and 1L of waste water were filled overflowing into a 10 L another plastic container to remove the oxygen bubbles entrapped. The container was closed with a cap tightly to get anaerobic condition.

During the acclimatization stage of seed sludge, nutrients are to be supplied to boost sludge growth by addition of Sucrose ($C_6H_{12}O_6$) and diammonium hydrogen phosphate $(NH_4)_2HPO_4$ at regular intervals. The slurry after 120 days was filtered by using 3mm aperture mesh to remove the undigested animal feed.

At the initial stage the colour of starter was a dark greenish and after 120 days of time, after the bacterial growth and decomposition of organic matter it has turned to dark brackish colour with numerous colonies of different kinds of microbes growing at the top of the starter could be seen along with significant odour of gases formed. Then it was ready to use as a starter.

D. Design of lab scale UASB reactor

For this laboratory scale experimental study, lab scale UASB reactor was fabricated by using glass sheets with 14 L total working volume. UASB reactors have either a round or rectangular shape. The round shape has the advantage of higher structural stability, but the construction of a round separator is difficult. For this reason, large UASB reactors are usually built with a rectangular shape. In practice very often more than one reactor are built, to increase operational stability. In that case the rectangular form has the advantage that slide wall may be shared by different reactors. In this study, rectangular shaped reactor was designed and fabricated.

The design calculations are as shown below.

Total working volume=14 L

Length to Height ratio, L:H=1:14

Height of the reactor = 140 cm

Length of the base=10 cm

Width of the base =10 cm

Area of the reactor, A= 100 cm^2

Influent COD concentration= 531 mg/l

Diameter of pipe for Biogas effluent,

DgL/6 =10/6

=1.67m

Flow rate, Q= 28 L/day

Up flow velocity, V = Q/A

$$= \frac{\frac{28}{24}}{14} \times \frac{10^{-3}}{10^{-4}} \text{m/h}$$

$$= 0.116 \text{ m/h}$$

Organic loading rate

$$= Q \times COD$$

Volume of reactor

$$= \frac{28 \times 531}{1400}$$

$$= 1.062 \text{ Kg COD/m}^3$$

Calculation of gas solid liquid separator

It was calculated as per tentative guidelines [17]

The slope of settler bottom = 55^0

Gas deflector, B=0.335 cm

Width of settler, B= 3.6 cm

Height of the settler=5.1 cm

D_h=10 cm

Scum layer baffles installed infront of the effluent weirs

E. design details of lab scale UASB reactor

It was fabricated at Environmental Engineering Laboratory M Dasan Institute of Technology(M-DIT) Ulliyeri,Kozhikode.

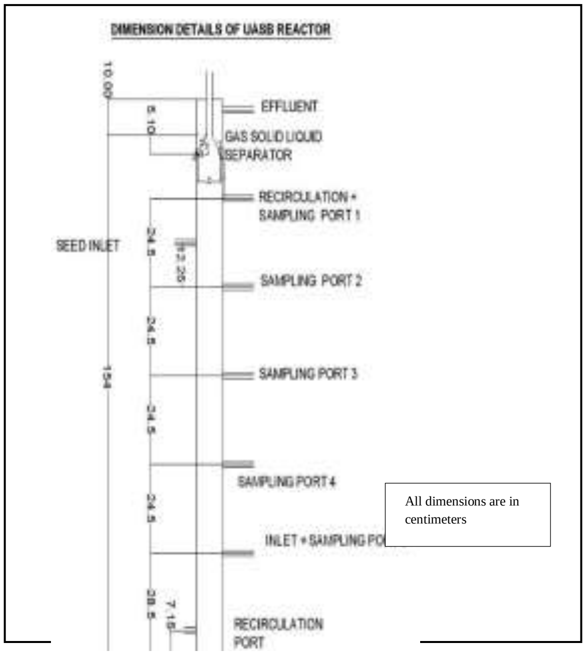

Fig Fi.1 Design details of UASB reactor

As shown in figure 1, it has a total height of 154 cm and length of base is 10 cm. Upto 140 cm the waste water will be filled i.e. effective volume of reactor is 14 L and remaining for gas collection and effluent removal purposes. The organic loading rate was 1.062 Kg COD/m^3 and upward velocity was 0.116m/hr.

