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Efficiency of Coagulation Process and Constructed Wetland for the Treatment of Municipal Solid Waste Landfill Leachate

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Abstract: Landfill leachate is a fluid that is from the external water which enter into the landfill solid waste, dissolve and rinse the dissolved materials including organic matter. It usually has high content of organic matter, electrical conductivity and high concentrations of nitrogen, toxic compounds and heavy metals. Hence, formation of landfill leachate threatens the public health and environment. Proper treatment of landfill leachate is therefore vital to remove hazardous components before discharge. Further, composition of landfill leachate varies from time to time and site to site. There are number of leachate treatment methods which have been used. Some methods are inefficient, and some are expensive and energy consuming and thus not suitable for many landfill sites, particularly in rural areas of developing countries. Assessment of available and affordable treatment methods for a particular landfill site is necessary to find out their efficiency in removing hazardous matters from the leachate. In this context, the present study was aimed to characterize the landfill leachate and to determine the efficiency of coagulation process and constructed wetland for the treatment of landfill leachate. Coagulation studies were performed with Alum and Calcium hydroxide at various doses to find the effect of coagulant type and its dose on removal of COD and turbidity. Constructed wetland vegetated with *typha latifolia* was used to assess its ability to remove COD, BOD_5 and NH_4-N. Landfill leachate was found to have high concentration of TDS, COD, BOD_5 and NH_4-N. It was observed that Alum can remove up to 50% COD at 15 g/l dose whilst Calcium hydroxide removes up to 75% COD at 20 g/l dose. More than 90% of turbidity could be removed by coagulation process using Alum and Calcium hydroxide. Constructed wetland removes more than 68% of COD, 70% of BOD_5 and 50% NH_4-N at seventh day of incubation. The removal efficiency increases with retention time.
Keywords: Alum, Calcium hydroxide, coagulation, constructed wetland, landfill leachate

INTRODUCTION

Generation of municipal solid waste has been accelerated due to rapid increase in population growth and industrialization, and changes in peoples' lifestyle. Issues related to disposal of generated solid waste have become challenging task all over the world. In general, solid waste is disposed in an open dump, particularly in developing countries. Open dumping is an illegal method of disposal of solid wastes and poses serious threats to water resources and soil. Municipal solid waste landfill is one of least expensive methods for disposal of solid wastes, designed to protect the environment from contaminants. The liner systems in the landfill minimize the migration of contaminants from the waste.

Landfill leachate is the liquid that drains or leaches from a landfill. The composition of leachate varies with different sites and environmental conditions, depending on nature of the deposited wastes, on soil characteristics, rainfall pattern and age of the landfill [1]. Generation of leachate is a complex combination of physical, chemical and biological processes [2]. After a landfill site is closed, a landfill will continue to produce leachate and this process could last for 3-5 decades [3]. It usually has high content of organic matter, electrical conductivity (EC) and high concentrations of nitrogen, toxic compounds and heavy metals. Landfill leachate threatens the public health and environment when migrating from the landfill and contaminates the surrounding land and water resources. Treatment of landfill leachate is therefore vital to remove the hazardous components before it enters the surrounding environment. Because, once the leachate enters the water bodies, it is very difficult to clean up the contaminated water bodies and it is very expensive too. However, treatment of landfill leachate has become a challenging task due to high fluctuations in its composition and quality, and high concentration of specific pollutants, ammonia nitrogen and COD [4].

There are two strategies which have been used in landfill leachate management. The first one is the leachate recirculation and other one is the single pass leaching [5]. Leachate recirculation process is simple method with low operational cost. However, this is most appropriate for warm areas with low rainfall. The single pass leaching strategy is widely used in landfills where the generated leachate is collected and treated to remove most of the contaminants before it is discharged into the environment. There are different methods which have been used to treat landfill leachate. Some methods are inefficient, and some are expensive and energy consuming and thus not suitable for many landfill sites, particularly in rural areas of developing countries. Hence, assessment of available and affordable treatment method/s for a particular landfill site is necessary to find out their efficiency in removing hazardous matters from the generated landfill leachate. In this context, the present study was aimed to characterize the landfill leachate and to determine the efficiency of coagulation process and constructed wetland for the treatment of landfill leachate.

