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Original Research Paper

Comparative Study of Different Media in the Treatment of Sago Wastewater using HUASB Reactor

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ABSTRACT

Processing of sago generates enormous quantities of high strength wastewater requiring systematic treatment prior to disposal. The present study is an attempt to compare the three media such as polypropylene ring, rosette filter and PVC carrier, in the treatment of sago wastewater using Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactor. Three HUASB reactors each with a volume of about 4.7 L and effective volume of 4.2 L was operated and packed with the above three media separately in each reactor along with the effective microorganisms (EM) solution added in 1:1000 ratio of reactor volume. The initial OLR (Organic Loading Rate) range was about 0.75 kg.COD/m^3.day and further increased. Various effluent characteristics like pH, COD, total suspended solids (TSS), VFA, alkalinity and biogas production were studied until the attainment of steady state. The pH of treated effluent during steady state condition was almost neutral for all the three reactors even though the influent had an acidic pH. The optimum HRT was found to be 10h for both polypropylene media and PVC carrier media and 8h for rosette filter media. The maximum COD and TSS removal efficiencies for the reactor packed with polypropylene were as high as 88% and 77% in HUASB reactor in the presence of effective microorganisms with an OLR of 9 kg.COD/m^3.day. And for the reactor packed with rosette filter, the maximum COD and TSS removal efficiencies were 84% and 76% in HUASB reactor in the presence of effective microorganisms with an OLR of 9 kg.COD/m^3.day. Similarly, for the reactor packed with PVC carrier media, the maximum COD and TSS removal efficiencies were 86% and 78% in HUASB reactor in the presence of effective microorganisms with an OLR of 9 kg.COD/m^3.day. The maximum gas production for these three reactors packed with polypropylene ring, rosette filter and PVC carrier media were 2.8 L/d, 0.66 L/d and 1.7 L/d respectively in the presence of effective microorganisms. It is found that from an overall assessment, the HUASB reactor packed with polypropylene ring has proved superior in its performance compared to the HUASB reactor with other packing media.

INTRODUCTION

Sago industry is one of the major small scale sectors in India and over 800 units are located in the southern state of Tamilnadu. Most sago industries produce large amounts of effluent with highly polluting loads. Discharging of the effluent into the environment causes considerable environmental impact due to their high biodegradable organic materials and compounds which are toxic to aquatic organisms. Many researchers have been developing techniques for the biological treatment of sago effluents. The biological wastewater treatment offers one of the major steps in eliminating biodegradable organic matter present in sago wastewater. Biological treatment offers a better conservation of energy by regenerating fuel from the wastewater (Lettinga et al. 1991). Various anaerobic technologies including conventional anaerobic treatment (Pescod & Thanh 1977) and fluidized beds (Saravanane et al. 2001) have been used to treat sago wastewater. Anaerobic digestion can be operated in a wide range of temperatures (Van Lier et al. 1997). Published works indicate that most of the negative aspects of high rate anaerobic digestion can be overcome by restricting the supporting material to the top 25 to 30% of the reactor volume (Guiot & Van den berg 1985). An anaerobic process is considered more suitable to treat high strength organic effluents (Kim et al. 2002). For digestion systems, which incorporate solids recycle, the SRT will be greater than the HRT and the OLR indicates both the anaerobic digester volume utilisation efficiency and the overall process loading. There are many high-rate bioreactors which have uncoupled the liquid retention, and biomass retention has made treatment process more efficient

(Kennedy & Barriault 2007). The Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactor is one of high rate anaerobic reactors (HRAR) which is a combination of the positive features of both the Anaerobic Filter (AF) and Upflow Anaerobic Sludge Blanket (UASB) reactor. HUASB reactor needed lesser time for start-up and showed better removal efficiencies as compared to AF reactor using the same substrate of wastewater (Rajakumar & Meenambal 2008). Although hybrid reactor design is expected to work efficiently without granular sludge, it is desirable to cultivate granular biomass (Tilche & Vieira 1991).

