Process optimization of tertiary biological treatment of MSW leachate by innovative PVA Gel technology

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ABSTRACT

In developing country like India, where Municipal Solid Waste (MSW) Management is at a nascent stage, open dumpsites lead to negative impact on the health and environment. Leachate generated from non-segregated MSW leachate has been a major concern. Biological treatment like PVA gel technology has been proved to be effectual for treating the MSW leachate. The current study was

Current study was conducted out at Municipal Solid Waste based 12 MW Waste-to-Energy Plant in Ghazipur, eastern part of Delhi, India.

Physio- chemically and anaerobically treated leachate samples were subjected to PVA gel reactor. Parameters like BOD COD and Hydrolic retention time (HRT) were changed to get the optimized the treatment efficiency of PVA gel on non-segregated MSW leachate. Number of samples were analyzed to get the optimum strength of PVA gel while reducing BOD, COD, and with varying duration of HRT. Observation concluded that partially treated leachate having BOD nearly 600mg/L, COD nearly 1500mg/L, HRT of 5hr or more and temperature range of 30-40°C have shown maximum treatment efficiency of PVA gel.

Key words: BOD; COD; HRT; Polyvinyl Alcohol (PVA) Gel; Municipal Solid Waste; Waste Water

1. INTRODUCTION

Cities and towns in India are facing major problems related to management of municipal solid waste (MSW) due to overpopulation and accelerated urbanization. Waste generation in India is increasing at a rapid pace and municipal authorities are not being able to scale up their facilities in order to manage these increasing quantities. It is a common sight in most cities to find garbage piled in heaps along the

roadside. Besides being visually unappealing, it emanates a foul odour, releases particulate matter and hazardous gases into the air. It also contaminates the soil and groundwater in addition to attracting flies, rodents as well as other disease vectors. Therefore, waste causes a public health hazard if it is not managed properly.

In developing countries like India, landfilling has become the most widely accepted method for disposal of these increasing waste quantities due to its economic advantages. These landfills are usually built without engineered liners and leachate collection systems. Therefore, risk of groundwater pollution is the most severe environmental impact from such landfills. Recently, the installation of liners, leachate collection systems and a plan for leachate treatment have been mandated by regulations in many countries [Kjeldsen 2002]. In India, the Solid Waste Management Rules notified in 2016 provide detailed guidelines on sanitary landfilling and leachate treatment parameters. These rules define leachate as "the liquid that seeps through solid waste or other medium and has extracts of dissolved or suspended materials from it" [MOEF 2016]. This polluted waste water poses a serious threat to the surrounding ecosystem as it often percolates down and contaminates the groundwater and runs as a stream into the surrounding water bodies.

Leachate is generated as a consequence of precipitation, surface run-off and infiltration or intrusion of ground water percolating through a landfill, biochemical processes and the inherent water content of wastes themselves. Leachate is the liquid residue that results due to various chemical, physical and biological processes occurring within a landfill or waste dumpsite [Bhalla 2014]. Pollutants are transferred from the waste material to the water through a combination of physical, chemical and microbial processes [Christensen 1989]. As mixed municipal solid waste (MSW) piles up, the compaction of waste layers and biodegradability of organic content creates an anaerobic environment. Therefore, the composition of leachate has many similarities among different landfills [Kjeldsen 2002].

Landfills that receive mixed waste generate leachate that can be characterized as a water-based solution of four groups of pollutants - dissolved organic matter, inorganic macro components, heavy metals, and

xenobiotic organic compounds [Christensen 1994]. The usual prerequisites before discharging leachates into natural waters include removal of organic material based on chemical oxygen demand (COD), biological oxygen demand (BOD) and ammonium. Toxicity analysis carried out using various test organisms have confirmed the potential dangers of leachates and the necessity to treat them so as to meet the standards of discharge in receiving waters [Renou 2008].

In India, the quality and characteristics of leachate are very dynamic. Their nature varies from city to city and even within the boundaries of cities due to variations in the lifestyles and wide socio-economic differences. The nature of leachates is also heavily influenced by factors such as, the composition of solid waste, age of waste, moisture content of waste, rate of water movement through the waste, temperature, chemical and biological activity, precipitation and seasonal variations in weather [Mcardle 1988]. Thus, the leachates found here contain high values of total suspended solids, inorganic salts, organic contaminants, high ammonia concentration, halogenated hydrocarbons and heavy metals and therefore, its treatment and disposal process becomes difficult [Kumar 2013, Trebouet 2001].

PVA gel is a bio-carrier that can be used to treat wastewater. It is a porous hydrogel that is useful for immobilization of microorganisms that degrade the environmental pollutants in the waste water. This technology is being explored by several researchers today due to its inherent advantages over other technologies for waste water treatment. The PVA gel beads are contain pores that allow cultivation of bacteria in a sheltered environment and prevent sloughing of biomass [Hoa 2006, Keenan 1984].

