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# Anaerobic Baffled Reactor: A promising wastewater treatment technology in tropical countries

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**ABSTRACT: With the deterioration of the water resources of the world, looking for an economically viable solution to treat wastewater is a challenge, especially in developing countries, where the costs of setting up, operation and maintenance of conventional aerobic treatment plants are difficult to be met with. The various advantages of the anaerobic treatment technologies over the existing aerobic treatment technologies are lower energy requirements, lesser excess sludge production and energy production in the form of biogas. The only major disadvantage for anaerobic treatment is the requirement of relatively higher temperatures for optimum operation, but this is not a barrier in tropical countries like India, hence making high rate anaerobic reactors a reliable technology in countries like India. Anaerobic reactors have an advantage of maintaining high biomass concentration and maintaining longer SRTs (Sludge Retention Time) at shorter HRTs (Hydraulic Retention Time). ABR (Anaerobic Baffled Reactor) is one of the simplest anaerobic reactors, which has been widely studied as a potential reactor for decentralised wastewater treatment in developing tropical countries, because it provides higher treatment efficiencies at lower costs.**

## I. INTRODUCTION

Water, a valued resource is vital to the existence of all living forms on earth, but is being threatened due to ever increasing demand for high quality of water. In a developing country like India the major reason behind the pollution of the water bodies is urbanization. The wastewater generated from the municipalities is higher than the industrial wastewater generated, but the treatment capacity available for the domestic wastewater is lesser than that for the industrial wastewater. This gap in the treatment of domestic wastewater can be overcome by the collecting, treating and disposing wastewater appropriately. This in turn can be ensured by setting up wastewater treatment plants. The high rate anaerobic systems like the UASB, anaerobic contact process, anaerobic filters and baffled reactors are finding wide acceptance for the treatment of municipal wastewaters, especially in tropical countries. The major advantage of these high rate anaerobic reactors is their ability to maintain high biomass concentrations, which enable higher COD loading rates and maintaining longer SRTs at relatively shorter HRTs (Van Lier *et al*., 2008).

Anaerobic Baffled Reactor (ABR) is a series of simplified UASB reactors. It was developed at Stanford University by Mc Carty and co workers. Simplification of the original design of the UASB reactor decreases the construction as well as maintenance costs. The complex GSL separator is replaced by simple baffles to guide the flow of waste water, thus the anaerobic baffled reactor consists of a tank containing alternate hanging and standing baffles that compartmentalise the reactor. The influent distribution system is simplified by reducing the number of distribution tubes. The biosolids in these compartments treat the wastewater as it passes through. The sludge is made up of microbial granules that resist being washed out with the flowing water because of their weight. The baffles also prevent the washing out of the sludge. These microbes in the sludge degrade the organics present in the wastewater flowing through. As a result of this anaerobic degradation, gases like methane and carbon dioxide are produced.

The anaerobic digestion in the ABR is accomplished by three groups of micro organisms. The first one is the acidogenic, which convert complex polymer substrates into the simpler sugars, alcohols, organic acids, hydrogen and $CO_2$. The second being the acetogenic and hydrogen producing micro organisms that convert the previous stage products into acetate and $CO_2$. The third group is the methanogens that convert simple compounds formed in the previous step into methane (Foxon *et al*., 2007).

## II. WASTEWATER TREATMENT USING ABR

Although ABR is not a highly developed technology on large scale, it has various advantages over other well established technologies. It is because of these advantages that the reactor has been used in research and treatment of several low strength wastewaters (Krishna *et al.*, 2007). It is simple in design, has no moving parts, has low construction and operating cost and doesn't require any mechanical mixing. There is no strict requirement for biomass with specific settling properties and the sludge generation rate is lower in comparison to other high rate treatments like the activated sludge process, high SRTs can be achieved for lower values of HRTs, the biomass can be retained without using any fixed media. The most noteworthy advantage of the reactor is the compartmentalised structure which allows the separation of acidogenesis and methanogenesis longitudinally down the reactor allowing different micro organisms to dominate different compartments (Barber and Stuckey, 1999).

The treatment of the low strength wastewater was studied in eight chambered ABR, and compartment wise profiles indicated that most of the reduction of organic matter occurred in the initial compartments only. Also, the first compartment showed a sudden pH drop and increase in VFAs, indicating acidogenesis and acetogenesis. The pH further increased and the volatile fatty acid concentration decreased down the reactor, suggesting that compartmentalisation separates the acidogenesis and methanogenesis longitudinally down the reactor (Krishna *et al.*, 2007). In another case, a 4 compartment ABR used for wastewater treatment in a small Chinese town also showed the removal efficiency of the first compartment to be better than the other three indicating that most of the hydrolysis occurs in this first compartment (Zhao *et al.*, 2012).