Packing material is used for the growth of microorganisms in the attached manner (Elmitwalli et al. 2000). New technologies are being produced to optimize the anaerobic treatment of wastewater, one of these new technologies being proposed is the use of Effective Microorganisms (EM). A microbial inoculant containing many kinds of naturally occurring beneficial microbes called 'Effective Microorganisms' has been used widely in nature and organic farming (EI Karamany et al. 2001). EM is a mixture of group of organisms that has a reviving action on humans, animals and the natural environment (Higa & Parr 1994). Many different organisms live within the wastewater itself, assisting in the breakdown of certain organic pollutants. The basis for using these EM species of microorganisms is that they contain various organic acids due to the presence of lactic acid bacteria, which secrete organic acids, enzymes, antioxidants and metallic chelates (Higa & Chinen 1998).

MATERIALS AND METHODS

Composition of wastewater: The sago mill wastewater sample was analysed to determine some of its general characteristics. The seed sludge was collected from an anaerobic reactor of sago mill wastewater, and was used for the inoculation in the HUASB reactor. This was used as the inoculum because the sludge had sufficient number of acetogenic and methanogenic bacteria (Bischofsberger et al. 2005).

Reactor set-up: Three lab scale Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactors each of 4.7 litres capacity were fabricated for lab scale studies, with effective volume of 4.2 litres. They were fabricated using transparent acrylic fibre sheet with a diameter of 10 cm and a height of 60 cm and with a wall thickness of 3 mm. Four sampling ports were provided along its length at equal distance. Inlet end opens towards the bottom of the reactor, so the feed strikes at the bottom. An outlet was provided at the top, which was connected to the effluent tank. On the top of the reactor a gas solid separator was provided to separate gas and solids raised due to the upward movement of the feed. The gas outlet was connected through rubber tubing to the liquid displacement system to measure the gas production. The amount of gas produced is equal to the amount of liquid displaced and hence gas produced can be measured at regular intervals of time. These reactors were operated at mesophilic temperature (27±5°C). The excess suspended solids (SS) in the reactor are wasted periodically, and hence a constant SS value was maintained in the reactor. The wastewater comprising substrates, glucose, plus balanced nutrients and alkalinity were fed in the reactor using a peristaltic pump.

Inlet and outlet distribution systems: At the bottom, the feed inlet pipe of 8mm diameter was provided which was connected to a peristaltic pump, through ¼ inch check valve and silicon tubing arrangement, for pumping the feed. This 8mm diameter was enough to avoid clogging in the inlet pipe due to biomass in the feed. The inlet pipe opens towards the bottom of the reactor, so the feed strikes at the bottom and helps in uniform mixing in the system. Just over the packing media a collection tube of ¼ inch was connected to collect the processed effluent.

Sampling ports: In order to determine the sludge concentration profile over the reactor height, the reactor was fixed with sampling ports made up of brass pipe of ¼ inch was connected below the packing.

Packing media: Fixed screens at a gap of 15cm and a distance of 14.5cm from the top of the reactor were fixed. The gap between these screens was filled with packing media. Three types of the filter media used in the study were polypropylene rings, rosette filter and PVC carrier.

***Polypropylene rings*:** Usually various filter media of different sizes range from 12 to 55 mm in diameter and their surface area of about 600 m^2/m^3 of the reactor volume. A filter medium of height 15 cm made of polypropylene rings was provided at the middle of the first reactor. About 16 rings were packed in the reactor for consistency. The surface area of each ring was $24.25m^2/m^3$ and the total surface area occupied by the packing was $388m^2/m^3$.

***Rosette filter media*:** Rosette filter media having a surface area of 500 m^2/m^3 and thickness of 26 mm and average diameter of 4.5 cm was used in the second reactor

***PVC carrier media*:** The gap between these screens was filled with packing media of PVC rings having inner diameter of 20 mm and outer diameter of 22 mm. Porosity of the biofilm is 80% and the specific surface area is $345m^2/m^3$.

Gas Collection Set-Up: Gas is collected through the gas vent opening provided at top of the reactor. Amount of gas displaced is collected in the brine bottle. This collected gas will cause rise in water level in the water displacement jar

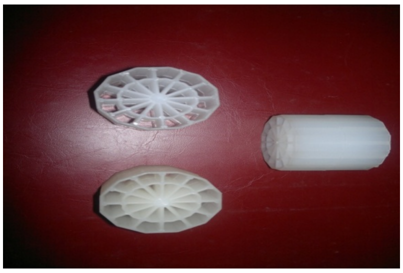

Fig.1: Polypropylene ring.

Fig.2: rosette filter media.

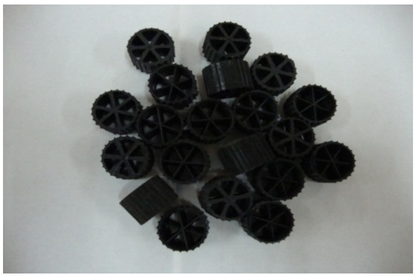

Fig. 3: PVC carrier media.

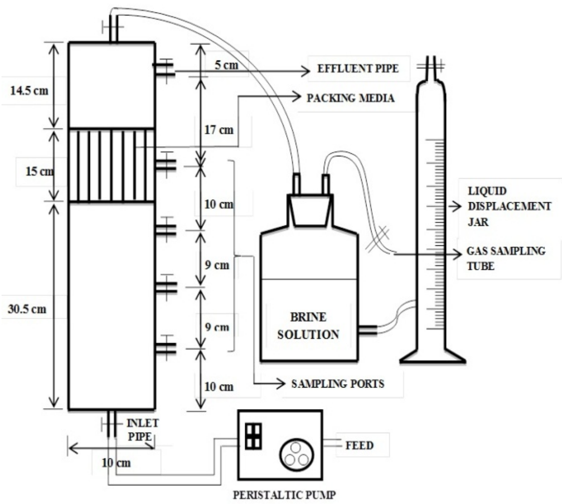

Fig. 4: Schematic diagram of hybrid up-flow anaerobic sludge blanket reactor.

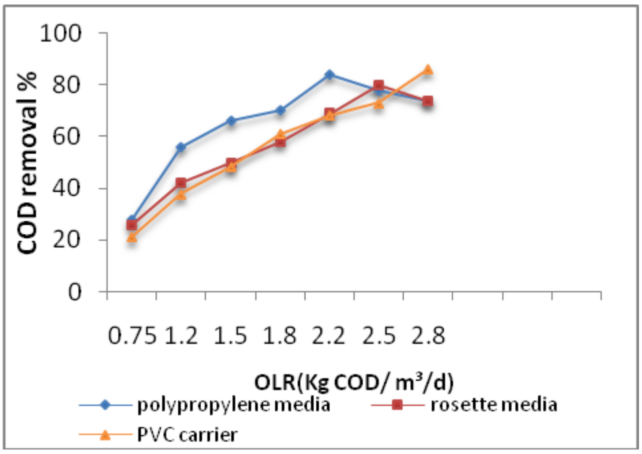

Fig. 5: Performance of COD removal at different OLR during start-up of HUASB reactor.

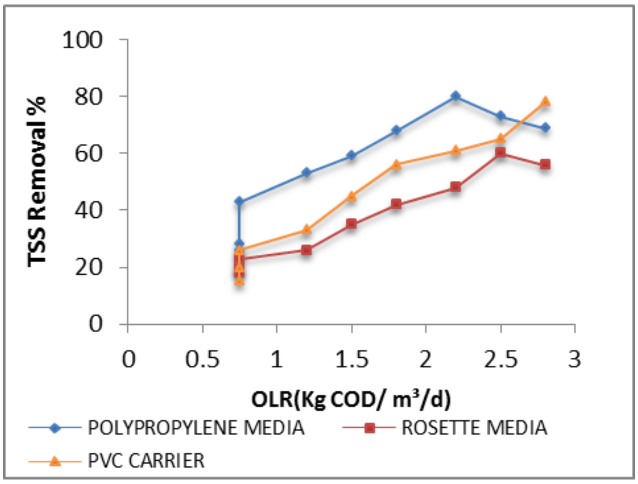

Fig. 6: Performance of TSS removal at different OLR during start-up of HUASB reactor.

