Pilot Up-flow Anaerobic Sludge Blanket Reactor and High Rate Algal Pond for Complete Sewage Treatment

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Background

- Traditionally, wastewater treatment has focused on pollution abatement, public health protection and environmental protection by removing biodegradable material, nutrients and pathogens.
- Wastewater recycling, reuse and resource recovery can be a very good approach to conserve water particularly in areas of water shortage.
- Conventional sewage treatment processes involve high capital, maintenance and operational cost, huge energy requirements, which makes them unsuitable for use in developing countries.
- Energy efficient low-cost waste treatment systems are the best choice for such countries.
- Anaerobic treatment systems excel in such respect.
- UASB reactors are the most widely used high rate anaerobic sewage treatment process and several full scale reactors are in operation world-wide.

Need of Study

- Most of the successful applications of UASB reactors are to treat high strength industrial wastewaters.
- Sato et al. (2006) evaluated the treatment efficiency of the sixteen UASB reactor based sewage treatment plants on the Yamuna river basin in India and observed that none of the plants met the discharge standards.
- In order to improve the effluent quality up to disposal standards, polishing ponds with short retention time were used to treat the UASB effluent.
- Unfortunately, effluent quality did not follow the desired standard limits even after the polishing ponds.

Objectives

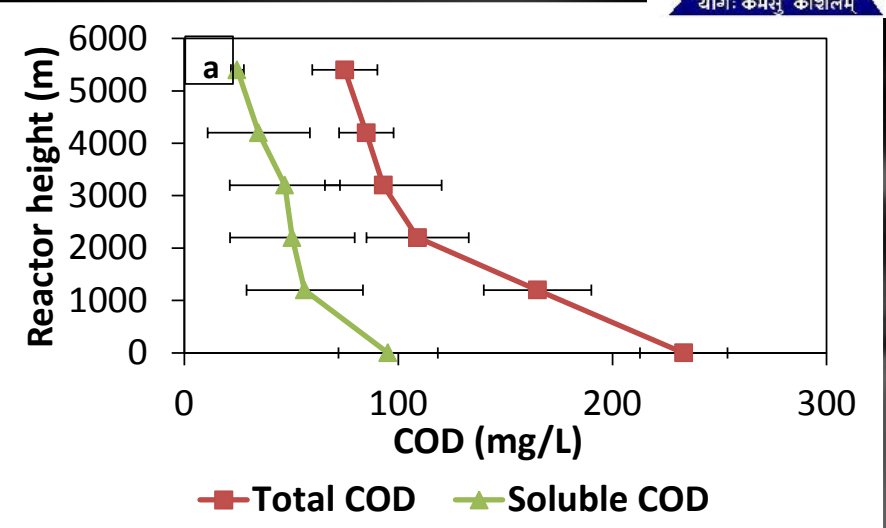
- Possibility of producing reusable quality treated wastewater by a combined UASB-HRAP system is explored.
- While UASB will help in organic matter removal, HRAP will abate nutrients and pathogens.
- The treated wastewater after UASB-HRAP can be used for landscape irrigation (parks, playgrounds, and school yards), fire protection, construction, ornamental fountains, recreational impoundments; in-building uses (toilet flushing) etc.

