Coagulation-Flocculation In Leachate Treatment Using Combination Of PAC With Cationic And Anionic Polymers

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Abstract

A study was conducted to treat the leachate through coagulation-flocculation. Polyaluminium chloride (PAC) was used as coagulant with cationic and anionic polymers as coagulant aids. The results were subsequently compared with the study in which PAC was used alone for the treatment. Jar test apparatus was used to conduct research work. The results of the study revealed that the combination of PAC with cationic polymer resulted in optimum for suspended solid (SS) removal of 99.2%, color removal of 89.8%， COD removal of 59% and ammoniacal nitrogen removal of 49%. The combination of PAC with anionic polymer resulted in optimum for SS removal of 99%, color removal of 89.4%, COD removal 56% and ammoniacal nitrogen 46%. The results of the above combinations were compared with those when PAC was used alone for the treatment.

keywords—coagulation-flocculation, leachate, coagulant, polymer

I. INTRODUCTION

Landfill leachate is defined as any contaminated liquid effluent percolating through deposited waste and emitted within a landfill or dump site through external sources, of which its route of exposure and toxicity often remains unknown. Throughout recent decades, the wastewater treatment industry has identified the emission of organic, inorganic and heavy metals compounds due to leachate seepage into the waterways as a risk the natural environments (Ghafari et al., 2010).

Landfill leachate can be a significant environmental contaminant if it leaves the landfill site, which can occur if the site is designed as a dilute and disperse site, if the landfill is unlined or if the landfill is lined but the lining fails. Typically, leachate that leaves a landfill site will enter the ground water as a contaminant plume, where it is then diluted and also transformed by a variety of processes such as sorption, chemical precipitation and microbial degradation. Heavy metals are a concern due to their adverse effect on the environment, through very low concentration of Heavy metals are observed in the methanogenic(Li et al 2010).

Leachate composition varies significantly among landfills, depending on waste composition, waste age, climate, hydrogeological conditions and land filling technology. The main characteristic of landfill leachate is high concentration of organic matter and as a result, high concentration of BOD and COD. The management of leachate is among the most important factors to be considered in planning, designing, operation, and long term management of municipal solid waste (MSW) landfill (Rivas et al, 2004).

Leachate treatment technique can be classified as combined treatment with domestic sewage, biological treatment and physic-chemical methods. Selections of the most appreciate method for leachate treatment is very important but often difficult because of the highly variable quantity and quality of landfill leachate (Sartaj et al., 2010, Bashir, et al., 2011).

Sanitary landfill is defined as a land disposal site that applies an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the solid wastes to the smallest practical volume, and applying and compacting cover material at the end of each day. Sanitary landfilling is an acceptable and recommended method for ultimately disposing of solid waste. The sanitary landfill is an engineered landfill that requires sound and detailed planning and specification, careful construction, and efficient operation (Al – Abdali et al., 2008, Al – Yaqout et al., 2005).

Coagulation-flocculation is a relatively simple technique that may be employed successfully for the treatment of landfill leachate. The removal mechanism of this process mainly consists of charge neutralization of negatively charged colloids by cationic hydrolysis products, followed by incorporation of impurities in an amorphous hydroxide precipitate through flocculation (Wang et al., 2009).

II. COAGULATION-FLOCCULATION

Coagulation-flocculation has been employed for the removal of non-biodegradable organic compounds and heavy metals from landfill leachate. The coagulation process destabilizes colloidal particles by the addition of a coagulant. Coagulation is usually followed by flocculation of the unstable particle into bulky floccules so that they can settle more easily. The general approach for this technique includes pH adjustment and involves the PAC as the coagulant to overcome the repulsive forces between the particles (Gnandi et al., 2005; Tatsi et al., 2003).

In water treatment, coagulation and flocculation are still essential components of the overall suite of treatment processes. From an engineering survey of the quality of water treatment at water treatment plants, the chemical pretreatment prior to filtration is more critical to success than the physical facilities at the plant. Coagulation and flocculation are useful because the flocculated particles can reduce fouling by producing more permeable deposits (Gnandi et al., 2005; Golob et al., 2005).

The removal of SS, color, COD and ammoniacal nitrogen form stabilized leachate was investigated using coagulation with PAC and polymers. pH and coagulant dosage has been observed to significantly affect to efficiency of coagulation and flocculation process. The best conditions for coagulation and flocculation tests on SS, color, COD and ammoniacal nitrogen removal are evaluated and optimized (pH and coagulant dosage) by a jar test technique. The first, effect of pH values and then coagulant and coagulant aids dosage on the efficiency was evaluated. The optimum pH for the treatment was determined. The study was carried out between the pH values of 2 -12. Desired pH values of leachate were adjusted by using H_2SO_4 and NaOH.

III. MATERIAL

A. Sampling

Leachate samples were collected from Pasir Gudang sanitary landfill, Pasir Gudang, Johor, Malaysia. Leachate was collected from the leachate collection pond. The sample was the raw sample and it was without any treatment.

B. Coagulant

The commonly used metal coagulants fall into two general categories: those based on aluminum and those based on iron. The aluminum coagulants include aluminum sulfate, aluminum chloride, sodium aluminate, aluminum chlorohydrate, poly aluminum chloride, poly aluminum sulfate chloride, poly aluminum silicate chloride, and forms of poly aluminum chloride with organic polymers. The iron coagulants include ferric sulfate, ferrous sulfate, ferric chloride, ferric chloride sulfate, poly ferric sulfate, and ferric salts with organics polymers (Gurses et al., 2003; Casey., 1997).

C. Polyaluminium chloride (PAC)

PAC is a group of highly effective coagulants in water treatment that have replaced a large part of traditional aluminous coagulants because of low dosage, high efficiency, low cost and convenient usage. In order to improve the coagulation efficiency and to suit different conditions, many sorts of PAC with different organic polymers has been investigated. It is more effective coagulation species in polyaluminum coagulants due to its strong charge neutralization capability, high structure stability and nanometer molecular diameter (Li et al., 2010; Zhang et al., 2008).

Polymer as a coagulant aids in the treatment of water and wastewater. It also used as primary coagulant for the same treatment. Generally, a little amount of polymer dosage is enough to reach high efficiency. Cationic polymer was the most effective followed by anionic and non-ionic (Zahrim et al., 2011). The improvement in removal by PAC while using polymers as a coagulant aids was studies by varying the PAC dose and adding a fixed dose of a polymer. The optimal combination of PAC and polymers doses that fixed 2000 mg/L PAC and use 5 mg/L for cationic polymer or anionic polymer. All these polymers were in dry form and it were prepared in 1% solution by using distilled water.

D. Polymers

Polymers refer to a large variety of natural or synthetic, water soluble, macromolecular compounds, which have the ability to destabilize or enhance flocculation of the constituents of a body of water. Although natural polymers products have the advantage of being virtually toxic free, the use of synthetic polymers is more widespread (Sun et al., 2011). This experiment aims to identify the effectiveness and capabilities of polymers to increase the percent removal of suspended solids (SS), color, COD and ammoniacal nitrogen (NH_3N) in the leachate sample. Two types of coagulant aids were used in this part that was cationic polymer FO4290 SH and anionic polymer AN934 SH.

IV. COMPOSITION AND CHARACTERISTICS OF LEACHATE

Leachate tends to percolate downward through solid waste, continuing to extract dissolved or suspended materials. In most landfills, leachate seeps through the landfill from external sources, such as surface drainage, rainfall, groundwater, and water from underground springs, as well as from the liquid produced from the decomposition of the waste. Many factors influence the production and composition of leachate. One major factor is the climate of the landfill. For example, where the climate is prone to higher levels of precipitation, there will be more water entering the landfill and therefore more leachate generated. Another factor is the site topography of the landfill, which influences the runoff patterns and again the water balance within the site (Tzoupanos & Zouboulis, 2010; Maleki et al, 2009).

The composition of leachate is important in determining its potential effects on the quality of nearby surface water and groundwater. Contaminants carried in leachate are dependent on solid waste composition and on the simultaneously occurring physical, chemical and biological activities within the landfill. The quantity of contaminants in leachate from a completed landfill where no more waste is being disposed of can be expected to decrease with time, but it will take several years to stabilize. Landfill more than 10 years old was in the methanogenic phase and the leachate was produced as stabilized leachate (Bashir et al., 2011; Durmusoglu et al., 2006).

V. RESULT AND DISCUSSION

Coagulation-flocculation process was conducted for the leachate treatment. Jar tests were carried out in order to establish a practical to find the optimum pH. SS and color removal seems to be quite efficient with the PAC and polymer. The removal efficiencies can reach over 80%.

A. Effect of settling time

The highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 96%, 86%, 49% and 29% for PAC in the Figure 4.1. The percentage for PAC 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.

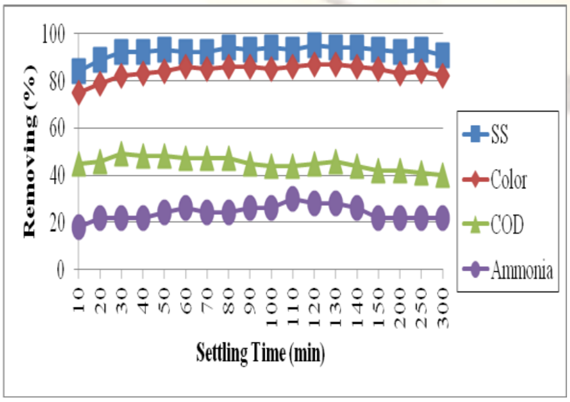

Figure 4.1: Percentage of removal in SS, color, COD and ammoniacal nitrogen for settling time, rapid mixing in 150 rpm for 3 minute, 2000 mg/L PAC, pH 7 and slow mixing in 30 rpm for 20 minute.

For cationic polymer, the highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 99%, 94%, 57% and 33% for PAC. For anionic polymer, the highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 99%, 91%, 54% and 28% for PAC. The results showed in the Figure 4.2 and Figure 4.3.

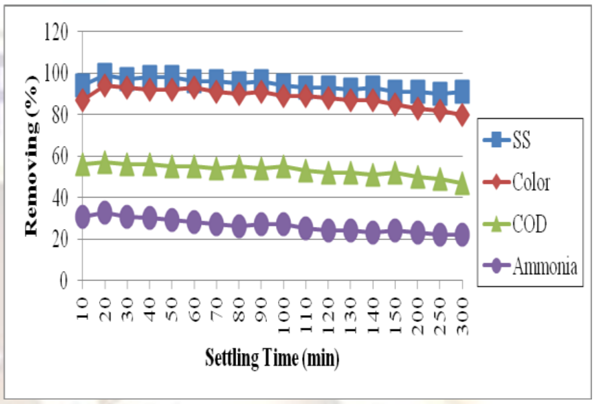

Figure 4.2: Percentage of removal in SS, color, COD and ammoniacal nitrogen for settling time, rapid mixing in 150 rpm for 3 minute, 2000 mg/L PAC, pH 7,slow mixing in 30 rpm for 20 minute and 10 mg/L cationic polymer.

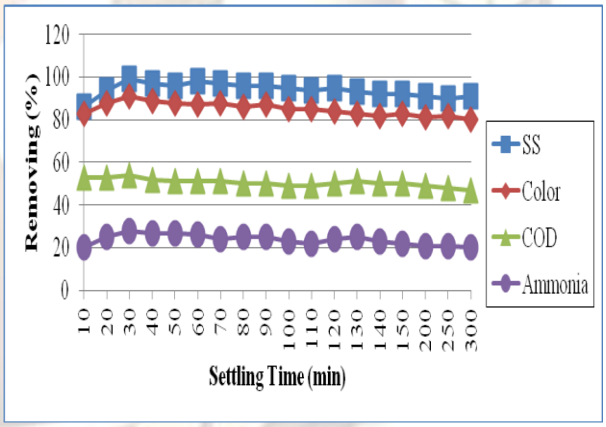

Figure 4.3: Percentage of removal in SS, color, COD and ammoniacal nitrogen for settling time, rapid mixing in 150 rpm for 3 minute, 2000 mg/L PAC, pH 7, slow mixing in 30 rpm for 20 minute and 10 mg/L anionic polymer

B. Effect of pH on coagulation

In the coagulation-flocculation process, pH is very importance since the coagulation occurs within a specific pH range for coagulant. In this study, a wide range of pH between 2 –12 was selected (Tatsi et al., 2003). pH is an important parameter for coagulation process since it controls hydrolysis species. Results showed the optimum pH for 7 provides the highest percentage of removal in SS, color, COD and ammoniacal nitrogen for the PAC. The highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 98%, 92%, 80% and 31% for PAC in the Figure 4.4. The removal percentage decreased slowly when pH was greater than 7. It was also found that the SS, color, COD and ammoniacal nitrogen removal increased slightly at the 2000mg/L dose of PAC.

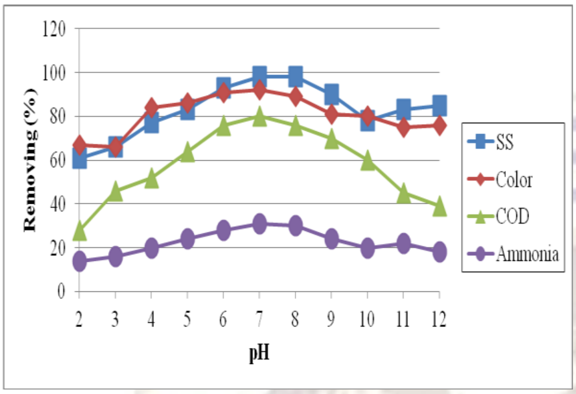

Figure 4.4: Percentage of removal in SS, color, COD and ammoniacal nitrogen for pH by using 2000 mg/L PAC, rapid mixing speed in 150 rpm for 3 minute, slow mixing speed in 30 rpm for 20 minute and the settling time of 30 minute.

C. Effect of PAC

Results showed the optimum dose with increase the dose of PAC in the Figure for different dosage of PAC (500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500 and 5000 mg/L). PAC provides the highest percentage of removal in SS, color, COD and ammoniacal nitrogen. Dose optimum PAC, alum and ferric chloride was 2000 mg/L. The highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 96%, 95%, 58% and 35% for PAC in the Figure 4.5.

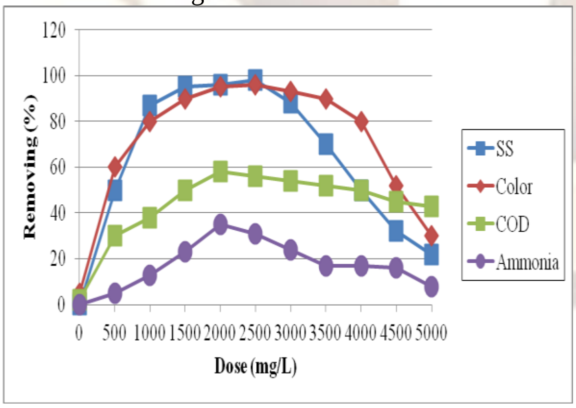

Figure 4.5: Percentage of removal in SS, color, COD and ammoniacal nitrogen for dose PAC in pH 7, rapid mixing speed 150 rpm for 3 minute, slow mixing speed 30 rpm for 20 minute and the settling time of 30 minute.

D. Effect of polymers

Synthetic polymers were added to improve settling characteristics. It was observed that the addition of polymer significantly for leachate treatment (Haydar et al., 2009; Aboulhassan et al., 2006). With the addition of an effective polymer, the highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 99.2%, 89.8%, 59% and 49% for PAC mixed with cationic polymer that showed in the Figure 4.6. The percentage of anionic polymer was lowered compared to cationic polymer. The highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 99%, 89.4%, 56% and 46% for PAC mixed with anionic polymer that showed in the Figure 4.7. The figure showed resulted of the removal in SS, color, COD and ammoniacal nitrogen improved slightly from 0 mg/L to 10 mg/L doses of polymer. The SS improved over 90% to an almost complete removal to 100% at 5 mg/L dose of polymer.

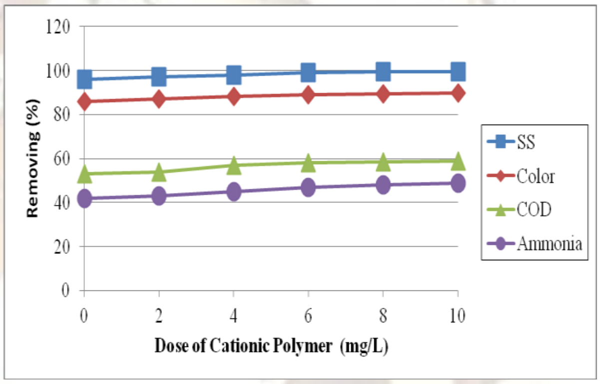

Figure 4.6: Percentage of removal in SS, color, COD and ammoniacal nitrogen for dose cationic polymer in pH 7, by using 2000 mg/L PAC, rapid mixing speed 150 rpm for 3 minute, slow mixing speed 30 rpm for 20 minute and the settling time of 30 minute.

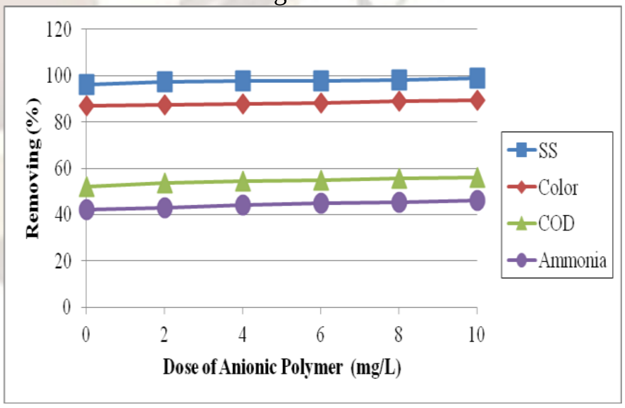

Figure 4.7: Percentage of removal in SS, color, COD and ammoniacal nitrogen for dose anionic polymer in pH 7, by using 2000 mg/L PAC, rapid mixing speed 150 rpm for 3 minute, slow mixing speed 30 rpm for 20 minute and the settling time of 30 minute.

VI. CONCLUSION

Results showed that the PAC was effective in leachate treatment. The used of synthetic polymer proved to be effective as coagulant aids for lechate treatment. The used of 2000 mg/L coagulant (PAC) with different of doses of polymers caused an increase in suspended solid (SS), COD, color, and ammoniacal nitrogen (NH_3N) removal efficiency. A synergistic effect of a coagulant + coagulant aids combination produced a higher removal efficiency of the contaminants than the use of coagulant alone. The addition of different dosage (2 mg/L, 4 mg/L, 6 mg/L, 8 mg/L and 10 mg/L) of polymer to a fixed coagulant dose (2000 mg/L) enhanced removal efficiency of suspended solid (SS), COD, color, and ammoniacal nitrogen (NH_3N). In this study, 10 mg/L were the optimum doses of coagulant and polymers for the leachate treatment. Cationic polymer was achieved higher percentage of removal in suspended solid (SS), COD, color, and ammoniacal nitrogen (NH_3N) compared with anionic polymer. However, some researcher proved that the removal efficiency decreased with an increasing dose of coagulant and polymers. Therefore, the dose of polymers was set in 5 mg/L. Finally, the results showed the PAC combined with cationic polymer (PAC + cationic polymer) was more than PAC combined with anionic polymer (PAC + anionic polymer) and using PAC alone. The highest percentage of removal in SS, color, COD and ammoniacal nitrogen are 99.2%, 89.8%, 59% and 49% for PAC mixed with cationic polymer.

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REFERENCES

[1] S, Ghafari, H,A, Aziz, and M,J,K, Bashir,``The use of poly-aluminium chloride and alum for the treatment of partially stabilized leachate: A comparative study," *Desalination*, 257, 2010, pp. 110-116.

[2] W, Li, T, Hua, Q, X, Zhou, S, G, Zhang and F, X, Li, "Treatment of stabilized landfill leachate by the combined process of coagulation/flocculation and powder activated carbon adsorption, *Desalination*, 264, 2010, pp. 56-62.

[3] F, J, Rivas, F, Beltran, F, Carvalho, Acedo, B and Gimeno, O, "Stabilized leachate: sequential coagulation-flocculation + chemical oxidation process," *Journal of Hazardous Materials*, B116, 2004, pp. 95-102.

[4] M, Sartaj, M, Ahmadifar and A,K, Jashni, "Assessment of in-situ aerobic treatment of municipal landfill leachate at laboratory scale," *Iranian Journal of Science & Technology, Transaction B, Engineering*, 34 (B1),2010, pp. 107-116.

[5] M, J, K, Bashir, H, A, Aziz and M, S, Yusoff, "New sequential treatment for mature landfill leachate by cationic/anionic and anionic/cationic processes: Optimization and comparative study," *Journal of Hazardous Materials*, 186, 2011, pp. 92-102.

[6] S, N, Al-Abdali (2008), "Physic-chemical treatment of bukit tegar sanitary landfill leachate using P-Floc 775 and ferric chloride. University Malaya: Master's Thesis.

[7] A, F, Al-Yaqout, M, F, Hamoda and M, Zafar, "Characteristics of wastes leachate and gas at landfills operated in arid climate," Practice Periodical of Hazardous, