

Coagulation-Flocculation In Leachate Treatment By Using Ferric Chloride And Alum As Coagulant

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Leachate was treated by using coagulation-flocculation. Coagulation-flocculation as a relatively simple physical-chemical technique was applied in this study. This study examined aluminum sulfate (alum) and ferric chloride in treating a stabilized leachate, and compared the results in respect to the removal of suspended solid (SS), chemical oxygen demand (COD), color and ammoniacal nitrogen. The optimum pH for the tested coagulants was 7. The optimum dosages were 9000 mg/L for alum and 3000 mg/L for ferric chloride. Among the both coagulants, ferric chloride showed the highest SS removal efficiency (96%), color removal efficiency (84%), COD removal efficiency (37%), ammoniacal nitrogen (26%) and with settling time for 30 minute.

Keywords—Leachate, coagulation-flocculation, alum, ferric chloride

I. INTRODUCTION

Leachates are defined as the aqueous effluent generated as a consequence of rainwater percolation through wastes, biochemical processes in waste's cells and the inherent water content of wastes themselves. Leachate usually contain large amounts of organic matter, ammonia nitrogen, heavy metals, chlorinated organic and inorganic salts, which are toxic to living organisms and ecosystem (Zouboulis et al., 2008). Leachate composition depends on many factors such as the waste composition, site hydrology, the availability of moisture and oxygen, design and operation of the landfill and its age. Landfill leachate is generally characterized by a high strength of pollutants (Chen., 1996).

Leachate production starts at the early stages of the landfill and continue several decades even after closure of landfill. It is generated mainly by the infiltrated water, which passes through the solid waste fill and facilitates transfer of contaminants from solid phase to liquid phase (Parkes et al., 2007). Due to the inhomogeneous nature of the waste and because of the differing compaction densities, water percolates through and appears as leachate at the base of the site.

Depending of the on the geographical and geological nature of a landfill site, leachate may seep into the ground and possibly enter groundwater sources. Thus it can be major cause of groundwater pollution (Cook & Fritz 2002; Mor et al., 2006).

Landfill leachate has an impact on the environment because it has very dangerous pollutants such as ammonium nitrogen, biodegradable and refractory organic matter and heavy metals. In fact, the ammonium concentration in leachate found to be up to several thousand mg/L. in addition, leachate cause serious pollution to groundwater and surface waters. It is important to note that the chemical characteristic of leachate varies and as a function of a number of factors such as waste composition, the degradation degree of waste, moisture content, hydrological and climatic conditions (Sartaj et al., 2010).

Contamination of groundwater by landfill leachate, posing a risk to downstream surface waters and wells, is considered to constitute the major environmental concern associated with the measures to control leaking into the groundwater, and the significant resources spent in remediation, support the concern of leachate entering the groundwater (Veli et al., 2008). Leachate treatment facility is required before discharging leachate into the environment and this depends on several factors such as the characteristics of leachate, costs, and regulations. Specific treatment techniques can be used to treat this hazardous wastewater in order to protect the ecosystem such as coagulation-flocculation (Abdulhussain et al., 2009).

II. CHARACTERIZATION OF THE LEACHATES

The leachates were collected from Pasir Gudang sanitary landfill that located at Johor, Malaysia. The Pasir Gudang sanitary landfill with largeness of 50 acres and average 350 tonnes of waste per day. The types of solid waste at Pasir Gudang sanitary landfill were housing, domestic, commercial, industry, institutions, market and construction.

Pasir Gudang landfill leachate has very high ammoniacal nitrogen in the range 1350 mg/L to 2150 mg/L. The average values of BOD₅ and COD were

131.5 mg/L and 2305 mg/L respectively, and the ratio of BOD₅/COD of raw leachate was about 0.05. Old or stabilized leachate are usually high in pH (>7.5) and NH₄-N (>400 mg/L) and low in COD (<3000 mg/L), BOD/COD ratio (<0.1) and heavy metal (<2 mg/L) (Ghafari et al., 2010, Neczaj et al., 2005, Bashir et al., 2011). Treatment of stabilized leachate from old landfill was more effective using the physic-chemical process (Durmusoglu & Yilmaz., 2006).