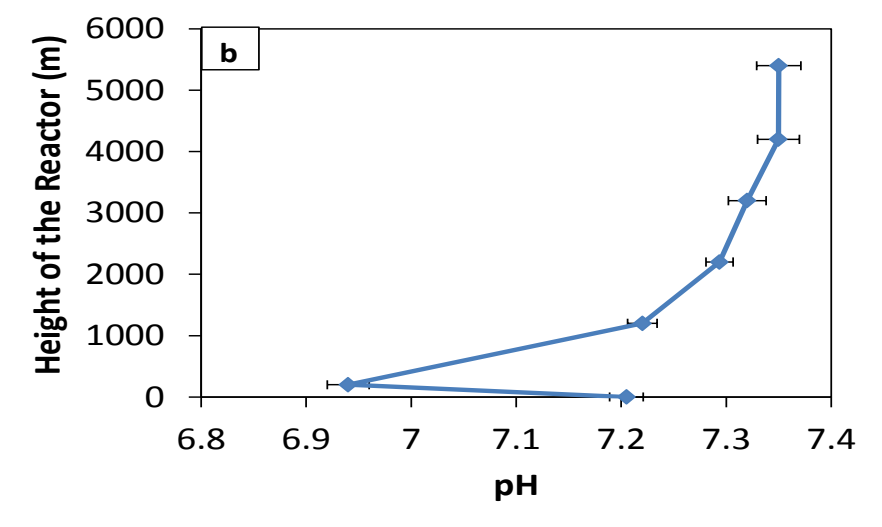
UASB-HRAP

The UASB reactor was having a height of 5.3 m and diameter of 5.6 m, which is followed by a 15.8 m long and 7.9 m wide HRAP.

General Performance of UASB reactor

- The UASB reactor was operated for a total of 250 days.
- COD removal efficiency kept on increasing with operation time, with a maximum soluble COD removal of 73 ± 6% and maximum total COD removal of 66 ± 10%, in the month of June.
- Average effluent COD throughout the entire range of operation was 75 ± 15 mg/L.
- Average gas production rate was 0.39 ± 0.10 m^3/kg COD removed.
- Methane content in the biogas was 68%.
- Average TSS and VSS in the effluent of the UASB reactor was 31 ± 17 mg/L and 20 ± 10 mg/L, respectively.



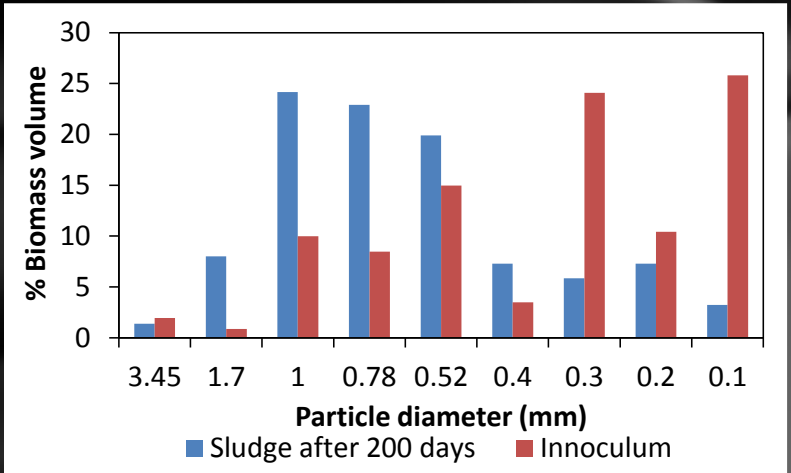


Monthly average of COD removal in the UASB reactor

Month	COD inlet (mg/L)	COD outlet (mg/L)	Total COD removal (%)	Soluble COD inlet (mg/L)	Soluble COD outlet (mg/L)	Soluble COD removal (%)
Nov	167 ± 30	123 ± 30	27 ± 12	110 ± 12	77 ± 12	30 ± 8
Dec	162 ± 30	79 ± 41	49 ± 26	94 ± 21	35 ± 7	63 ± 7
Jan	193 ± 26	98 ± 19	49 ± 9	95 ± 3	39 ± 1	59 ± 1
Feb	187 ± 61	76 ± 17	56 ± 16	78 ± 23	33 ± 13	57 ± 9
Mar	250 ± 61	100 ± 18	58 ± 12	101 ± 21	38 ± 7	63 ± 10
April	195 ± 49	71 ± 11	61 ± 11	83 ± 19	23 ± 2	70 ± 8
May	215 ± 44	78 ± 31	63 ± 14	91 ± 29	23 ± 3	72 ± 7
June	232 ± 60	75 ± 15	66 ± 10	95 ± 23	25 ± 3	73 ± 6

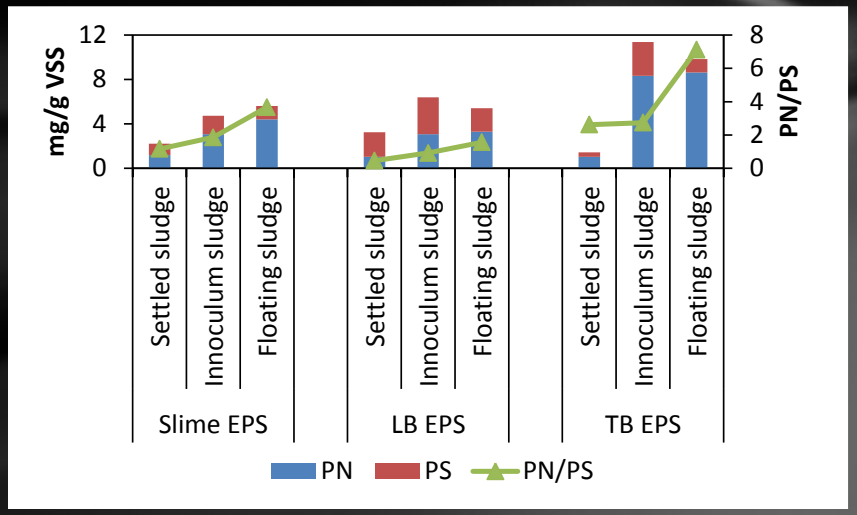
Biomass Granulation

- Good granular sludge (percentage of granules more than 50%, w/w) can be developed in UASB reactor if BGI is maintained in the range of 240 to 560.
- When the BGI was calculated initially with inoculum sludge concentration of 8 g/L, BGI was 185; however, with continued operation and increase in sludge concentration within the reactor the BGI value increased to an average of 280 and a maximum of 380, indicating a 50 – 60% possibility of granulation.
- 63.47% of the sludge inside the UASB reactor after 200 days of operation was granular sludge.
- Such percentage of granulation has not been reported while treating sewage in full scale UASB reactor earlier.
- SVI_5 and SVI_{30} of the sludge was 31 mL/g and 28 mL/g, respectively, after 200 days of operation of the pilot reactor.



Biomass Characterization

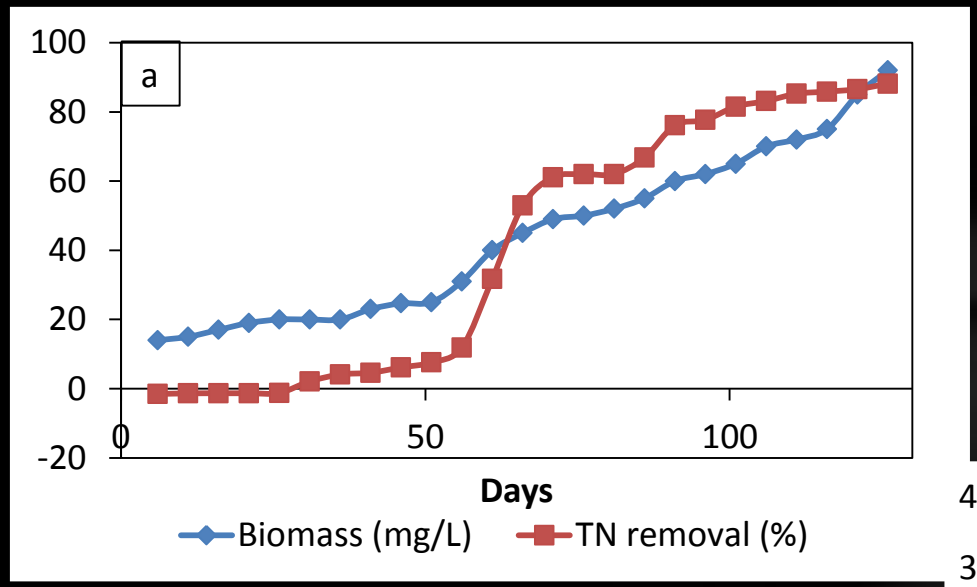
- The average VSS/SS ratio in the sludge was 0.56 and it was above 0.6 for the winter months.
- Lower biogas production rate was observed in the winter months from the reactor.
- Sludge collected had an integrity coefficient of 3.74%. Integrity coefficient should be less than 20% for good strength sludge.
- Total EPS content of the sludge collected from the bottom of the UASB reactor was 12.94 mg/g VSS.
- The ratio of proteins and carbohydrates in sludge is used to determine its strength, stability and settling ability, with a higher ratio indicating low strength granules with bad settling properties and poor stability