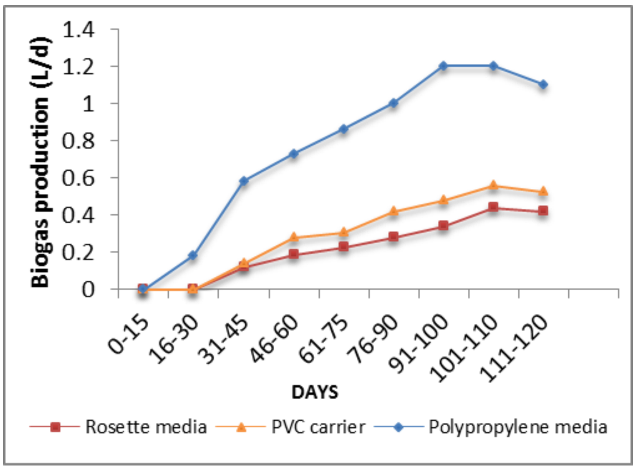

Fig. 7: Biogas production during start-up of HUASB reactor.

Table 1: Construction details of each HUASB reactor.

Sl. No.	Particulars	Specification
1.	Total volume	4.7 litres
2.	Working volume	4.2 litres
3.	Packing material	Polypropylene ring, Rosette media and PVC carrier media
4.	Inlet height from the bottom	0.5 cm
5.	Outlet height from the bottom	55 cm
6.	Packing media depth	15 cm
7.	No of sampling port	4

Table 2: Characteristics of Sago Wastewater.

S.No.	Characteristics	Observed Result(mg/L)
1.	pH	4.2-4.6
2.	Colour	Milky White
3.	TS	16300-16500
4.	TDS	8060-14260
5.	TSS	2240-8240
6.	VS	13570-14580
7.	COD	3000-5000
8.	VFA	440-450
9.	Chlorides	990-1010
10.	Acidity	900-1000

indicating the amount of gas that has been produced in the reactor.

Start-up phase of the reactor: For most wastewaters, the start-up of an anaerobic treatment plant is a time consuming and sometimes rather difficult process, due to the fact that a large bacterial mass, adapted to the particular characteristics of the wastewater, has to develop. During this start-up period the danger of overloading exists and if this occurs, acid fermentation can become predominant over methanogenic fermentation, resulting in souring of the reactor contents. Since the industrial wastewater lacks the presence of bacterial populations necessary for anaerobic digestion, an inoculum is required for the reactor start-up

The start-up period of an anaerobic reactor is proportional to the concentration of the microbial population. Rate of start-up depends on the type of inoculum, the type and strength of waste, level of volatile acids maintained, etc. Normally, reactors are started by acclimatizing the biomass with glucose. Glucose is a readily degradable, soluble carbohydrate that does not, itself, limit the rate of anaerobic biodegradation. It produces readily measurable intermediary metabolites in anaerobic digestion, and is commonly used as a carbonaceous substrate in many experimental studies. Glucose was, therefore, used as a substrate during the initial acclimatization phase of this study, and during the latter stages of which it was gradually replaced with sago industry wastewater.

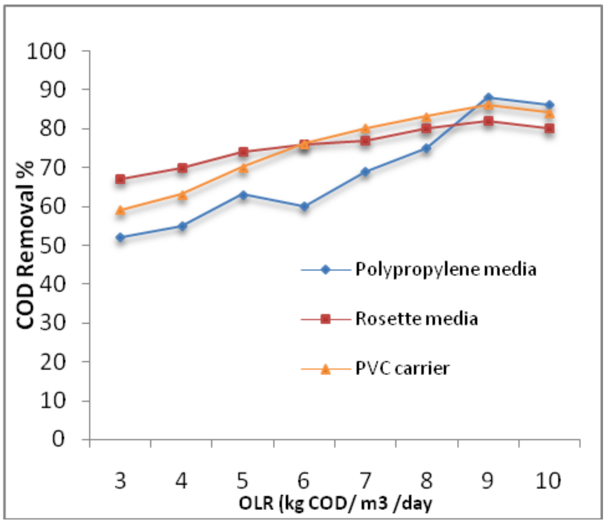

Fig. 8: Performance of COD removal at different OLR after start-up of HUASB reactor.

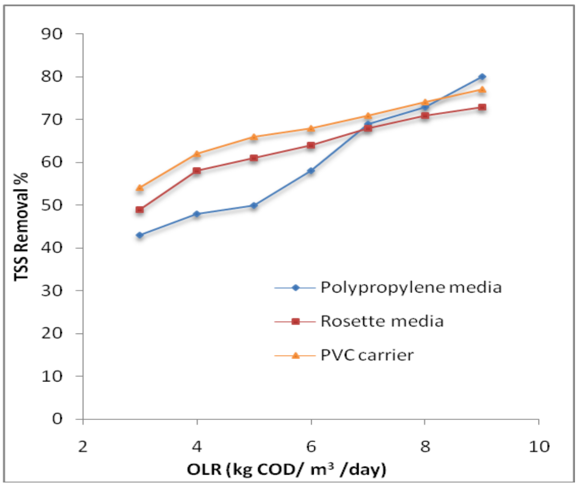

Fig. 9: Performance of TSS removal at different OLR after start-up of HUASB reactor.

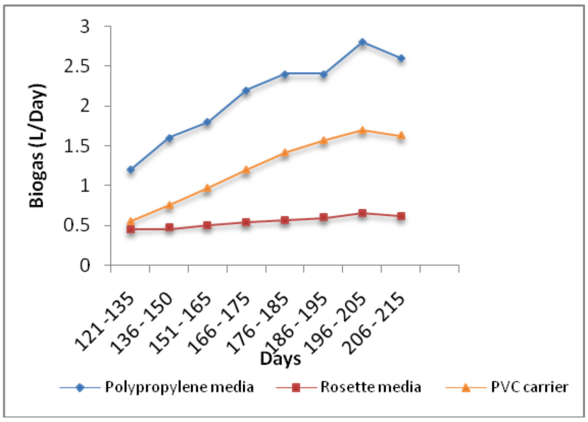

Fig. 10: Biogas production after start-up of HUASB reactor.

Anaerobic seed culture collected from a reactor treating sago mill wastewater was used for the inoculation in the HUASB reactor. The reactor was operated in a continuous mode of operation. The feed composition of the HUASB reactor was as follows: Glucose-1.0 g/L, NH_4Cl-800 mg/L and KH_2PO_4-200 mg/L. COD:N:P ratio was maintained around 300:10:1. The outlet pH was found to be in the range of 7.5-7.6 indicating an active metabolism of the methanogens (Hwang et al. 2004). The best operation of anaerobic reactors can be expected when the pH is maintained near neutral.

Operation and monitoring: Operation and monitoring will be done in order to find out the feasibility of the hybrid up-flow anaerobic sludge blanket (HUASB) reactor. In the operation phase, the reactor will be operated in continuous mode for different loading rates. The pH of the reactor will be maintained near neutral by adding necessary amount of base or acid solution. The reactor was closely monitored for parameters like pH, Volatile Fatty Acid (VFA), COD, biogas production and its methane content, and alkalinity during entire operation periods. The samples were collected from the outlet provided in each reactor and analysed immediately after collection. The flow rate, pH of influent and effluent, and amount of gas generated were recorded daily. The parameters such as total and soluble COD, VFA and alkalinity were measured.

RESULTS AND DISCUSSION

Characteristics of sago wastewater: The sago mill wastewater sample was analysed to determine some of its general characteristics. The results obtained are given in Table 2

Characteristics of seed sludge: The seed sludge was collected from a reactor treating sago wastewater. It was then filtered to remove the large suspended particles. This seed sludge was then mixed with 500 mL of EM solution before feeding it into the reactor.