Five sample ports were provided at equal intervals of 24.5 cm from the bottom sample port 5. Recirculation port was provided at 7.15 cm from the bottom of the reactor and inlet plus sample port 5 was provided at 28.5 cm from the bottom for the settlement and collection of sludge. Starter inlet was provided at upper section of UASB reactor at height of 12.25 cm from sampling port 2.

Gas deflectors were provided for the collection of gas produced. In this zone any flocs with a settling velocity higher than the liquid velocity at the effluent discharge level can be retained. These will accumulate on the GLS separator until a sufficient mass is formed to overcome the friction, whereupon the solids will slide back into the digestion zone under the GLS separator.

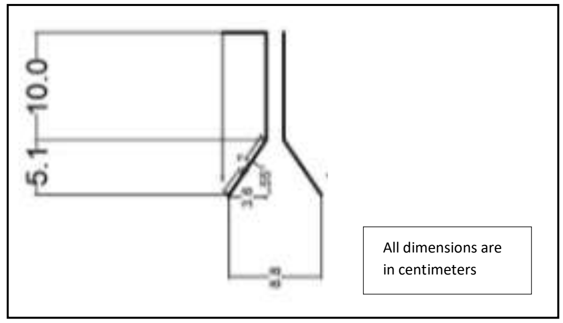

Fig.2 Design details of gas solid liquid separator

Gas solid liquid separator was made of plastic and the dimension details is shown as in figure 2. The slope of settler bottom was given as 55^0.Width of settler, B was 3.6 cm and height of the settler was 5.1 cm. Height of gas collecting tube provided was 10.0 cm.Gas outlet was tripped with rubber balloon for the collection of gas

F. Fabrication of laboratory scale UASB reactor

The arrangement of reactor and other apparatus used for the experiment is as shown in figure 3.6. Two submersible pumps were used. One for the pumping of influent waste water from the storage tank into the UASB reactor via sample port 5 and another for recirculation of waste water inside reactor through the recirculation port and sampling port 1. Waste water is stored in a feed tank and effluent is collected via effluent port in effluent tank. The digested waste could be could be collected through digested waste outlet provided at the bottom of the reactor

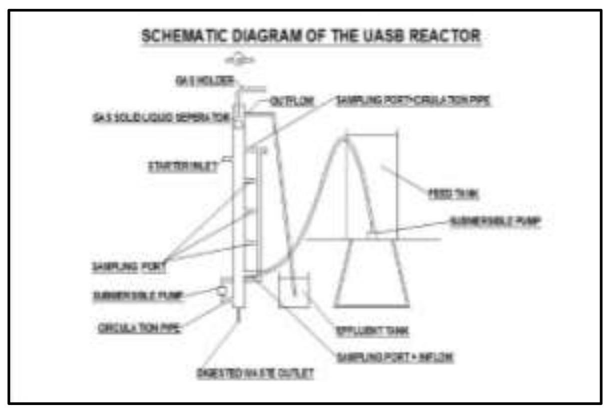

Fig.3 Schematic diagram of lab scale UASB reactor

G. Materials

The UASB reactor was made of glass sheets. The base and side walls were made of 6mm while top portion was of 3 mm glass sheet. Two submersible pumps used for the experimental purpose. It has amaximum lifting height of 2 metre and the discharge was 180L/h. The discharge of pump that we used was greater than the discharge that needed for UASB reactors. So, by making use of T joint, specific discharge of 28 L/day was pumped into the reactor and the remaining waste water was again pumped back into the feed tank by making use of T joint.The waste water was circulated to and out of the reactor by using the hose. Scum layer baffles were made of plexiglass and they are having triangular cross having 1.25 cm for each side and having length of 8.8 cm. To regulate the flow of waste water in the reactor, valves were used at the recirculation pipes, at the influent and effluent pipes. For the collection of gas formed during the process, a gas solid liquid separator which was made of plastic.For the support of Lab Scale UASB reactor, iron rod is used

H. working procedure of UASB reactor

Wastewater was taken in a container and cooled down to room temperature. Then it was adjusted the desired pH 6.7±0.1 with commercial grade of sodium hydroxide. Take another big container and fill 10 litres of waste water and 4 litres of already prepared starter into it. Fill this mixture into the UASB reactor upto a height of 14 m. The recirculation pump was connected at the bottom of the tank which pumped the waste water from the bottom of the tank .The recirculation velocity is checked using a valve at the inlet. The gas produced in the process is collected in a bottle via a delivery tube. The effluent is collected at regular intervals (i.e., after 2st week, 4nd week, 6rd week and 8th week) from sample ports.At the end of the process the effluent waste water is collected and tested for various physical, chemical and biological properties and is compared with the initial waste water and the standard values.

III. RESULTS

The whole treatment process was performed in the Environmental Engineering laboratory where the temperature varied from 25 ºC to 35 ºC continuously for 56 days. Waste water was filled in the reactor on February 21st. Reactor was working continuously for 56 days. Small sludge granules started forming after 20 days of working. Thereafter dense granular flocs were formed with time.

A. Influent characteristics

Influent characteristics of waste water is shown in table I

TABLE I

INFLUENT CHARACTERISTICS OF WASTE WATER

Characteristics	Units	Value
pH		4.4
Alkalinity	mg/L	520
Turbidity	NTU	926
Conductivity	mS/ppt	248.08
TDS	mS/ppt	1164.12
BOD	mg/l	359
COD	mg/l	531
DO	mg/l	4.9
Chloride	mg/l	2.26
Microbial Content	CFU/ml	20 x 10^6

B. Effluent characteristics

i) pH

Samples were collected from the top 3 sample ports below which dense sludge blanket were form and shown in table II

TABLE II

PH VALUES OF EFFLUENT SAMPLE

Days	Sample port 1	Sample port 2	Sample port 3
14	7.45	7.22	7.16
28	6.74	6.71	6.76
42	4.13	4.14	4..21
56	7.61	7.62	7.62

From the analysis it was found that in the initial two weeks, reactor pH ranged between 7.17 to 7.45 It decreased to 6.74 during the fourth week due to acidogenesis. It dropped very sharply and remained below the influent value on day 42 due to fermentation of glucose to acetate. After 8 weeks pH value of waste water was 7.61

ii) Alkalinity

The sample was collected from topmost sample port 1 and the values are shown in table III

TABLE III

ALKALINITY VALUES OF EFFLUENT SAMPLE

Days	Alkalinity (mg/L)
14	1680
28	925
42	432
56	550

The actual alkalinity of sample was 520 mg/L. To maintain pH at 6.7, standard NaOH of 3.6 grams was added on zeroth day and the alkalinity value was raised to 1800mg/L. There was a steep decrease in alkalinity value from day 0 to day 42 due to acidogenesis and acidogenesis of organic matter. From day 42 to56 there was a slight increase in the alkalinity level. This was due to the conversion of all acids formed in the process to CH_4, CO_2 hydrogen and ammonia etc.

iii) Turbidity

The sample was collected from topmost sample port 1 and it is shown in table IV

TABLE IV

TURBIDITY VALUES OF EFFLUENT SAMPLE

Days	Turbidity (NTU)	Percentage removal %
14	856	7.55
28	759	18.03

42	451	51.29
56	255	72.4

From the results obtained it was found that turbidity gets decreased mainly because of the upward flow of water. Due to upward flow of waste water all the minute impurities and large particles get trapped in the sludge blanket or are consumed by the microbial activity of the reactor.

iv) Conductivity

The samples were collected from sample port 1 and the values are shown in table V

TABLE V

CONDUCTIVITY VALUES OF EFFLUENT SAMPLE

Days	Conductivity (mS/ppt)	Percentage removal
14	203.85	17.83
28	161.64	34.84
42	84.71	65.85
56	38.42	84.51

The dissolved salts in the influent waste water was the reasons for high conductivity. From the results obtained it was found that the dissolved salts started decreasing steeply from 28th day to 422nd day. After that a slow increase in conductivity can be seen.

v) Total Dissolved Solids (TDS)

The effluent sample was taken from sample port 1 and values are given in table VI

TABLE VI

TOTAL DISSOLVED SOLIDS IN EFFLUENT WATER

Days	TDS (mS/ppt)	Percentage removal
14	968.44	16.8
28	684.43	41.2
42	158.42	76.39
56	163.07	85.99

Half of the dissolved solids were removed in the initial days itself and on the successive days gradual increase in removal took place and it had reached a maximum value of 95.99 % removal in the dissolved salts from the influent.

vi) Biochemical oxygen demand (BOD)

The BOD samples were taken from sample port 1 and the values is shown in table VII

Days	Sampleport 1(mg/L)	Percentage removal
14	276	23.05
28	149	48.6
42	97	72.9
56	79	77.95

TABLE VII BOD

VALUES OF EFFLUENT SAMPLE

In the initial stage there was only 23.05 % removal took place. It was due to the fact that dense granules were not formed in the initial stages but upon time sludge started maturing at the removal percentage has increased from 58 to 77 % on 56th day.ie. it has removed round 78 % of BOD from Waste water.

vii) Chemical oxygen demand (COD)

Effluent sample was taken from sample port 1 and tha values are shown in table VIII

Table VIII

COD VALUES OF EFFLUENT SAMPLE

Days	Sample port 1(mg/L)	Percentage removal
14	345	24.28
28	232	46.21
42	126	76.29
56	94	82.38

In the initial stage there was only 24 % removal took place. Same as in case of BOD, dense granules were not formed in the initial stages but upon time sludge started maturing and the removal percentage has increased from 46.21 to 82.38 % on 56th day.ie. it has removed round 82.3 % of BOD from waste water.

viii) Dissolved oxygen (DO)

Effluent sample was taken from sample port 1 and the values are shown in table IX

TABLE IX

DO VALUES OF EFFLUENT SAMPLE

Days	Sample port 1(mg/L)
14	1.1
28	0
42	0
56	0

As anaerobic condition was prevailing in the reactor dissolved oxygen content depleted from waste water. So, the effluent need post treatment such as aeration treatments for the restoration of dissolved oxygen.

ix) Chloride

Effluent sample was taken from sample port 1 and the values are shown in table X

TABLE X

CHLORIDE VALUES OF EFFLUENT SAMPLE

Days	Sample port 1(mg/L)	Percentage removal
14	1.79	20.68
28	1.01	54.28
42	0.56	75.29
56	0.424	81.26

In the initial stage there was only 20.68 % removal took place. Dense granules were not formed in the initial stages but upon time sludge started maturing and the removal percentage has increased from 54.28 to 81.26 % on 56th day.ie. it has removed round 82 % of Chloride from waste water.

x) Microbe count

Effluent sample was taken from sample port 5 and the values are shown in table XI

TABLE XI

MICROBE CONTENT IN EFFLUENT SAMPLE

Days	Sample port 1(CFU/ml)
14	27×10^6
28	29×10^6
42	24×10^6
56	19×10^6

Fig .6 Microbe content in effluent sample V/s No of days

Since the reactor was operated in anaerobic conditions, without any supply of fresh sewage, the microbe concentration decreases with time in the absence of organic food. In a full scale operating treatment unit, there is a continuous supply of raw sewage and hence microbe concentration remains in equilibrium.

C. *Methane Collection*

Less quantity of methane was produced from the laboratory scale UASB reactor. The methanogenetic bacteria is active in a pH range of 6.7 to 7.4 and that pH was achieved in the reactor from 48 to 56 days. So, we need a daily alkalinity addition for to maintain a pH level of 6.7 to 7.4 inside the reactor.

D. Discussions

i) General effluent standards

The BOD (3 days at 28°C) of effluent should be less than 30 mg/L if it is to be discharged to the inland surface water [As per E (P) rules, schedule VI part A]. The BOD (3 days at 28°C) of effluent should be less than 100 mg/L, if it is to be used for land irrigation. [As per E (P) rules, schedule VI part A].The waste water after treatment can be used for land irrigation as it has only 79 mg/l of BOD [As per E (P) rules, schedule VI part A].The COD value as per standards for inland surface should be within 250mg/l. Treated waste water has a COD value of 94 so it can be used for inland surface .pH value should be between 5.5 -9 for Inland surface water, Public Sewers Land, for irrigation and Marine coastal areas. The treated water has a pH of 7.46. So it can be used for all these purposes. Total residual chloride content as per E(P) rule is 250 mg/L.So treated water has chlorine content of 0.424mg/L which is within permissible limit of discharge The value of DO was zero in the effluent sample. So, post treatments such as aeration of waste water should be done to restore the oxygen content. Also the microbial content is to be removed by disinfection.