MATERIALS AND METHODS

Analytical methods

Landfill leachate samples were collected from Kannagipura solid waste landfill site. The analysis was carried out according to the standard protocols and methods of American Public Health Organization [6]. The pH, EC and TDS of the leachate were measured using digital pH, digital EC and digital TDS meters, respectively. The TSS and TDS were measured by the filtration process according to the standard methods of APHA [6] and Sawyer *et al.* [7]. The turbidity of the water samples was measured by Nephelometer using optical properties of light. The BOD_5 was analysed by Winkler's titrimetric method modified by sodium azide whilst COD was determined by the standard closed reflux method using COD reactor.

Treatment methods

Coagulation/flocculation

In this study, coagulation/flocculation tests were carried out in a Jar-test apparatus. Calcium hydroxide and Alum were used as coagulants to analyse the efficiency of these coagulants in removing COD, and turbidity of the landfill leachate. Coagulants were used at various dosage (10 mg/l, 15mg/l, 20 mg/l, 25 mg/l and 30 mg/l) at optimum pH 8. This test was carried out in three steps such as (1) initial rapid mixing for 10 minutes at 200 rpm, (2) slow mixing for 30 minutes at 60 rpm, and (3) settling for 60 minutes. The supernatants after settling step were taken for chemical analysis.

Constructed wetland

A horizontal surface flow wetland of 8 m x 2 m was constructed and internally sealed with clay to the thickness of 60 cm. This liner was compacted sufficiently to minimize the infiltration and seepage losses in order to avoid possible contamination of groundwater. Thereafter, the compacted clay liner was covered by on site soil for about 30 cm and vegetated with *typha latifolia*. Leachate collected from the landfill site was poured into the constructed wetland and the effluents from the outlet were taken and analysed to evaluate the efficiency of the constructed wetland in removing BOD_5, COD and NH_4-N at 3rd, 5th and 7th days after incubation.

RESULTS AND DISCUSSIONS

Leachate characterization

Chemical composition of landfill leachate depends on several factors such as solid waste composition, landfill management, age of the waste, hydrogeological conditions in and around the landfill site, rate of water flow through the waste, landfill chemical and biological activities, temperature, moisture content and pH of landfill and seasonal weather variations. In this study, landfill leachate sample was characterized in terms of pH, TDS, TSS, COD, BOD_5, EC, NH_4-N and turbidity. Table 1 shows the general characteristics of the landfill leachate.

Table–1: Characteristics of landfill leachate

No.	Parameters	Unit	Value
1	pH	-	7.4
2	Total Dissolved Solids (TDS)	mg/l	6130
3	Total Suspended Solids (TSS)	mg/l	3254
4	Chemical Oxygen Demand (COD)	mg/l	3739
5	Biological Oxygen Demand (BOD_5)	mg/l	939
6	BOD_5/COD ratio	-	0.3
7	Electrical Conductivity (EC)	µS/cm	9042
8	Ammonium nitrogen (NH_4-N)	mg/l	1211
9	Turbidity	NTU	412

The pH is a measure of the acidic or alkalinity of water and influences most chemical and biological processes. The pH of landfill leachate ranges from 4.5 - 9 [8]. The young leachate is found to have pH less than 6.5 whilst old landfill leachate has pH higher than 7.5 [9]. The pH of the leachate sample was found to be 7.4.

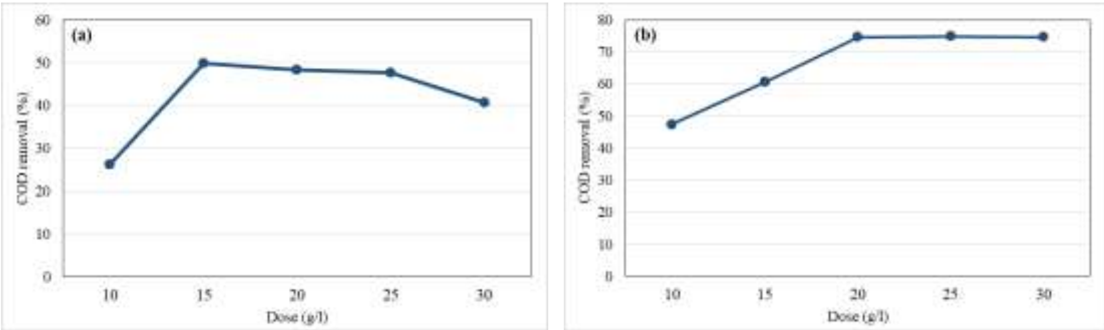
High concentration of volatile fatty acids (VFAs) leads to low pH at the initial stage [10], while stabilized leachate shows the pH values range from 7.5 - 9 [11]. Landfill leachate sample was found to have high values of TDS (6130 mg/l) and EC (9042 S/cm). In general, both of these parameters are influenced by the total amount of dissolved organic and inorganic materials. The amount of TDS reflects the extent of mineralization while EC represents the ability of water to carry an electrical current.

Organic matter is the major pollutant in wastewater which has been measured as BOD and COD [12]. The BOD is the measure of the amount of dissolved oxygen used by microorganisms to oxidize the organic matter in water. The BOD_5 (five days biological oxygen demand) is the most widely used parameter of organic pollution in wastewater and surface water. The COD is the measure of oxygen needed to completely oxidize the organic waste chemically. The initial COD and BOD_5 of leachate were 3,739 mg/l and 939 mg/l, respectively. The values of COD and BOD_5/COD ratio give information about the landfill age. The young landfill (< 5 years), in general, consists of large amount of biodegradable matter with higher COD level (>10,000 mg/l). The COD level reduces with age of the landfill. In the collected landfill leachate sample, the BOD_5/COD ratio was 0.3 and the COD value falls between 500-10,000 mg/l. Thus, this landfill site comes under medium age (5-10 years) landfill [2]. Further, TSS concentration of sample leachate was 3254 mg/l whilst the initial turbidity was 412 NTU.

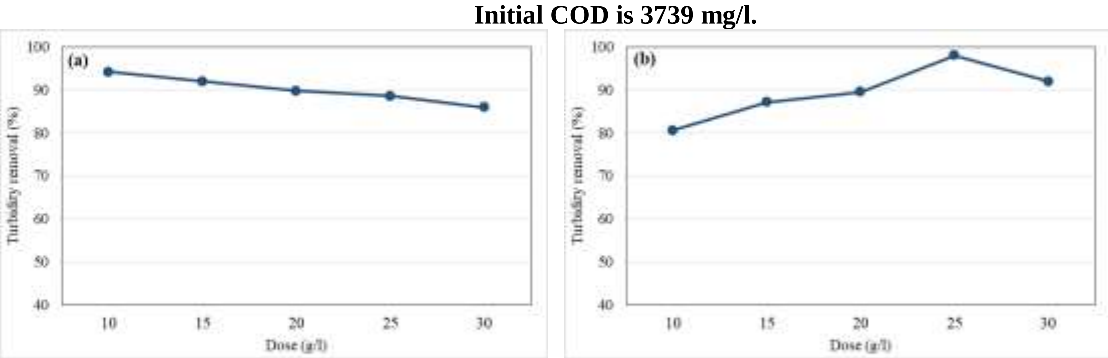
Ammonia is considered as long-term pollutant due to its stability under anaerobic condition and it represents the major proportion of total nitrogen [11]. It was found that the mean concentration of ammonia in landfill leachate ranges from 500-1500 mg/l after 3-8 years of waste placement and continues to be within this range over 50 years [13]. It was found that the leachate sample was rich in NH_4-N (1211 mg/l) due to hydrolysis and fermentation of nitrogenous fractions of biodegradable refuse substrates [14, 9]. The release of leachate containing high concentration of NH_4-N into water bodies enhances algal growth and causes eutrophication [15-16].