For the purpose of experimentation in this study, PVA gel beads were used in a demonstration and test facility located within the premises of a 12 MW Waste-to-Energy Plant in Delhi, India. The study was specifically aimed at analysis of BOD, COD and hydraulic retention time (HRT) of leachate through the PVA gel technology. This study examines the effectiveness of treating leachate generated from heterogeneous Indian MSW through PVA gel beads.

2. METHODOLOGY

2.1 Leachate processing

The leachate flows into the leachate drain through a screen bar built at the bottom of the MSW pit. The screen also helps in the physical separation of the leachate from other waste items that can block the drain. The leachate is finally emptied into anequalization tank from where it is taken to the Leachate Treatment Plant. Samples of treated leachate were collected through the outlets of pilot study of selected technologies for comparison. The partial treatment of leachate was done as discussed by Chaturvedi *et al.*, 2018 [Gani 2016].

The analysis was started with initial BOD of 301 mg/L and COD of 758 mg/L, other parameters like flow rate was maintained at 40 L per hour, Hydrolic retention time (HRT) of 5 hrs, pH at 7.5 and temperature at 35^{o}C and kept constant for entire study.

2.2 Efficiency of PVA Gel treatment process on different concentrations of BOD and COD in the partially treated leachate under controlled parameter

Different concentrations of BOD and COD were made by adding raw leachate and fresh water in the partially treated leachate in the experimental reactor. After mixing raw leachate and fresh water, leachate of experimental reactor was analyzed with the APHAmethod [Chaturvedi 2018] to obtain the values of BOD and COD in mg/L. Test samples with different values of BOD and COD were prepared and analyzed to achieve the aim of this study.

2.3 Effect of Hydrolic retention time (HRT) on the treatment of partially treated leachate by PVA gel

To identify optimum hydrolic retention time (HRT) for observing potential reduction in the BOD and COD. HRT was varied from 1 hour to 7 hours i.e. the flow rate of experimental reactor was changed from 200 L per hour to 28.6 L per hour to obtain the potential HRT for PVA Gel to get the potential reduction in the organic load. Fixed concentration of partially treated leachate were fed into the experimental reactor to observe the optimum HRT with respect to maximum reduction of BOD and COD.

3. RESULTS AND DISCUSSION

In the current pilot study efficacy of PVA Gel media has been observed against the variable parameters of Biological Oxygen Demand (BOD) and Hydrolic Retention Time (HRT). Inlet leachate for pilot study was taken from the leachate treatment plant at Ghazipur 12MW Waste to Energy plant East of Delhi after physico- chemical treatment and anaerobic treatment.

A pilot scale study was designed to identify the efficiency of PVA gel with respect to BOD& COD in the partially treated MSWleachate. PVA gel has been reported for its application in waste water treatment.

PVA Gel tank having capacity of 200 liters with 10% media quantity (i.e. 20 liters) was set up with constant flow of 40 liters per hours and HRT of 5 hours. Air flow during the study was maintained at 1.0 cubic meters per hour and pH remained constant at 7.5 and temperature was at 35^0C during all the readings (Supplementary table 1).

Partially treated leachate with BOD range from 301 mg/l to 901 mg/l was fed to reactor tank with respective COD range from 758 mg/l to 2290 mg/l. Sevenreadings have been analyzed to identify the best efficiency of PVA Gel media. Analysis was evaluated at inlet BOD of 301 mg/l and COD of 758 mg/l with other parameters kept constant. After the 5 hrs of retention time in pilot tank 87% and 84% of reduction was observed in BOD and COD respectively.This reading was followed by another feed of partially treated leachate with BOD & COD values of 402 mg/l and 1021 mg/l and 89% & 87% reduction was found in BOD and COD respectively.

In other set of feeding with 497 mg/l of BOD and 1297 mg/l of COD resulted in reduction of 92% in BOD and 91% in COD. In next feed BOD was increased to 606 mg/l and COD was maintained at 1522 mg/l and keeping the same test conditions 95% and 93% reductions were observed in BOD and COD values in final outlet.According to the research conducted by Singh et al. (2016) [APHA], PVA gel has efficiency of ≥ 90% for COD, BOD as well as nitrogen removal at optimum conditions. BOD & COD were increased

to 703 mg/l and 1729 mg/l and at the outlet 94% and 92% of reduction was observed in BOD and COD respectively. (Singh 2016)

In another set of analysis BOD was again increased to 798 mg/l with corresponding COD of 2034 mg/l. after the treatment in pilot tank with PVA Gel the values of BOD & COD got decreased up to 94% and 91% respectively.Final reading was taken with inlet parameters of BOD & COD kept at 901 mg/l and 2290 mg/l and reduction of 92% and 90% were obtained at the outlet.Best reduction in BOD and COD was observed in the rage of 606 mg/l and 1522 mg/l with 95% of BOD and 93% of COD reduction respectively in the partially treated leachate with when passed with PVA Gel beads in the pilot study tank, while other parameters were kept constant.In next set of experiment was to analyze the optimum Hydrolic retention time for the treatment of partially digested leachate with PVA Gel technology. In this set of experiment PVA Gel tank having capacity of 200 liters with 10% media quantity (i.e. 20 liters) was set up with constant flow of 40 liters per hours and BOD and COD of inlet leachate were maintained at 604 mg/L and 1507 mg/L respectively. Air flow during the study was maintained at 1.0 cubic meters per hour and pH remained constant at 7.5 and temperature was at 350C during all the readings. HRT were made variable to identify the best Hydrolic retention time with PVA Gel technology.

Study was initiated with one hour of HRT in which 200 L of partially digested leachate was exposed to PVA Gel while other parameters were remained constant. At one hour of HRT the reductions in BOD and COD were noted at 74% and 70% respectively. In next reading HRT was kept at 2 hours and it was observed that the digestion of BOD and COD were slightly higher as compared to one hour of retention with 83 and 77% of reduction in BOD and COD from the inlet feed.

In next two analysis the HRT was increased to 3 and 4 hours and digestion of BOD and COD was increased up to 90% and 87% respectively. Further the HRT was increased gradually from 5 to 7 hours and effect of higher HRT was observed on the reduction of BOD & COD. It was observed that reduction was highest with 95% of BOD removal and 94% of COD removal. It was identified that highest reduction in BOD and COD

was occurred at 5 hours of HRT and no significant increase in BOD & COD reduction even after increasing the HRT further to 7 hours (Supplementary table 2).

4. CONCLUSION

A large number of waste management plants are imminent in the era of a conscious approach towards environmental protection. The focus of various waste management firms and the government is being directed towards solving the humungous problem of leachate generation from waste management processes. The current study was focused on the characterization of leachate for the improving the efficiency of PVA. The study revealed that the change in physical parameter like HRT as well as chemical parameter like BOD and COD tend to improve the efficiency of PVA gel for treatment of non-segregated MSW leachate. Results indicated that BOD of 600mg/L, COD of1500mg/L, HRT of 5hr or more at temperature range of 30-40°C are optimized for potential reduction in organic load.

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Conflict of interest

There is no conflict of interest.

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Inlet Parameter						Outlet Parameter			
Flow rate (Q)	HRT OF PVA Gel Tank	BOD in to PVA Gel tank	COD in to PVA Gel tank	PH	Temp	BOD out from PVA Gel tank	BOD removal ratio	COD out from PVA Gel tank	COD removal ratio
(L/Hour)	Hrs	(mg/L)	(mg/L)		(ºC)	(mg/L)		(mg/L)	
40.0	5.0	300	758.0	7.50	35.0	40	87%	120.0	84%
40.0	5.0	402	1021.0	7.50	35.0	46	89%	136.0	87%
40.0	5.0	497	1267.0	7.50	35.0	41	92%	119.0	91%
40.0	5.0	606	1522.0	7.50	35.0	31	95%	101.0	93%
40.0	5.0	703	1729.0	7.50	35.0	39	94%	141.0	92%

40.0	5.0	798	2034.0	7.50	35.0	51	94%	179.0	91%
40.0	5.0	901	2290.0	7.50	35.0	69	92%	221.0	90%

Supplementary table 1: **Reduction in BOD and COD of inlet leachate after treating with PVA gel technology.**

Primary Parameter						Outlet Parameter			
Flow rate (Q)	HRT OF PVA Gel Tank	BOD in to PVA Gel tank	COD in to PVA Gel tank	PH	Temp	BOD out from PVA Gel tank	BOD removal ratio	COD out from PVA Gel tank	COD removal ratio
(L/Hour)	Hrs	(mg/L)	(mg/L)		(°C)	(mg/L)		(mg/L)	
200.0	1.0	604	1507.0	7.50	35.0	149	75%	453.0	70%
100.0	2.0	604	1507.0	7.50	35.0	102	83%	351.0	77%
66.0	3.0	604	1507.0	7.50	35.0	81	87%	278.0	82%
50.0	4.0	604	1507.0	7.50	35.0	61	90%	198.0	87%
40.0	5.0	604	1507.0	7.50	35.0	31	95%	101.0	93%
33.0	6.0	604	1507.0	7.50	35.0	30	95%	96.0	94%
28.0	7.0	604	1507.0	7.50	35.0	29	95%	93.0	94%

Supplementary table 2: **Optimization of Hydrolic retention time (HRT) for reduction in BOD and COD with PVA gel technology.**