Start-up of the reactor: A laboratory scale study was conducted to investigate the performance of an HUASB reactor with different packing media for treating sago wastewater. The sago industry wastewater fed with an OLR of 0.75 kg COD/ m^3/d. All the three reactors were started with an initial OLR of 0.75 kg COD/ m^3/d and an HRT of 24 hrs, further it was increased by reducing the HRT to achieve the steady state condition. All the three reactors were closely monitored for pH, VFA, COD and biogas production. Start-up was completed at the end of 120 days. At this startup period the OLR was 2.8 kg COD/m^3/d for HUASB reactor in the presence of effective microorganisms.

Reactor operation during start-up: After start-up of the reactor with an initial OLR of 0.75 kg COD/ m^3/d, it was loaded with increasing OLR and reducing the HRT. At each OLR, the reactors were operated continuously so as to reach steady state conditions. Effluent pH and methane production remained relatively constant. The pH of the outlet stream during start-up days varied from 6-7 for HUASB and UASB reactors. This indicates that acid fermentation phase is always more rapid than that of methanogenic phase. The increase in pH was due to conversion of stronger VFA to weaker acids and the observed VFA level at the outlet was low. The alkalinity was increased in both the reactors when loading rates were increased.

All the three reactors were maintained for a period of 15 days in the same loading rate and removal efficiencies in terms of COD were 84%, 80% and 86% for reactors with polypropylene media, rosette filter media and PVC carrier media respectively. Similarly removal efficiencies of TSS were 80%, 60% and 78% for reactors with polypropylene media, rosette filter media and PVC carrier media respectively. Comparative analysis of COD removal and TSS removal efficiencies of reactors packed with polypropylene media, rosette filter media and PVC carrier media during start-up days are shown in Figs. 5 and 6. During the stepped increase of OLR, the removal efficiency of TSS and COD gradually increased.

The gas production increased with increased OLR. The maximum gas production of 1.8 L/d was achieved for HUASB reactor with polypropylene ring in the presence of effective microorganism. Similarly the gas production of 0.4 L/d and 0.56 L/d was recorded for HUASB reactor packed with rosette filter media and HUASB reactor with PVC carrier media respectively. All the three reactors experienced increases in biogas production during the startup period which is shown in Fig. 7. From these comparative analyses, it is found that reactor packed with polypropylene rings was having high COD and TSS removal efficiencies and also yields a high biogas production of 1.8 L/d during start-up period itself.

Performance of HUASB reactor-after startup: After achieving the start-up at an OLR of 2.2 kg/m^3/day the reactor was further loaded with increasing OLR to assess the optimum loading rate of the reactor. The HUASB reactor in the presence of EM start up took 120 days. Increase in pH was achieved during the startup period in both the reactors but in HUASB in the presence of EM the highest pH was attained on 90^{th} day of reactor operation. During the treatment phase all the three reactors attained almost neutral pH level of 7.4, 7,22 and 7.13 respectively. Neutral pH level in the treated effluent was the indication of healthy anaerobic environment and satisfactory methanogenic activity.

The maximum COD and TSS removal efficiencies were as high as 84% and 80% in HUASB reactor with polypropylene ring as packing material as compared with other HUASB reactors with rosette and PVC carrier as packing media, which experienced 84% and 76% and 86% and 78% respectively during the steady state period as shown in Figs. 8 and 9. The maximum COD removal efficiency in these three reactors was due to the formation of well settling granules.

The biogas production with respect to time period for all the three reactors is shown in Fig. 10. The gas production increased with increased OLR. The maximum gas production in the presence of effective microorganisms was 2.8 L/d, 0.66 L/d and 1.7 L/d for HUASB reactor packed with polypropylene, rosette and PVC carrier respectively.

