PERFORMANCES OF LOW – COST MATERIALS AS PACKING MEDIA FOR ANAEROBIC FILTER TO TREAT LANDFILL – LEACHATE

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Abstract

The landfill- leachate consists of different organic and inorganic compounds that may be either dissolved or suspended, which may pose hazards to receiving water bodies. It may be toxic to life or may simply alter the ecology of the stream or watercourse if not removed by treatment. Depending on the geographical and geological nature of a landfill site, leachate may seep into the ground and possibly enter groundwater sources. Therefore proper leachate treatment is very essential. Attached growth technologies have successfully been used for landfill-leachate treatment. If naturally available low cost materials can be used as packing media rather than using expensive materials such as plastic, synthetic polymers and crushed rocks, attached growth process would be a prominent technology in the area of landfill-leachate treatment. Hence the aim of this study was to utilize low- cost locally available materials such as coconut coir fiber, rice straw, rice husks and saw chips as packing media in laboratory scale anaerobic filter columns to treat landfill-leachate. The leachate was collected from the Galle Municipal Council dumpsite. The filter column experimental set-up consisted of 4 columns each with 35 cm height and 8.9 cm inner-diameter. The initial height of packing media was 24 cm. The influent which was stored in an overhead tank was loaded on to each column via a shower. Approximately a constant application rate was maintained by adjusting a valve. The effluent was collected in an effluent tank kept below each column. Influent and effluent were characterized in terms of several wastewater parameters. All the columns were sealed to fulfil anaerobic conditions. There were two experimental runs with durations 9 and 7 days. The degrees of contaminant removal of different packing media did not show much variation with each other. There was a reduction in organic matter, total nitrogen, nitrate nitrogen, total dissolved solids, chlorides and sulfates. Anaerobic digestion, adsorption and denitrification could be principal treatment mechansms.The rate of removal of COD and chlorides in the experimental run 1 were excellent with rates greater than 80 and 90 percent, repectively.

Keywords: Landfill-leachate, Anaerobic filter columns, Low - cost packing media, Organic matter

1. Introduction

Landfill leachate is generated from liquids existing in the waste as it enters a landfill or from rainwater that passes through the waste within the facility. The leachate consists of different organic and inorganic compounds that may be either dissolved or suspended. During the percolation of rainwater and moisture through municipal solid waste (MSW) in a landfill, the liquid medium absorbs nutrients and contaminants from the waste and exudes as leachate from the landfills posing a hazard to the receiving water bodies. This leachate contains many substances which depend on the types of waste disposed on to the landfill, and may be toxic to life or may simply alter the ecology of the stream or watercourse if not removed by treatment. Depending on the geographical and geological nature of a landfill site, leachate may seep into the ground and possibly enter groundwater sources. Though natural processes within the soil layers can remove a part of the contaminants from the leachate, groundwater contamination can be hazardous as drinking water sources may be affected. Generally leachate may contain large amount of organic matter as well as ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts which are a great threat to the surrounding soil, ground water and even surface water(Renou et al.,2008; Robinson, 2005).

Therefore proper leachate treatment is very essential in landfill handling. Leachate treatment technologies fall into two basic types, biological and physical/chemical. Attached growth technologies have successfully been used for landfill-leachate treatment. The main advantages of attached growth processes over suspended growth processes are lower energy requirements, simpler operation, no bulking problems, less maintenance, and better recovery from shock loads (McBean et al, 1995).Attached growth processes in wastewater treatment are very effective for the removal of biochemical oxygen demand, nitrification, and denitrification. Most of the available leachate treatment methods are very expensive. Therefore it is very essential to introduce low - cost innovative methods for leachate treatment. If naturally available low cost materials can be used as packing media rather than using expensive materials such as plastics, synthetic polymers and crushed rocks, attached growth process would be a prominent technology in the area of landfill-leachate treatment. Therefore the aim of this study was to find out the efficiency of low cost locally available materials such as coconut coir fibre, rice straw, rice husks and saw chips as packing media in laboratory scale anaerobic filter columns in treating landfill-leachate.