The mechanism of pollutant removal, start up performance and pathogen removal potential were studied in a carrier anaerobic baffled reactor at 28±1°C. The total COD removal efficiency decreased from 79% at an HRT of 48 hours to 69% at18 hours. This occurred due to washout of the biomass. The soluble COD removal efficiency remained constant. The reactor had a very little effect on the removal of pathogens (Feng *et al.*, 2008). In another study, the low strength wastewater was treated in a lab scale eight chambered anaerobic baffled reactor. The reactor was started at an HRT of 20 hours and the COD removal efficiency was in the range of 50 to 60% and in about 50 days, it increased to 70 to 80 %. Further the HRT was brought down to 16 and then to 12 hrs, by increasing the flow rates and the COD removal efficiency rose to 80%. The HRT was further decreased to 8 hours and it initially resulted in the decrease in the COD removal efficiency, but gradually improved and pseudo steady state was attained. When the HRT was lowered to 6 h, it resulted in the washout of the solids. The reactor was then operated at an increased HRT of 10 hours. Thus the reactor showed successful COD removal with efficiencies of up to 90% at HRTs of 8 and 10 hr (Krishna *et al.*, 2007).

A modified anaerobic baffled reactor was studied at pilot scale to evaluate its suitability for municipal wastewater treatment. During the period of study, the removal efficiencies were estimated at HRTs varying from 6 days to 3 hours and an HRT of 6 hours was found to be appropriate and at this HRT, the removal efficiencies for SS, BOD and COD were found to be 86%, 87% and 84% respectively. The reactor showed consistent performance at a given HRT, irrespective of varying influent concentration. The effluent SS, BOD and COD were 40 mg/l, 30 mg/l and 44 mg/l, hence proving it to be a suitable reactor for municipal wastewater treatment in tropical climate conditions like India. The COD removal and gas production were found to be the functions of OLR (Organic loading rate) and HRT (Bodhke, 2009). The ABR was studied as a potential primary treatment unit for domestic wastewater. At an HRT of 22 hr, the removal efficiencies for COD were between 58% and 72%, TSS and pathogen indicator organisms were also reduced. It was felt that better removal of COD would have been possible if the flow rates were reduced to allow complete fermentation of particulate COD (Foxon *et al.*, 2007).

## III. FACTORS AFFECTING THE TREATMENT IN ABR

**Temperature:** Bacteria need an optimum temperature to grow, generally for anaerobic reactors, it is 25 to 35°C. The removal efficiencies fall down if the temperatures are below the optimum range (Zhu *et al.*, 2015). The carrier anaerobic baffled reactor was studied for its performance at varied temperatures. The operational temperature was initially controlled at 28±1°C, then it was decreased to 18±1°C at a rate of 1°C per day and the reactor was operated for 10 days at a constant feed strength, then temperature was further reduced to 10±1°C at the same rate, the operating conditions being the same. The temperature was found to influence the SS removal, and high VFA concentration prevailed at low temp, showing that the reaction rates were influenced by the decrease in temperature (Feng *et al.*, 2009). In another case, the reaction rate decreased when the temperature was reduced to below 15°C (Nasr *et al.*, 2009; Zhu *et al.*, 2015).

**pH:** pH is an important controlling factor for operation of the ABR. pH is an indicator, whether the anaerobic system is working normally or not. The pH in the ABR is determined by the alkalinity and the VFA concentration. As mentioned above, there is compartmentalization in the ABR, and the favourable pH of each compartment differs. Due to fermentative bacteria the VFAs accumulate in the initial chambers, but the pH increases down the reactor due to decrease in VFA concentration and increase in alkalinity (Feng *et al*., 2009). The souring caused by excessive accumulation of the VFAs can lead to the process failure (Zhu *et al*., 2015). Therefore in order to prevent these fluctuations, pH can be adjusted using different substances like NaOH and $NaHCO_3$ (Arnirfakhri *et al*., 2006).

