MECHANICAL COAGULATION PROCESS OF LANDFILL LEACHATE IN REMOVING COD, AMMONIA (NH_3) AND COLOUR USING POLY-ALUMINIUM CHLORIDE (PAC) AND ALUM

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Abstract

Sanitary landfill leachate is considered as heavily polluted industrial wastewater, which has extremely high pollution load that may pollute subsoil and ground water. Special attention must be paid for its perfect collection and efficient treatment before disposal. This study was conducted to treat the partially stabilized leachate using coagulation-flocculation process as a single treatment method. Jar test experiments were employed in order to determine the optimum chemical and physical variables including coagulant dose, pH and speed of rapid and slow mixing. Two coagulants were tested in this work : Poly-aluminium chloride (PAC) and aluminium sulfate (alum). Performance of PAC which is not widely used in leachate treatment was the main focus of this study. Efficiency of alum as a conventional coagulant in wastewater treatment was determined to compare with PAC effectiveness. The optimum condition was applied to determine the removal of colour, chemical oxygen demand (COD) and ammonia (NH_3) using both coagulants.

Introduction

Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it. In most landfills the liquid portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquid that has entered the landfill from external sources, such as precipitation and runoff (Peavy *et al.*, 1985).

Due to the cost implication, considerable attention must be given in selecting the most environmentally responsible, cost effective alternative for treatment leachate and disposal. Leachate treatment needs depend upon the final disposition of the leachate. Leachate treatment is often difficult because of high organic strength, irregular production rates and composition, variation in biodegradability and low phosphorous content (if biological treatment is considered). Coagulation-flocculation is a widely used method in wastewater treatment plants. However, its usage on leachate is quite limited. No study reported to date on its use on leachate. Poly-aluminium chloride as a known coagulant in water treatment is not widely used in leachate treatment. PAC was examined in this study to remove COD, NH_3 and colour in lab scale experiments.

Experimental

Materials

The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. Since the range of measured COD in previous studies for the same leachate was high, COD was measured in accordance with the “5220 D- closed reflux, colourimetric method” of the standard methods for the examination of water and wastewater (APHA, 1992) was followed. Ammonia was determined at 425 nm using a DR2010 spectrophotometer, using the Nessler Method, method 8038 (Hach Company Procedure), adapted from standard methods for the examination of water and wastewater. Colour was determined at 455 nm using a DR2010 spectrophotometer, using the APHA Platinum-Cobalt standard method, method 8025 (Hach Company Procedure), adapted from standard methods for the examination of water and wastewater.

Procedures

Coagulation-flocculation and further sedimentation experiments were carried out in a conventional jar test apparatus with six agitators, equipped with 6 corresponding beakers. Agitation was mechanically implemented by using an impeller with a 2.5cm x 7.5cm blade. The time and speed of mixing during rapid and slow mixing were controlled automatically by a timer installed a jar test apparatus. For jar test experiment, leachate samples were removed from the cold room and were conditioned for about 1 hour under ambient temperature. Sample container was thoroughly shaken for re-suspension of possible settling solids. 500 mL of raw leachate or pH adjusted leachate was transferred into the cylindrical beakers of 1 L of capacity. Jar test process consists of three distinct steps (Zamorano, M. *et al*. 2004):

1. Rapid mixing stage: the coagulant is added to the influent water and a rapid and high-intensity mixing is initiated. The objective is to obtain complete mixing of the coagulant with the wastewater to maximize the effectiveness of the destabilize colloidal particles and to initiate coagulation.
2. Slow mixing stage: the suspension is slowly stirred to increase contact between coagulating particles and to facilitate the development of large flocs.
3. Settling time: mixing is terminated and the flocs are allowed to settle.

Jar test was applied to optimize the variables including coagulant dose, pH and speed of rapid and slow mixing, respectively. These variables were optimized based on the highest percentage removal of leachate characteristic in the supernatant.

Result and discussion

Jar test as a conventional method which has been used more than 50 years was applied to optimize the variables including coagulant dose, pH and speed & duration of rapid & slow mixing (Zamorano *et al.*, 2004). In this study poly-aluminium chloride and alum were examined. Following the same study by Amokrane, *et al*., (1997) several coagulant doses were tested at neutral pH using PAC and alum separately. The results of experiments are presented in Figure 1 and 2. It can be observed that the optimal coagulant dose (OpCD) of PAC was extremely different as compared to alum. The experimental data revealed that the OpCD values were 1.9 g/L and 9.4 g/L respectively for PAC and alum. Removal percentage increases with increase in the dosage up to the optimum dose. The results indicated that the removal of NH_3 was fairly low for PAC but can reach maximum value of 20% for alum.