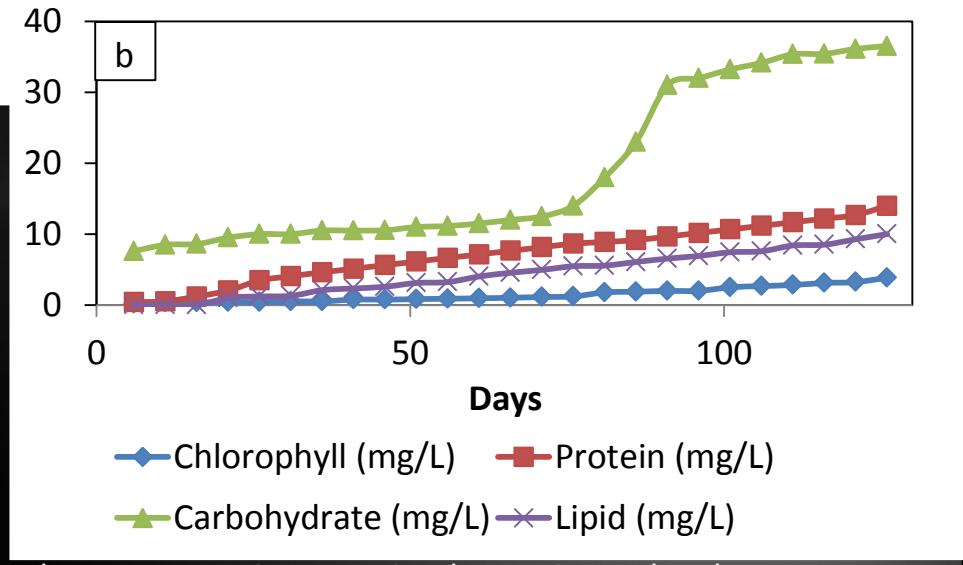


Performance of HRAP

- Start-up of the algal pond comprised of two steps based on the ammonium removal performance: lag phase (1 – 50 days) and propagation phase (still continuing).
- During this lag period a reduction of ammonium was observed, but only after one month of operation, before which an increase of ammonium ion was detected due to organic hindrance or self-degradation of nutrients in wastewater thus making it unavailable to species.
- Ammonia removal increased to 85.1 ± 2.4%. With influent ammonia nitrogen concentrations of 20 ± 3 mg/L the average effluent ammonia nitrogen concentration was 3 ± 1 mg/L.
- Stable phosphate removal of 91 ± 1% observed.
- A final effluent total COD of around 50 ± 6 mg/L could be obtained after treatment with HRAP.
- There was a 4 log scale pathogen removal after treatment with HRAP with MPN of the final effluent being less than 1000/100 ml.

Performance of HRAP





Monthly average of performance data of HRAP

Month	BOD outlet (mg/L)	COD outlet (mg/L)	TN Outlet (mg/L)	TP Outlet	MPN Outlet
Mar	26	68	8	0.2	15000
April	28	54	5	0.5	970
May	27	77	7	0.7	920
June	21	70	7	0.1	1000
July	24	45	5	0.4	1000

Summary of Results

- UASB reactor successfully gave more than 70% COD removal with biomass granulation.
- Approximate height of sludge bed is less than 1 m at present. Further improvement in organic matter removal efficiency is expected with higher depth of sludge bed.
- Utilization of nutrients present in the treated sewage for the growth of microalgal species will not only control eutrophication but will also help in sustainable energy development.
- The findings of this study suggest that sewage can be directly used for mass cultivation of microalgae without requiring additional nutrient supplements.
- The effluent of the algal pond was directly reused for horticulture, landscaping and aesthetic enhancement.

Acknowledgements

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THANK YOU

Biomass Granulation Index

$$BGI = (G_w * t_w)^{0.45} + (G_g * t_g * SCI)^{0.55}$$

Velocity gradient due to liquid upflow velocity, $G_w = \sqrt{\frac{g * \Delta h_b}{\upsilon t_w}}$

Velocity gradient due to biogas upflow velocity $G_g = \sqrt{\frac{g * L_b * Q_g}{\upsilon t_g}}$

Sludge concentration index, $SCI = \frac{X_c}{\rho_c}$

Head loss in sludge bed due to liquid upflow velocity,

$$\Delta h_b = 180 * \frac{V_w}{g} * \frac{\nu}{d^2} * L_b * \frac{(1-w)^2}{w^3}$$