III. COAGULATION-FLOCCULATION

Coagulation-flocculation is widely used for wastewater treatment. This treatment is efficient to operate. It has many factors that can influence the efficiency, such as the type and dosage of coagulant/flocculants, pH, mixing speed and time and retention time. The optimization of these factors may influence the process efficiency (Ozkan & Yekeler., 2004). Coagulation-flocculation is destabilizing the colloidal suspension of the particles with coagulants and then causing the particles to agglomerate with flocculants. After that, it will accelerate separation and thereby clarifying the effluents (Gnandi et al., 2005).

Ferric chloride (FeCl₃) and alum were chosen as coagulants for coagulation-flocculation. The experiments were carried out in a conventional jar test apparatus. For the jar test experiment, leachate samples were removed from the cold room and were conditioned under ambient temperature.

The jar test process consists of three steps which is the first rapid mixing stage; aiming to obtain complete mixing of the coagulant with the leachate to maximize the effectiveness of the destabilization of colloidal particles and to initiate coagulation. Second step is slow mixing; the suspension is slowly stirred to increase contact between coagulating particles and to facilitate the development of large flocs. After that, the third step settling stage; mixing is terminated and the flocs are allowed to settle (Choi et al., 2006; Wang et al., 2009).

Jar test was employed to optimize the variables including rapid and slow mixing, settling time, coagulant dose and pH. These variables were optimized based on the highest percentage removal of the leachate constituents. The leachate samples were adjusted to pH 7 before the addition of FeCl₃ and alum. The amount of SS, color, COD and ammoniacal nitrogen removal were determined after coagulation-flocculation. 10% solution of ferric chloride and alum were used as solution in the experiments.

IV. RESULTS AND DISCUSSION

A. Rapid mixing speed and rapid mixing time

Coagulants are added to the flowing water and a high and fast intensity mixing is started. The

main target is to get complete mixing of the coagulant with wastewater in order to increase the effectiveness of colloidal particles which are destabilized and then starts coagulate (Rossini et al., 1999; Rivas et al., 2004; Amokrane et al., 1997). During the rapid mixing step, the velocity varied between 70 and 300 rpm and the period between 1 to 6 minutes in most cases and duration of 30 minutes.

In FeCl₃ coagulation, the results of the effects for different duration and speed of FeCl₃ as coagulant on the removal of SS, color, COD and ammoniacal nitrogen from the landfill leachate were shown in the Figure 2.1 and Figure 2.2. The optimum rapid mixing was 3 min at 150 rpm.

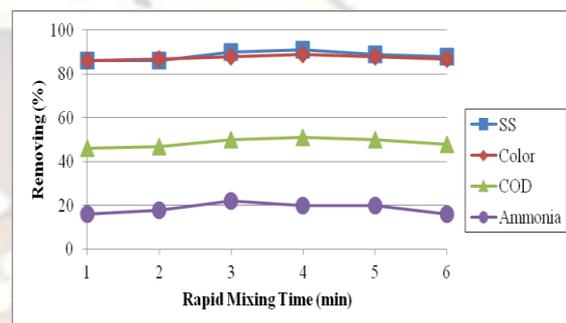


Figure 3.1: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for rapid mixing time in 150 rpm, 2000 mg/L ferric chloride, pH 7, slow mixing in 20 rpm for 20 minute and the settling time of 30 minute.

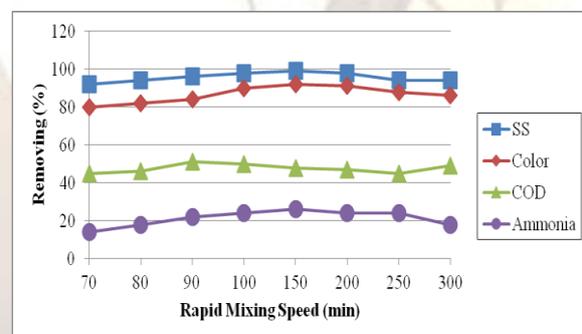


Figure 3.2: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for rapid mixing speed in 4 minute, 2000 mg/L ferric chloride, pH 7, slow mixing in 20 rpm for 20 minute and the settling time of 30 minute.