2. Methodology

Laboratory-scale anaerobic filter column tests with different media were conducted to find out the performances of those media in treating contaminants such as organic matter, nitrogenous compounds,total dissolved solids, chlorides and sulfates. Figure 1 shows the experimental set-up. It consisted of 4 columns each with 35 cm height and 8.9 cm diameter. At the bottom of the column initially existed a 5 cm thick gravel layer. The initial media height was 24 cm. There was a perforated plate between the media and the gravel layer to distribute effluent evenly to the gravel layer. There was another perforated plate over the media at the top of the column to

distribute influent evenly throughout the column and to prevent by-passing of water. The influent which was stored in an overhead tank was loaded on to the column via a shower. An application rate of approximately 0.4 mL/s was maintained by adjusting a valve.
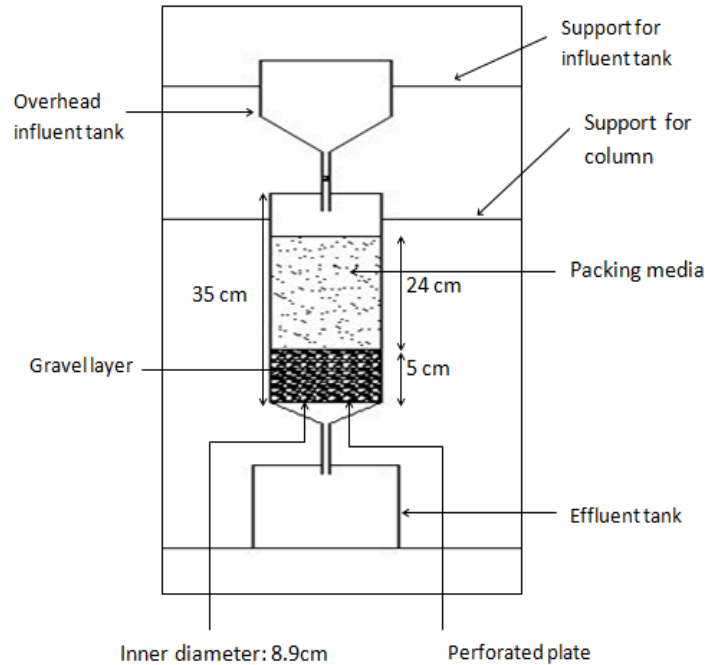

Figure 1: Experimental setup

Table 1: Concentration of different parameters in influent

Parameter	Run 1	Run 2
COD (mg/L)	22 106.3	4258.1
Ammonia Nitrogen (mg/L)	653.4	ND
NO_3^{2-} -N (mg/L)	ND*	324.7
Total Nitrogen (mg/L)	10 185.2	ND
Cl$^-$ (mg/L)	12 329.7	9197.1
SO_4^{2-}	ND	0.6
TDS (mg/L)	ND	39.2
Alkalinity (mg/L as CaCO₃)	18666.7	8000.0

Note: * No data

The effluent was collected in an effluent tank kept below each column. The influent was the leachate collected from the dumpsite of Galle municipal council. Two series of column experiments were conducted with packing media such as coconut coir fibre, rice straw, rice husks and saw chips. All the packing media were washed and dried before loading. Rice straw was cut into about 2 cm pieces. Influent and effluent were characterized in terms of several wastewater parameters such as chemical oxygen demand (COD), nitrate – nitrogen, ammonia-nitrogen, total nitrogen, total dissolved solids, chloride and sulfate. All the analyses of

wastewater were in accordance with the Standard Methods for the Examination of Water and Wastewater (1998). The durations of experimental run 1 and 2 were 9 and 7 days, respectively. Table 1 shows the influent characteristics.

3. Results and Discussion

3.1 Removal of organic materials

The efficiency of removing organic matter by each packing media was determined by measuring COD concentration in the effluent. COD reduced while flowing through all the filter columns. Figure 2 shows the variation of percentage removal of COD with time for the four different types of packing media. The filter columns with coconut coir fibre and rice husks became out of operation due to a mechanical failure in the mid of the experimental run and the two columns were not in operation for a consderable time period until the they were brought to the proper order. Thus the results of those two columns are not shown by the graph. The The removal percentage in the experimental run 1 was almost constant having a percent removal greater than 80 throughout the entire period. Since the packing media in all four columns were organic materials, adsorption may have taken place in all columns. The removal percentage in experimental run 2 lied very much below those of run 1. In attached growth systems, the primary mechanism for organic removal is not by filtering action of fine pores but rather by diffusion and microbial assimilation (Benefield et. al.,1985). According to Bagchi (2004), the surfaces of organic matter provide some adsorption sites; in addition they may serve as energy source for microorganisms. Adsorption is a very important method for removing contaminants, particularly organic contaminants from wastewater streams (Cooney, 1999). Therefore adsorption can also be considered a potential removal mechanism of organic materials in the columns with organic packing media. Ultimately biodegradable organic matter attached to media may undergo anaerobic digestion if all the conditions for anaerobic digestion is fulfilled with sufficient bio film attached to the media. Sorption refers to the exchange of molecules and ions between the solid phase and the liquid phase (Metcalf and Eddy, 2003). Hence adsorption capacity of the media decreases with time. As microorganisms consume substrate and carry out oxidation –reduction reactions, growth occurs by the production of additional cells. Thus, in wastewater treatment applications biomass is produced continuously as the substrate in the wastewater is consumed and biodegraded (Metcalf and Eddy, 2003). Therefore the rate of biodegradation may increase with time. According to the aforesaid description, adsorption could be the dominant treatment mechanism in run 1, and the principal treatment mechanism in run 2 could be biological uptake.