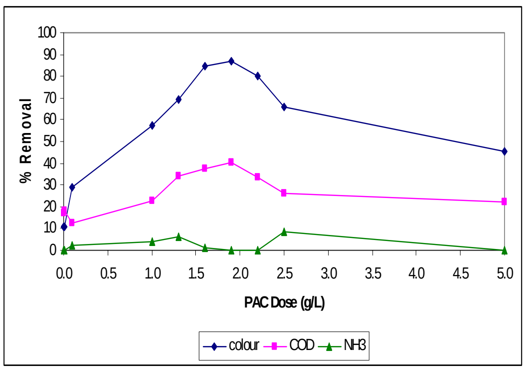

Figure 1: Percentage reduction of COD, colour and NH_4-N vs PAC dose. Test performed at neutral pH.

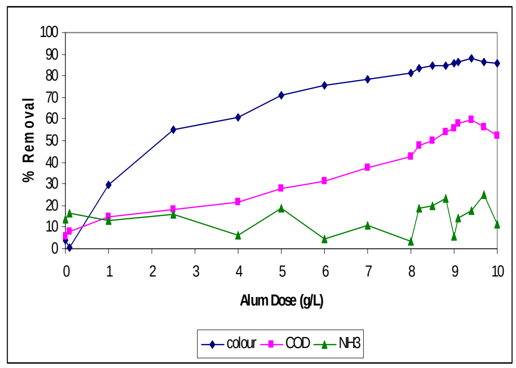

Figure 2: Percentage reduction of COD, colour and NH_4-N vs alum dose. Test performed at neutral pH.

To investigate the best pH, in which the best percent reduction of leachate characteristics occurred, different pH values were tested whereas optimum coagulant dose was applied to perform coagulation-flocculation. The range of examined pH between 2 to 12 while the original pH value of raw leachate was 8.44. Sulfuric acid (H_2SO_4, 5N) and sodium hydroxide (NaOH, 5N) were used for pH adjustment. Optimization of pH was carried out through 3 series of jar test for each coagulant. According to Figure 3 and 4, higher efficiency of coagulation-flocculation with PAC in pH range of 7.5 to 8.5 (approximately near to original pH) was obtained. According to obtained results the optimum pH was determined 7.5 with OpCD of PAC. Results from the same experiments for alum revealed that high removal efficiency was achieved in pH range of 6.5 to 8 and the optimum pH was 7.

To investigate the proper speed of rapid mixing, several experiments were performed in the wide speed range of 80 to 300 rpm at 45 seconds. OpCD and optimum pH were applied during experiments in different speeds were tested. Figure 5 and 6 show the investigation of the effect of different speeds (80, 100, 150, 200, 250 and 300 rpm) during 60 seconds. Consequently, the best removal observed in speed 80 and 100 rpm for alum and PAC. To investigate the appropriate speed of slow mixing which facilities the best contact between coagulating to develop large particles speed range of 10 to 60 rpm at 15 minutes were examined. OpCD, optimum pH and optimum speed of rapid mixing were studied in which different speeds of slow mixing were examined. Figure 7 and 8 present the effectiveness of slow mixing speed on efficiency of coagulation-flocculation using PAC and alum, respectively. Results shows that the best parameter removal achieved at the speed of 40 rpm during 15 minutes using PAC and speed of 30 rpm during 15 minutes using alum.

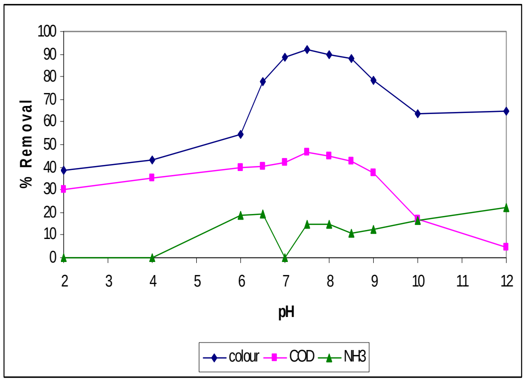

Figure 3: Percentage reduction of COD, colour and NH_4-N vs pH. Tests performed with OpCD of PAC.

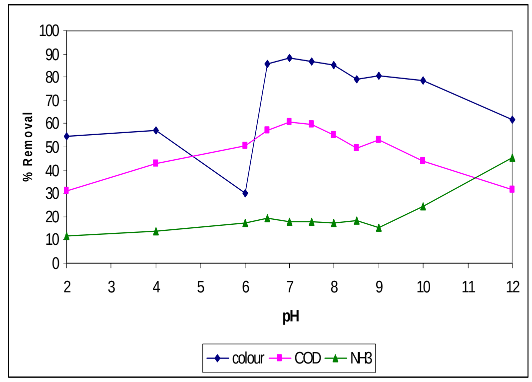

Figure 4: Percentage reduction of COD, colour and NH_4-N vs pH. Tests performed with OpCD of alum.