**Organic Loading Rate (OLR):** OLR doesn't directly influence the performance of an ABR, but has an impact on the removal efficiencies. ABR treating a complex wastewater was operated at different OLRs ranging from 0.6 to 2 kg COD/m$^3$day, for about 600 days without wasting sludge at temperatures of 20 to 38°C. The average COD removal decreased with decrease in OLR. At max OLR i.e. at minimum HRT, the COD removal exceeded 88% (Krishna *et al*., 2007). In the end it can be concluded that the OLR is an indicator of nutritional condition of microorganisms. Therefore when low-concentration wastewater is being treated, lower HRT and higher OLR are preferred to ensure the availability of nutrients to the microorganisms. When high-concentration wastewater is being treated, lower OLR is suggested to enable complete biodegradation of substrate and prevent sludge floating caused by higher yields of biogas (Zhu *et al*., 2015).

**Hydraulic Retention Time (HRT):** HRT is an important controlling factor in the ABR because it can control the organic and hydraulic load of the reactor. The effect of HRT on the COD removal efficiencies was studied in a four chambered ABR treating sewage at 25°C. The study was performed at 5 different HRTs of 20.5, 15.3, 9.6, 5.2 and 2.9 hours and corresponding OLRs of 0.30, 0.54, 0.79, 1.92 and 2.55 kg COD/m$^3$day. As the HRT was decreased from 20.5 hr to 15.3 hr, the COD removal efficiency increased from 82.5% to 88.1%, but as the HRT was further decreased to 9.6 hr, the removal efficiency decreased to 79.4% and it further decreased to around 68% at an HRT of 2.9 hr. Thus the removal rate was best at an HRT of 9.6 hr and OLR of 0.79 kg COD/m$^3$day (Zhao *et al*., 2012). The decrease in efficiencies at very lower HRTs could be because the bacteria did not get enough time to consume the substrate. Hydraulic shock loads can also result in process souring and failure due to accumulation of VFAs, as they could not be degraded effectively by the hetero tropic bacteria and methanogens. HRTs also can influence the dead space volume, at lower HRTs, hydraulic dead space increases, and at higher HRT, biological dead space increases (Zhu *et al*., 2015).

**Start up of the reactor:** The start up of the ABR takes time due to slow growth rates of anaerobic microbes, especially the methanogens. A low initial loading rate is suggested for the successful start up of the ABR because at lower loading rates, there is lower gas production and hence a lower wastewater up flow velocity. The reactor is started with a constant HRT, and gradual step wise increase in the substrate concentration or a constant substrate concentration and a gradual step wise decrease in the HRT. The later shows better performance and reactor stability (Liu *et al*., 2010; Barber and Stuckey, 1998). The start up of carrier ABR was studied at an HRT of 48 hrs at 28±1 °C. The successful start up was indicated in three weeks by the steady organic matter removal efficiency and the varying pH curve through the reactor. The pH gradually decreased initially, but later the fluctuations decreased and a mild increasing pattern in pH along the reactor was observed after 21 days (Feng *et al*., 2008). The start up of 2 phase ABR treating low concentration sewage was studied. The reactor successfully started up in 53 days. The COD removal efficiency improved, as the granular sludge formed rapidly during the start up period (Jing and Wang, 2014). The start up of a nine chambered modified ABR treating municipal wastewater was studied and it showed that the self inoculated reactor took a start up period of 90 days, which is comparable to the seeded reactors (Bodhke, 2009).

**Granulation:** Granular biomass enhances settleability, thus increasing biomass concentration in continuous reactors, leading to higher removal efficiencies. ABR, being a modification of UASB shows a potential to produce granular sludge (She *et al*., 2006). The sucrose fed ABR seeded with granular methanogenic sludge showed better removal efficiencies than the ABR with non granular digested sewage sludge, this could be because of good settling properties of this sludge. Also, the reactor with the granular sludge was more tolerant to decrease in HRTs and increase in OLRs (Baloch, 2011). The granule development in the lab scale ABRs seeded with sewage sludge from the primary anaerobic digester was studied and it was found that granulation was achieved in 75 days. The addition of granular active carbon, bentonite and polyacrlyamide was found to enhance granule formation (She *et al*., 2006). Although various studies indicate that granules appear under favourable conditions, but granulation is not necessary for the optimal performance of the ABR.

## CONCLUSION

As can be seen from the above studies, the ABR has appreciable treatment efficiencies and can be thought of as a suitable reactor for tropical climates, where temperatures remain high for most of the time, being suitable for anaerobic digestion. Also, ABR has certain merits over the traditional treatment technologies. The energy requirements are quite low as there is no requirement for supply of oxygen, the sludge produced is more stabilized and hence there is lesser excess sludge production and there is additional energy production in the form of biogas. The effluent from the ABR reactor however doesn't meet discharge standards and requires further treatment. ABR can thus be used as a primary treatment unit in the wastewater treatment scheme for domestic wastewater treatment, with the benefits of higher efficiency at a lower cost and excellent treatment stability, especially in tropical developing countries. It can therefore be considered as a potential anaerobic reactor for decentralised wastewater treatment in countries where urban centralised wastewater treatment using conventional technologies has become a challenge. ABR can thus be thought of as a sustainable and affordable treatment technique for urban communities in tropical countries.