Anaerobic processes are sensitive to pH and inhibitory substances. A pH value near neutral is preferred and the methanogenic activity is inhibited at a pH value below 6.8. An alkalinity concentration in the range of 3000 to 5000 mg/L as $CaCO_3$ is often found as to be sufficient to keep the pH in the optimum range (Metcalf and Eddy, 2003). As the influent alkalinity concentration was approximately 8000 mg/L, and effluent alkalinity concentration always lied between 3500-7000 mg/L for all packing media, it can be assumed that pH was in the optimum

range inside all columns. Nutrients, rather than carbon or energy sources, may at times be the limiting material for microbial cell synthesis and growth (Metcalf and Eddy, 2003). The influent of experimental runs 1 and 2 were rich in nitrogen, however deficient in phosphorous. Thus the nutrient defficiency could be a reason for the low rate of biodegradation.
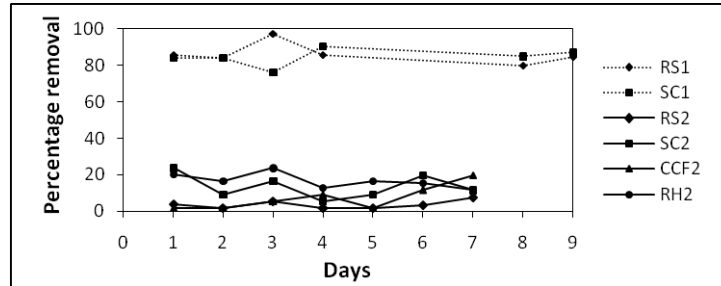

Figure 2: Percentage removal of COD with time (CCF-Coconut coir fibre; RS-Rice straw; SC-Saw chips; RH-Rice husks; 2-Experimental series 2)

3.2 Removal of nitrogenous compounds

Figure 3 and 4 show the percentage removal of total-nitrogen and nitrate-nitrogen by each column. The removal percentage of total nitrogen varied within 20 to 60 in all media throughout the experimental run. The removal percentage of nitrate nitrogen in all packing media varied in a wide range from 10-80. The results indicate that the adsorption of ammonium and denitrification may have occured in all columns. There is no considerable difference among packing media in terms of removal of total nitrogen. Saw chips showed better removal percentages for total nitrogen in the begining and the rate of removal has decreased in the latter period.
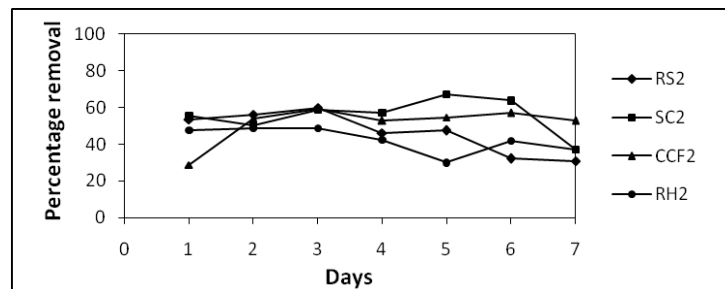

Figure 3: Percentage removal of Total-N with time(CCF-Coconut coir fibre;RS-Rice straw; SC-Saw chips;RH-Rice husks;2-Experimental series 2)
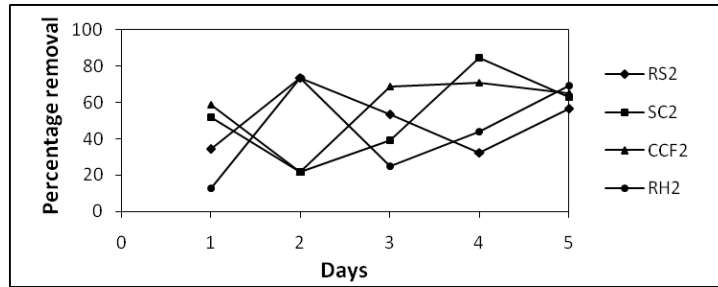
Figure 4: Percentage removal of NO_3^{2-}-N with time(CCF-Coconut coir fibre;RS-Rice straw; SC-Saw chips;RH-Rice husks;2-Experimental series 2)