In alum coagulation, the results of the effects for different duration and speed of alum as coagulant on the removal of SS, color, COD and ammoniacal nitrogen from the landfill leachate were shown in the Figure 2.3 and Figure 2.4. The optimum slow mixing was 20 min at 30 rpm.

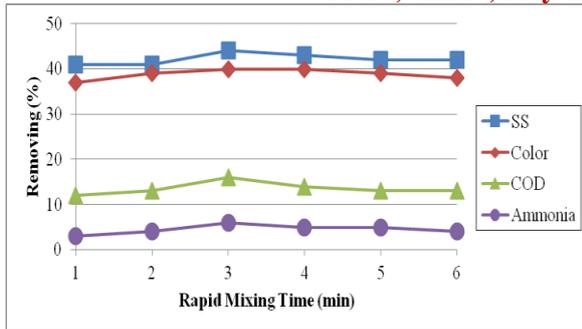


Figure 3.3: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for rapid mixing time in 150 rpm, 2000 mg/L alum, pH 7, slow mixing in 20 rpm for 20 minute and the settling time of 30 minute.

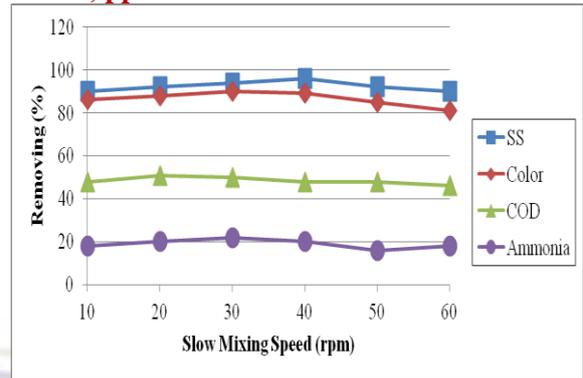


Figure 3.6: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for slow mixing speed in 25 minute, 2000 mg/L ferric chloride, pH 7, rapid mixing in 150 rpm for 4 minute and the settling time of 30 minute.

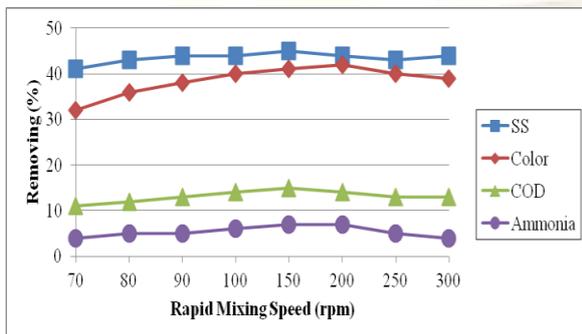


Figure 3.4: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for rapid mixing speed in 3 minute, 2000 mg/L alum, pH 7, slow mixing in 20 rpm for 20 minute and the settling time of 30 minute.

B. Slow mixing speed and slow mixing time

Through the slow mixing step, the speed varied between 10 to 60 rpm and the period from 5 to 30 minute with the duration of 30 minute.

In $FeCl_3$ coagulation, the results of the effects for different duration and speed of $FeCl_3$ as coagulant on the removal of SS, color, COD and ammoniacal nitrogen from the landfill leachate were showed in the Figure 2.5 and Figure 2.6.