Effect of doses and types of coagulant on COD, TSS and turbidity removal efficiency

Different doses of Alum and Calcium hydroxide were used to find out the effect of coagulant dose on COD and turbidity removal. Figure 1 shows the effect of various doses of Alum and Calcium hydroxide on COD removal efficiency. Accordingly, about 50% of COD removal was obtained at 15 g/l dose of Alum and the removal efficiency reduces with increasing dose of Alum. In case of Calcium hydroxide, COD removal efficiency increases with increasing dose and the maximum removal of 75% was observed at 20 g/l coagulant dose and constant COD removal was found after this dose.



Fig−1: Effect of Alum (a) and Calcium hydroxide (b) doses on the removal of COD from the landfill leachate. Initial COD is 3739 mg/l.

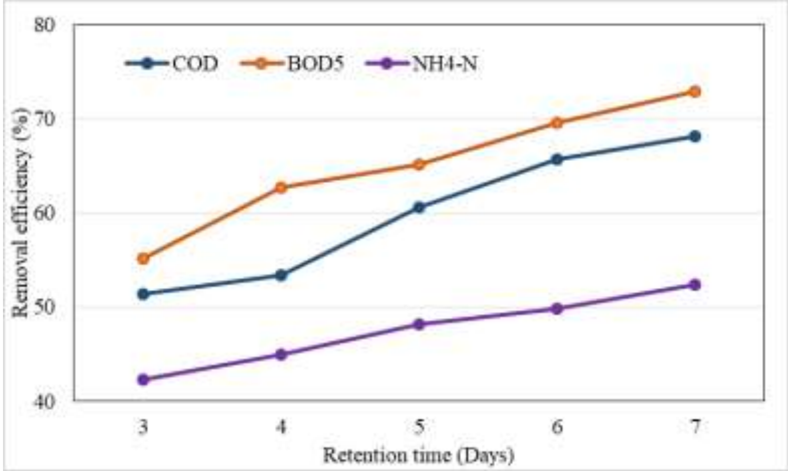


Fig−2: Effect of Alum (a) and Calcium hydroxide (b) doses on the removal of turbidity from the landfill leachate. Initial turbidity is 412 mg/l.

Nearly 94% of turbidity was removed at 10 g/l dose of Alum and the removal efficiency decreases with increasing dose (Figure 2). On the other hand, turbidity removal was increased when increase the concentration of Calcium hydroxide and the maximum removal of 98% was observed at 25 g/l dose and slightly reduced thereafter.

Effect of constructed wetland on COD, BOD_5 and NH_4-N removal efficiency

Constructed wetlands (CWs) have been widely used for over two decades to improve the quality of contaminated water and wastewaters; involve number of treatment processes including biological, chemical and physical processes [17]. It is inexpensive, simple in operation and has potential to remove organic carbon, nitrogen compounds and heavy metals [18]. Plants are an important component of constructed wetland system and their efficiency depend on several factors such as type of CWs, plant species, quality and quantity of wastewater loads etc. In this study, horizontal surface flow wetland vegetated with *typha latifolia* was used to assess its efficiency on removal of COD, BOD_5 and NH_4-N from landfill leachate. It was observed that the removal efficiency increases with retention time (Figure 3). For instance, nearly 51% of COD was removed at 3 days of incubation while 68% at seventh day. The removal efficiency is higher than the efficiency of Alum coagulation (50%) and lower than Calcium hydroxide (75%). Maximum removal of 73% of BOD_5 was obtained at seventh day. Removal efficiency of CW was relatively low for NH_4-N. Only about 52% of NH_4-N removal was recorded at seventh day of incubation.



Fig−3: Effect of Constructed wetland on the removal of COD, BOD5 and NH4-N from the landfill leachate. Initial COD, BOD5 and NH4-N are 3739 mg/l, 939 mg/l and 1211 mg/l, respectively.

CONCLUSIONS

There are different leachate treatment methods which have been used to treat landfill leachate all over the world. However, identification of efficient and cost effective method/s for a specific landfill site is necessary. From this study, it was found that Alum and Calcium hydroxide can remove nearly 50% and 75% of COD, respectively. More than 90% of turbidity could be removed by coagulation process using Alum and Calcium hydroxide. Constructed wetland vegetated with *typha latifolia* removes more than 68% of COD, 70% of BOD_5 and 50% NH_4-N at seventh day of incubation. The removal efficiency increases with retention time.

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