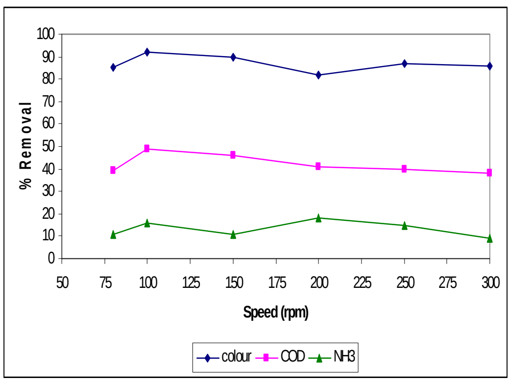

Figure 5: Percentage reduction of colour, COD and NH_3 vs speed of rapid mixing. Tests performed with OpCD and pH of PAC.

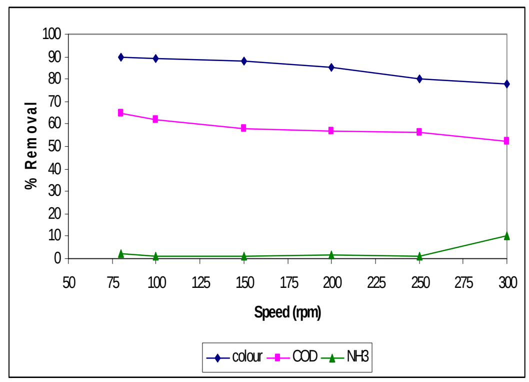

Figure 6: Percentage reduction of colour, COD and ammonia vs speed of rapid mixing. Tests performed with OpCD and pH of alum.

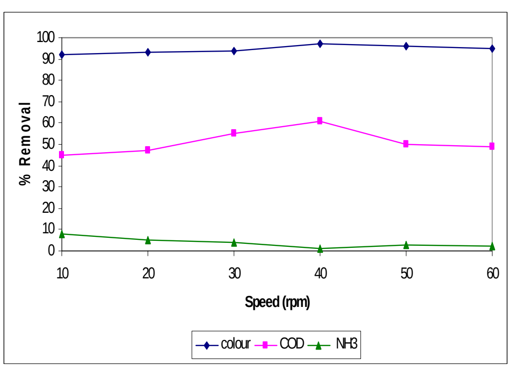

Figure 7: Percentage reduction of colour, COD and NH_3 in different speed of slow mixing. Tests performed with OpCD, pH and rapid mixing parameter using PAC.

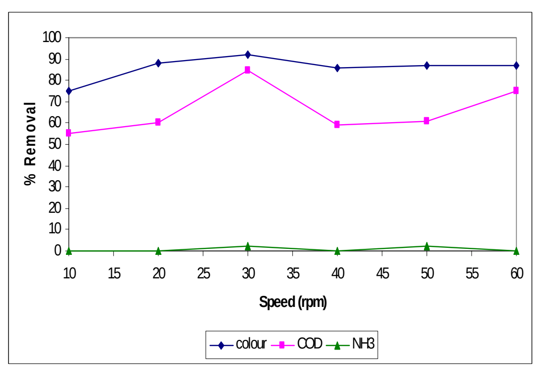

Figure 8: Percentage reduction of colour, COD and NH_3 in different speed of slow mixing. Tests performed with OpCD, pH and rapid mixing parameter using alum.

To investigate the effectiveness of settling time different settling times in the range of 30 to 120 minutes was experienced. Coagulation-flocculation performed while the prior achieved optimum parameters were applied. Supernatant was collected at different settling time of 30, 60, 90 and 120 minutes. Characteristics of collected supernatants revealed that there is no improvement in coagulation-flocculation due to settling time expansion. Nevertheless, settling time expansion caused more sludge compaction and less volume in wet sludge. Sludge compaction was observed strikingly during first hour, but not noticeable beyond.

Conclusion

The optimum reduction of COD, colour and NH4-N were obtained by adding 1.9 g/L PAC at pH 7.5 while the optimum dose and pH were 9.4 g/L and 7, respectively for alum. The optimum rapid mixing speed for PAC and alum were 100 and 40 rpm, respectively for 60 seconds, and the optimum of slow mixing for PAC and alum were 40 rpm for 15 minutes and 30 rpm for 15 minutes, respectively. Results indicated that, 97% removal of colour was obtained by PAC, whereas alum was capable of removing 92% of colour, respectively. COD removal by alum was 84.5% but only 61% removal of COD was achieved by PAC. However, the removal of NH_3 was fairly low and future studies are necessary to obtain its removal. Experiment observations indicated that large amount of sludge was produced by both coagulants, whereas deep scum generation was observed using high dose of PAC. This scum was partially stable and remained hours after sedimentation time.

References

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