In alum coagulation, the results of the effects for different duration and speed of alum as coagulant on the removal of SS, color, COD and ammoniacal nitrogen from the landfill leachate were showed in the Figure 2.7 and Figure 2.8

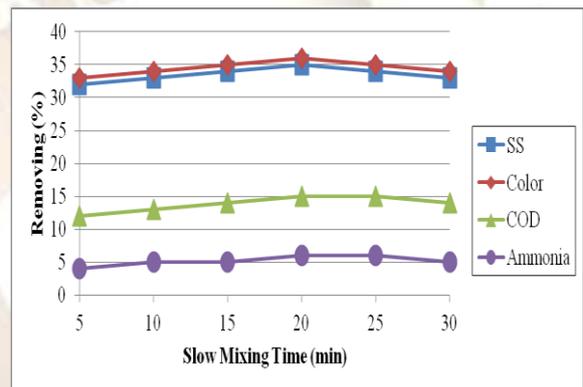


Figure 3.7: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for slow mixing time in 20 rpm, 2000 mg/L alum, pH 7, rapid mixing in 150 rpm for 3 minute and the settling time of 30 minute.

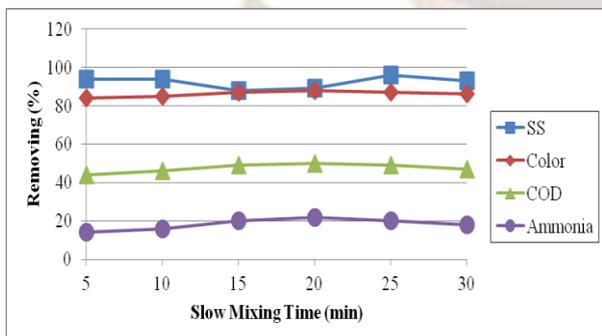


Figure 3.5: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for slow mixing time in 20 rpm, 2000 mg/L ferric chloride, pH 7, rapid mixing in 150 rpm for 4 minute and the settling time of 30 minute.

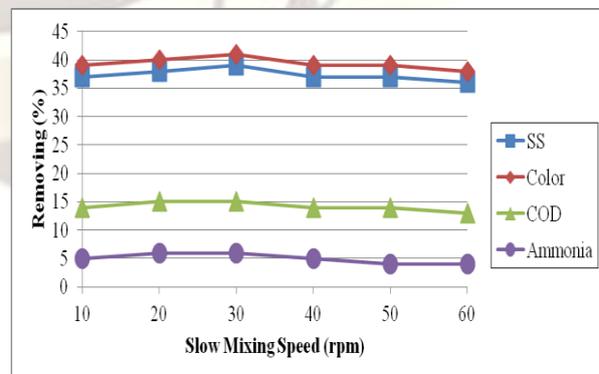


Figure 3.8: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for slow mixing speed in 20 minute, 2000 mg/L alum, pH 7, rapid mixing in 150 rpm for 3 minute and the settling time of 30 minute.

C. Settling time

The highest percentage of removal in SS, colour, COD and ammoniacal nitrogen were 40%, 18% and 6% for alum and 90%, 83%, 52% and 26% for ferric chloride. The percentage for alum and ferric chloride was in the same settling time which is 30 minutes. In coagulation-flocculation process, normally the settling time was about 30 minutes (Baeza et al., 2004). For the experiment, it showed no improvement in coagulation-flocculation process for settling times longer than 30 minutes. In the settling step, the duration of time different from 10 to 300 minute.

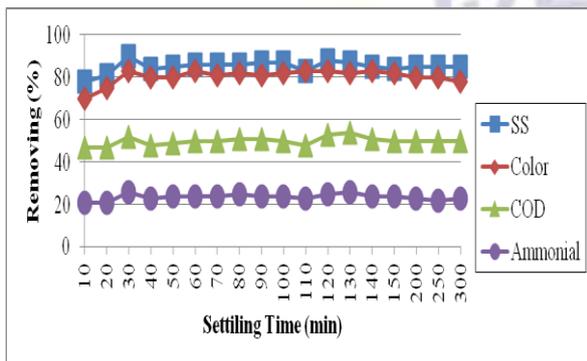


Figure 3.9: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for rapid mixing in 150 rpm for 3 minute, 2000 mg/L ferric chloride, pH 7 and slow mixing in 30 rpm for 20 minute.

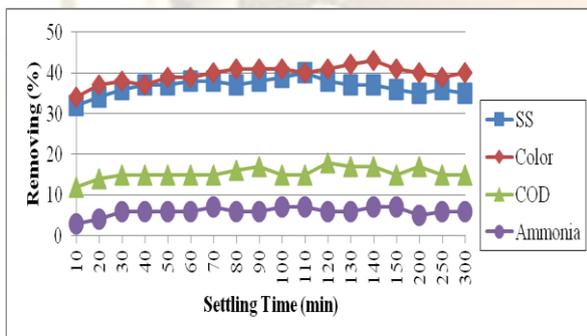


Figure 3.10: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for settling time, rapid mixing in 150 rpm for 3 minute, 2000 mg/L alum, pH 7 and slow mixing in 30 rpm for 20 minute.

D. Effect of pH

The pH influences the nature of produced polymeric metal species that will form as soon as the metal coagulants are dissolved in water (Guo et al., 2010). It was noticed that at pH 2 and pH 12 the colour of the supernatant was brown. The colour intensity reduced gradually as the pH approached the optimum. Eventually, it was light yellow at pH 7. Lower removal of COD was observed at higher pH. Coagulation-flocculation was most effective in the lower pH range in leachate treatment (Li et al., 2010).

Experiments were conducted at different pH while maintaining the concentration of $FeCl_3$ and alum at the 2000 mg/L. the optimum removal of pollutants using $FeCl_3$ and alum was at pH 7 and the removal decreased slowly after pH 7. $FeCl_3$ was effective in removing SS, colour, COD and ammoniacal nitrogen by 92%, 82%, 28% and 26% respectively compared with alum by 68%, 78%, 33% and 14% respectively. Alum was very effective in removal of color compared to SS, COD and ammoniacal nitrogen.

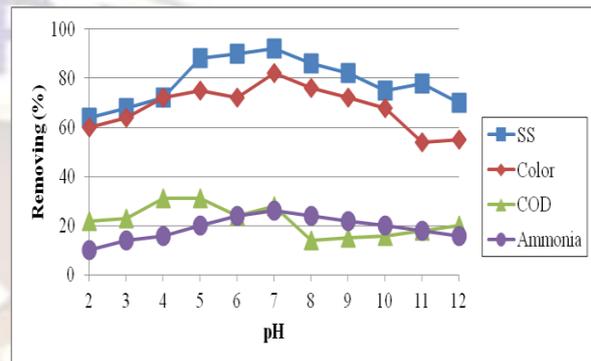


Figure 3.11: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for pH by using 2000 mg/L ferric chloride, rapid mixing speed in 150 rpm for 4 minute, slow mixing speed in 30 rpm for 20 minute and the settling time of 30 minute.

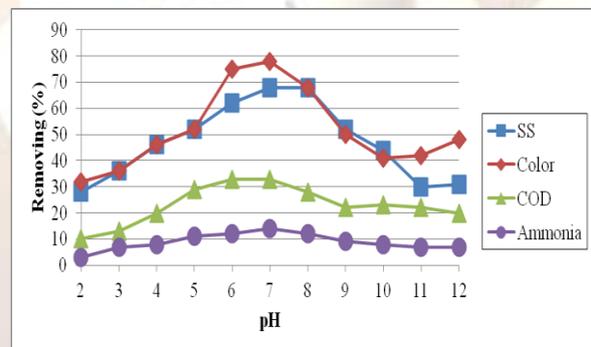


Figure 3.12: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for pH by using 2000 mg/L alum, rapid mixing speed in 150 rpm for 3 minute, slow mixing speed in 30 rpm for 20 minute and the settling time of 30 minute.

E. Effect of coagulant dosage

Based on the results, the coagulants dose that gave the highest percentage of SS, colour, COD and ammoniacal nitrogen was chosen as the optimum coagulant dose. The highest removals of SS, colour, COD ammoniacal nitrogen were obtained by 3000 mg/L ferric chloride and 9000 mg/L alum. The percentage removals were 96%, 84%, 37% and 26% respectively for ferric chloride. For alum, the percentage removals were 89%, 92%, 46% and 26% respectively. As seen from results, the percentage

removal of pollutants was increased with increasing coagulant dosage up to an optimum dosage and beyond which the removal percentage of pollutants decreased slowly (Park et al., 2008; Makhtar et al., 2010).

Ferric chloride exhibited good performance in removing color comparing to other parameter. When the dosage of ferric chloride was increased beyond 3000 mg/L, the removal efficiency decreased. With the addition of larger dosage of the coagulant, the surface charge of the particle gets reversed due to continued adsorption of mono- and polynuclear hydrolysis species of ferric chloride. As the colloidal particles become positively charged, they cannot be removed by perikinetic flocculation. The removal of color increased drastically with an increase of ferric chloride dose at pH 7. The results obtained from jar test experiment by comparing the performance of ferric chloride alum in removing SS, color, COD and ammoniacal nitrogen at different dosages of ferric chloride and alum

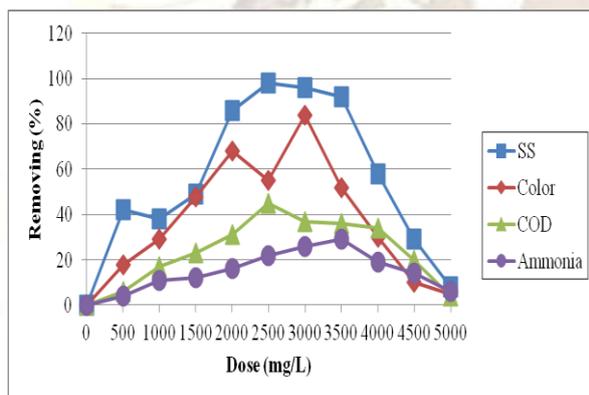


Figure 3.13: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for dose ferric chloride in pH 7, rapid mixing speed 150 rpm for 4 minute, slow mixing speed 30 rpm for 20 minute and the settling time of 30 minute.

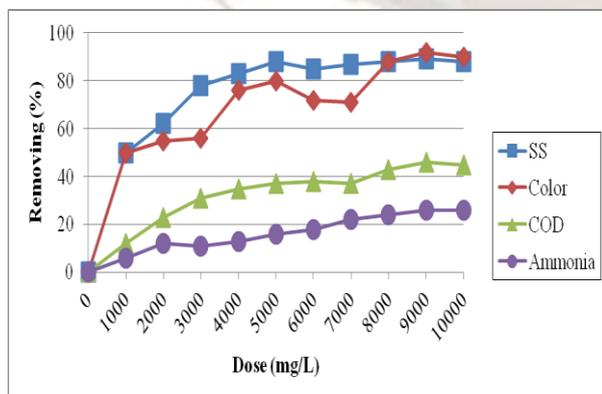


Figure 3.14: Percentage of removal in SS, colour, COD and ammoniacal nitrogen for dose alum in pH 7, rapid mixing speed 150 rpm for 3 minute, slow mixing speed 30 rpm for 20 minute and the settling time of 30 minute.

V. CONCLUSION

Results showed that the ferric chloride was more effective in leachate treatment compared with alum. Alum was categories as low efficiency in leachate treatment. However, alum was achieved higher percentage removal in colour.

The results showed the percentage change in the removal of suspended solid (SS), colour, COD, and ammoniacal nitrogen in the sample of leachate treated by using 2000 mg/L alum and 2000 mg/L ferric chloride for optimum pH. SS, color, COD and ammoniacal nitrogen removal as a function of alum and ferric chloride dosage is shown at different pH values (from pH 2 to pH 12). The highest percentage of removal in SS, colour, COD and ammoniacal nitrogen are 68%, 78%, 33% and 14% for alum and 92%, 82%, 28% and 26% for ferric chloride. The percentage of alum and ferric chloride were increased until achieved optimum dose and decrease slowly after that. Ferric chloride provides the highest percentage of removal in SS, colour, COD and ammoniacal nitrogen compared with alum. Dose optimum alum and ferric chloride was 9000 mg/L and 3000 mg/L respectively.

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