3.3 Removal of total dissolved solids (TDS) and anions

Soluble wastes can be effectively treated with an anaerobic filter (Benefield et. al.,1985). Figure 5 which shows the percentage removal of total dissolved solids (TDS) with time, is agreeable with this statement. The removal percentage varied within 20 to 60 percent.
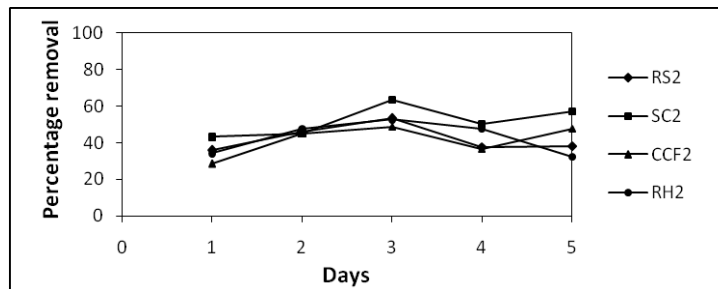

Figure 5: Percentage removal of TDS with time(CCF-Coconut coir fibre;RS-Rice straw; SC-Saw chips;RH-Rice husks; 2-Experimental series 2)
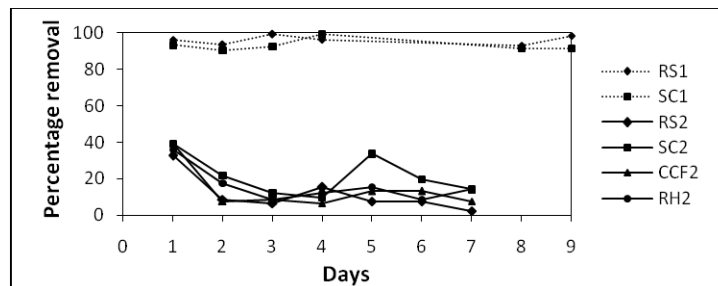

Figure 6: Percentage removal of Cl⁻ with time(CCF-Coconut coir fibre;RS-Rice straw; SC-Saw chips;RH-Rice husks;1-Experimental series 1;2-Experimental series 2)

Figure 6 shows the percentage removal of chloride with time. It is significant that the removal percentage in all packing media was higher than 90 % in experimental run 1, however the removal rate decreased below 40 % in run 2. According to these results, the reaction mechanism could be either ion exchange or adsorption of which the removal rate is proportional to the vacant sites.

Figure 7 shows the percentage removal of sulfate in all filter columns.Rice straw gave the best performance.All columns reduced sulfate to some extent. It shows that the columns had reducing conditions.
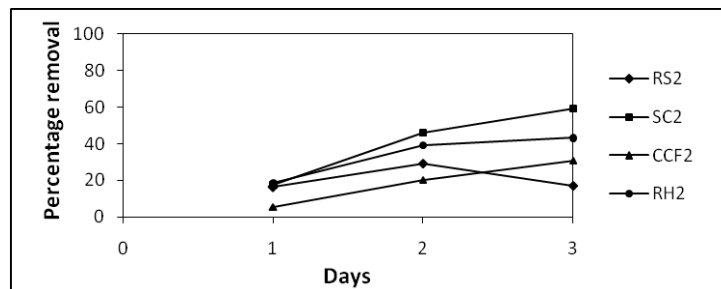

Figure 7: Percentage removal of SO_4^{2-} with time(CCF-Coconut coir fibre;RS-Rice straw; SC-Saw chips;RH-Rice husks;2-Experimental series 2)

4. Conclusions

The results show that the packing media such as rice husks, rice straw, saw chips and coconut coir fibre are able to remove contaminants such as organic matter, total nitrogen, nitrate-nitrogen, total dissoved solids,chlorides and sulfates to some extent in an anaerobic filter. The principal treatment mechanisms could be anaerobic decomposition for biodegradable organic materials, denitrification for nitrates and adsorption for organic matter,anions,dissolved solids and ammonium. Nutrient disproportion and low solids retention time could be reasons for the low efficiency of anaerobic decomposition.Therefore the study shows the importance of carrying out these column experiments for prolonged periods with optimum conditions to achieve better results because it would provide sufficient time and optimum requirements for anaerobic microorganisms to reproduce and grow. In addition operation in up flow mode will enhance the performance of the anaerobic filter.

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