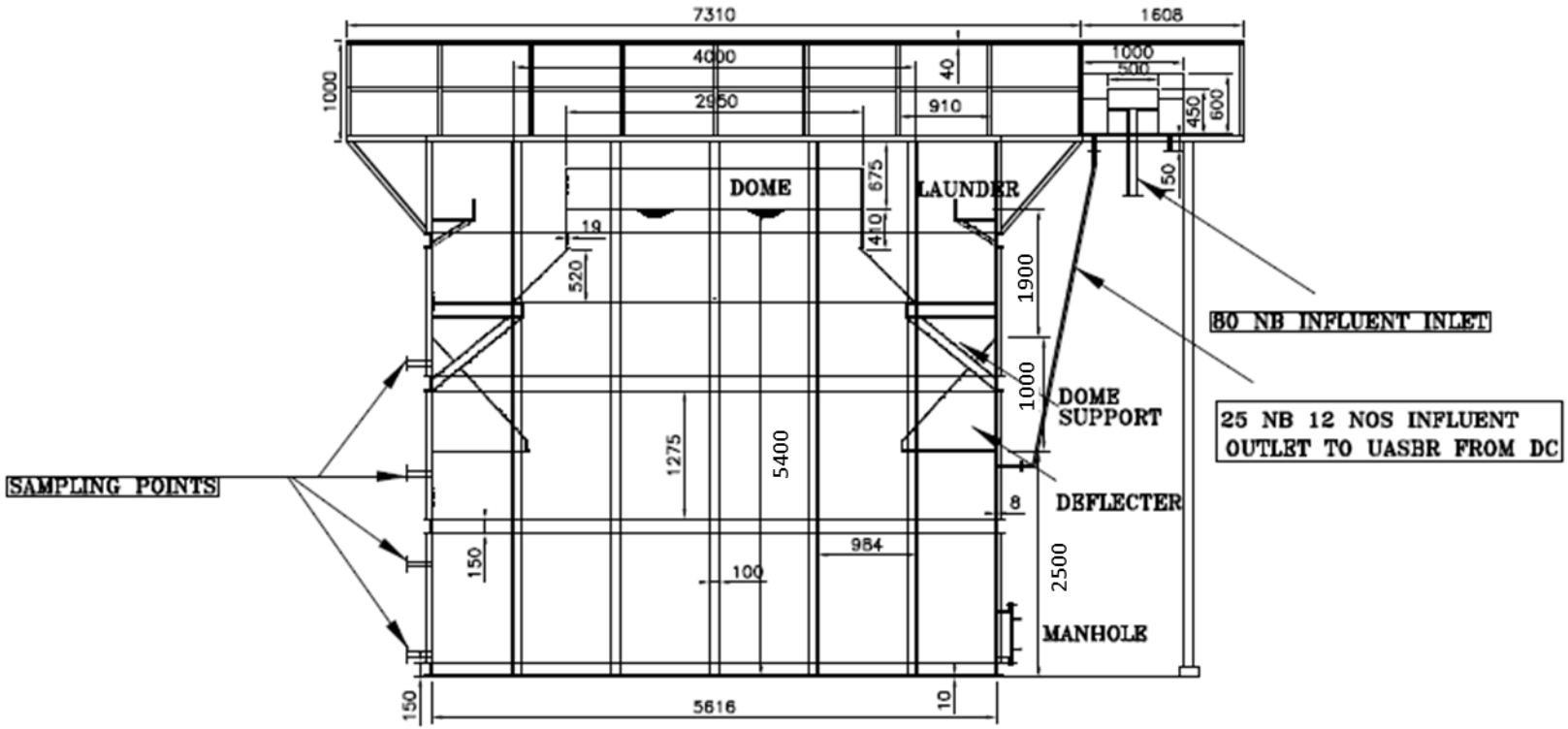
Porosity of sludge bed, $w = 1 - \frac{X_c}{\rho_c}$

t_w is retention time of wastewater and t_g is retention time of biogas in sludge bed.

L_b is height of sludge bed, Q_g is the ratio of biogas production rate to wastewater flow rate, υ is the kinematic viscosity of water, X_c is the concentration of innoculum sludge and ρ_c is the density of sludge.

All are SI units.

UASB Elevation



ELEVATION