## REFERENCES

[1]. Amirfakhri J, Vossoughi M, Soltanieh M. Assessment of desulfurization of natural gas by chemoautotrophic bacteria in an anaerobic baffled reactor (ABR). Chemical Engineering and Processing: *Process Intensification*. 2006 Mar 31; **45**(3): 232-7.

[2]. Baloch MI. Methanogenic granular sludge as a seed in an anaerobic baffled reactor. W*ater and Environment Journal*. 2011 Jun 1; **25**(2): 171-80.

[3]. Barber WP, Stuckey DC. The use of the anaerobic baffled reactor (ABR) for wastewater treatment: a review. *Water Research*. 1999 May 31; **33**(7): 1559-78.

[4]. Bodkhe SY. A modified anaerobic baffled reactor for municipal wastewater treatment. *Journal of environmental management.* 2009 Jun 30; **90**(8): 2488-93.

[5]. Feng H, Hu L, Mahmood Q, Fang C, Qiu C, Shen D. Effects of temperature and feed strength on a carrier anaerobic baffled reactor treating dilute wastewater. *Desalination.* 2009 Apr 30; **239**(1): 111-21.

[6]. Feng H, Hu L, Mahmood Q, Qiu C, Fang C, Shen D. Anaerobic domestic wastewater treatment with bamboo carrier anaerobic baffled reactor. *International Biodeterioration & Biodegradation*. 2008 Oct 31; **62**(3): 232-8.

[7]. Foxon KM, Pillay S, Lalbahadur T, Rodda N, Holder F, Buckley CA. The anaerobic baffled reactor (ABR): an appropriate technology for on-site sanitation. Water SA. 2007 Dec 4; **30**(5): 44-50.

[8]. Jing L, Wang XX. Research on the Start-Up Effect of Two-Phase Anaerobic Baffled Reactor. In Applied Mechanics and Materials 2014 Jan 20 (Vol. **448**, pp. 600-603).

[9]. Khan AA, Gaur RZ, Tyagi VK, Khursheed A, Lew B, Mehrotra I, Kazmi AA. Sustainable options of post treatment of UASB effluent treating sewage: a review. *Resources, Conservation and Recycling.* 2011 Oct 31; **55**(12): 1232-51.

[0]. Krishna GG, Kumar P, Kumar P. Treatment of low strength complex wastewater using an anaerobic baffled reactor (ABR). *Bioresource technology.* 2008 Nov 30; **99**(17): 8193-200.

[11]. Krishna GV, Kumar P, Kumar P. Complex wastewater treatment using an anaerobic baffled reactor. *Environmental Progress.* 2007 Dec 1; **26**(4): 391-8.

[12]. Liu R, Tian Q, Chen J. The developments of anaerobic baffled reactor for wastewater treatment: a review. *African Journal of Biotechnology*. 2010; **9**(11): 1535-42.

[13]. Nasr FA, Doma HS, Nassar HF. Treatment of domestic wastewater using an anaerobic baffled reactor followed by a duckweed pond for agricultural purposes. *The Environmentalist*. 2009 Sep 1; **29**(3): 270-9.

[14]. She Z, Zheng X, Yang B, Jin C, Gao M. Granule development and performance in sucrose fed anaerobic baffled reactors. *Journal of biotechnology*. 2006 Mar 23; **122**(2): 198-208.

[15]. Van Lier JB, Mahmoud N, Zeeman G. Anaerobic wastewater treatment. Biological Wastewater Treatment: Principle, Modelling and Design. IWA Publishing, London. 2008: 415-56.

[16]. Zhao J, Shi YS, Lu QJ. Experimental Study for ABR to Treat the Domestic Sewage. *In Advanced Materials Research* 2012 Feb 6 (Vol. **393**, pp. 1217-1223).

[17]. Zhu G, Zou R, Jha AK, Huang X, Liu L, Liu C. Recent developments and future perspectives of anaerobic baffled bioreactor for wastewater treatment and energy recovery. *Critical Reviews in Environmental Science and Technology.* 2015 Jun 18; **45**(12): 1243-76.