CONCLUSION

The study concludes that HUASB reactor with polypropylene ring as packing medium in the presence of effective microorganisms is superior and a promising technology as compared to other HUSAB reactor with rosette and PVC carrier in the treatment of sago industry wastewater. The optimum HRT for both HUASB reactor with polypropylene ring and PVC carrier is 10h, and for HUASB reactor with rosette carrier is 8h. The maximum COD and TSS removal efficiencies were as high as 88% and 80% in HUASB reactor with polypropylene ring as packing media in the presence of (EM) with an OLR of 9 kg.COD/m^3/day was achieved, and the rate of removal of total solids increased with an increase in organic loading rate. In 10h HRT, the maximum 85% of COD removal, 78% of total solids removal, and biogas production was 1.7 L/d with an OLR of 9 kg COD/m^3d. The reactor with packing material rosette filter media was also effective in COD removal and biogas production, but it is not much favourable compared to other packing media. In 8h HRT, the maximum COD removal and TSS removal efficiencies were 84 % and 76 % respectively with considerable amount of biogas production of 0.66 L/d. The optimum OLR was found to be 9 kg COD/m^3 d for maximum gas production and COD removal. Thus, the present study infers that the packing media of polypropylene rings present in the HUASB reactor was able to retain high biomass concentration without any serious sludge wash out even at higher organic loading rates.

REFERENCES

Bischofsberger, W., Dichtl, N., Rosenwinkel, K.H., Seyfried, C. F. and Böhnke, B. 2005. Anaerobtechnik, 2nd Edition, Springer-Verlag, Heidelberg, Germany.

EI Karamany, H.M., Naser, A.N. and Ahmed, D.S. 2011. Upgrading upflow anaerobic sludge blanket using effective microorganisms. IJETSE International Journal of Emerging Technologies in Science and Engineering, 5(2).

Elmitwalli, T.A., Van Dun, M., Bruning, H., Zeeman, G. and Lettinga, G. 2000. The role of filter media in removing suspended and colloidal particles in an anaerobic reactor treating domestic sewage. Bioresource Technology, 72: 235-242.

Guiot, S.R. and Van den Berg, L. 1985. Performance of an upflow anaerobic reactor combining a sludge blanket and a filter treating sugar waste. Biotechnology, Bioenergy, 27: 800-806.

Higa, T. and Parr, J. F. 1994. Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Center, Atami, Japan.

Higa, T. and Chinen, N. 1998. EM Treatments of Odor, Waste Water, and Environmental Problems. College of Agriculture, University of Ryukyus, Okinawa, Japan.

Hwang, M. H., Jang, N. J., Hyun, S. H. and Kim, I. S. 2004. Anaerobic bio-hydrogen production from ethanol fermentation: The role of pH. Journal of Biotechnology, 111(3): 297-309.

Kennedy, K. and Barriault, M. 2007. Effect of recycle on treatment of aircraft de-icing fluid in an anaerobic baffled reactor. Water SA, 31(3): 377-384.

Kim, M, Ahn, Y. and Speece, R.E. 2002. Comparative process stability and efficiency of anaerobic digestion; mesophilic vs. thermophilic. Water Res., 36: 4369-4385.

Lettinga, G., Field, J.A., Alvarez, R.S., Vanlier, J.B. and Rintala, J.B. 1991. Future perspectives for the anaerobic treatment of forest industry wastewaters. Water Sci. Technol., 24: 91-102.

Pescod, M.B. and Thanh, N.C. 1977. Treatment alternatives for wastewaters from the tapioca starch industry. Water Sci. Technol., 9(3): 63-574.

Rajakumar, R. and Meenambal, T. 2008. Comparative study on start-up performance of HUASB and AF reactors treating poultry slaughterhouse wastewater. Int. J. Environ. Res., 2(4): 401-410.

Saravanane, R., Murthy, D.V.S. and Krishniash, K. 2001. Anaerobic treatment and biogas recovery for sago wastewater management using a fluidized bed reactor. Water Sci. Technol., 44(6): 141-147.

Tilche, A. and Vieira, S.M.M. 1991. Discussion report on reactor design of anaerobic filters and sludge bed reactors. Water Science Technology, 24: 193-206.

Van Lier, J. B., Rebac, S. and Lettinga, G. 1997. High-rate anaerobic wastewater treatment under psychrophilic and thermophilic conditions. Water Science and Technology, 35(10): 199-206.