IV. CONCLUSION

The physicochemical and biological parameters of waste water quality are experimented and found out and design of lab scale reactor and design of proposed UASB reactor was done. Treated effluent taken from the UASB model shows following characteristics:pH of effluent increased with time and ranges from 4.4 to 7.6.Turbidity of effluent decreased with time and it has a percentage removal of 72.4.Conductivity of effluent decreased with time and it has a percentage removal of 84.51.TDS of effluent decreased with time and it has a percentage removal of 85.99.BOD of effluent decreased with time and it has a percentage removal of 77.95.COD of effluent decreased with time and it has a percentage removal of 82.38.Chloride of effluent decreased with time and it has a percentage removal of 81.26.All the values were within permissible limits of discharge except DO.

Methane gas was also collected from the reactor. If the pH was maintained at a range of 6.7, methanogenetic bacteria will be active and more methane can be collected. It can be achieved by the daily addition of standard $CaCO_3$. So, this treatment method is suitable for the treatment of waste water produced from M. Dasan Institute of Technology campus at a temperature range of 28 to 34 ^{0}C. The effluent parameters were within the permissible limits of discharge, so it can be directly discharged into the lands for irrigation purposes as it has high nutritional value and the biogas collected from the reactor can be used as an energy source. Along with this the treated water can be used for recharging ground water as the ground water level of our college is very low and in summer season, water scarcity is a major problem. The dissolved oxygen content can be increased by post treatment methods such as aeration.

From the design, it’s obvious that there is onlysmaller reactor volume required for the construction of the reactor. Hence minimum land area is required for the treatment of waste water and thereby cost of construction and cost of land will be economical. Also, sludge produced is very less and thereby sludge handling process and disposal cost are greatly reduced.

A.Scope for future study

Experiment was done within limited time period of 56 days. It can be extended for better results. With time the sludge gets more denser and the efficiency may be increased. Therefore, variation in removal percentage may occur in this thesis. The depth is to height ratio is taken as D:H =1:14, value taken from the journal for fabrication. This value may be changed for analyzing the performance of the reactor.The study can also be extended by including aeration process to increase the DO values. By maintaining pH at a range of 6.7 ,the maximum gas collected from a specific volume of waste water can be analyzed. The starter used for analysis was cow dung with nutrients supplied during acclimatization period. This starter can be substituted with sludge from other treatment plants and can be analyzed to find the performance.

REFERENCES

[1]. **A.A.Azimi** and **M.Zamanzadeh** (2004), Determination of design criteria for UASB reactors as a wastewater pretreatment system in tropical small communities, *International Journal of Environmental Science & Technology*, Vol. 1, No. 1, pp. 51- 57, Spring 2004

[2]. **Adrianus C, Van Haandel, Paula Frassinetti ,Catunda**and **GatzeLettinga**, The use of UASB reactor for industrial and domestic waste water treatment, *Biotechnology Bioengineering* 22: 699.–734.

[3]. **Adrianus C, Van Haandel, Paula Frassinetti ,Catunda**and **GatzeLettinga**, Application of the UASB reactor for sewage treatment, *Water Science and Technology* 44: 157-176.

[4]. **Bitton G.** (2005), Wastewater Microbiology, *Wiley Series in Ecological and Applied Microbiology). Third Edition*

[5]. **Das S.** and **Chaudhari S.** (2009), Improvement in Biomass Characteristics and Degradation Efficiency in Modified UASB Reactor Treating Municipal Sewage: A Comparative Study with UASB Reactor, *Asia-Pacific Journal of Chemical Engineering* 4: 596-601

[6]. **Delia Teresa Sponza**(2001), Performance of upflow anaerobic sludge blanket (UASB) reactor treating wastewaters containing carbon tetrachloride, *World Journal of Microbiology & Biotechnology* 17: 839–847, 2001. 839 - 2001

[7]. **Haandel A. C and Lettinga G.** (1994), Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate, *John Wiley & Sons, Chichester, England.*

[8]. **Hideki Harada, Shigeki Uemura, Ann-Cheng Chen** and**Jayabalasingham Jayadevan** (1996), Anaerobic treatment of a recalcitrant distillery wastewater by a thermophilic UASB reactor, *Bioresource Technology*, Volume 55, Issue 3,1996, Pages 215-221, ISSN 0960-8524

[9]. **Hina Rizvi, Nasir Ahmad, Farhat Abbas, Iftikhar Hussain Bukhari , Abdullah Yasar , Shafaqat Ali, Tahira Yasmeen and Muhammad Riaz** (2015), Start-up of UASB reactors treating municipal wastewater and effect of temperature/sludge age and hydraulic retention time (HRT) on its performance, *Arabian Journal of Chemistry (2015)* 8, 780–786

[10]. **Hulshoff L., Lens P., Castro S** and**Lettinga G.** (2004), Anaerobic Sludge Granulation, *Water Research 38: 1376-1389.*

[11]. **Icela Dagmar Barceló-Quintal, Mónica Liliana Salazar-Peláez, Julisa García-Albortante1** and **María Teresa Garza-González** (2005), Performance of an UASB Reactor at Lab-Scale Treating Domestic Wastewater with Low Concentrations of Copper, *British Journal of Applied Science & Technology* 7(5): 456-466, 2015, Article no. BJAST.2015.164 ISSN: 2231-0843.

[12]. **Jens E. Schmidt Birgitte K.** and**Ahring** (1996), Granular sludge formation in upflow anaerobic sludge blanket (UASB) reactors, *Biotechnology Bioengineering.* 1996 Feb 5;49(3):229-46.

[13]. **K. Karthikeyan** and **J. Kandasam** (2004), Upflow anaerobic sludge blanket (UASB) reactor in wastewater treatment(UASB) Reactor in Wastewater Treatment, *Encyclopedia of Life Support Systems(EOLSS)*

[14]. **K. Kaviyarasan** (2014), Application of UASB Reactor in Industrial Wastewater Treatment – A Review, *International Journal of Scientific & Engineering Research*, Volume 5, Issue 1, January-2014 584, ISSN 2229.

[15]. **L. A. S. Miranda1, J. A. P. Henriques and L. O. Monteggia** (2005), A full-scale UASB reactor for treatment of pig and cattle slaughterhouse wastewater with a high oil and grease content, *Brazilian Journal of Chemical Engineering* Vol. 22, No. 04, pp. 601 - 610, October - December 2005, ISSN 0104-6632.

[16]. **Liu Y.** and **Tay J.H** (2004), State of the Art of Biogranulation Technology for Wastewater Treatment, *Biotechnology Advances* 22: 533–563.

[17]. **Metcalf and Eddy,Inc** (2003) Waste water Engineering Teatment and its resuse,*Fourth edition.*

[18]. **McHugh S., O.'Reilly C., Mahony T., Colleran E.** and**O.'Flaherty V.** (2003), Anaerobic Granular Sludge Bioreactor Technology, *Reviews in Environmental Science and Biotechnology* 2: 225. –245.

[19]. **Nang Seng Moe** and**Ei Mon Aung (**2014), A laboratory scale up-flow anaerobic sludge blanket (UASB) reactor for distillery wastewater treatment, ISSN 2319-8885 Vol.03, Issue.20 september-2014, pages:4050-4055.

[20]. **Rodríguez-Gómez, Raúl** and **Moreno, Luis.** (2010), Modeling of substrate degradation and microorganism growth in an UASB reactor. 76-80. 10.1142/9789814295048-0016.

[21]. **S.K. Narnoli**and **Indu Mehrotra** (1997), Sludge blanket of UASB reactor: Mathematical simulation, *Water Researc*h, Volume 31, Issue 4,1997, Pages 715-726, ISSN 0043-1354.

[22]. **Seghezzo L, Guerra RG, González SM, Trupiano AP, Figueroa ME, Cuevas CM, Zeeman G** and **Lettinga G.** (2002), Removal efficiency and methanogenic activity profiles in a pilot-scale UASB reactor treating settled sewage at moderate temperatures, *Water Science and Technology*, 2002;45(10):243-8.

[23]. **Yoda M.** and **Nishimura S.** (1997), Controlling Granular Sludge Flotation in UASB Reactor, *Water Science and Technology* 36: 165-173.

[24]. **Z. A. Bhatti, F. Maqbool, A. H. Malik1** and **Q. Mehmood** (2006) UASB reactor startup for the treatment of municipal wastewater followed by advanced oxidation process, ISSN 0104-6632.

.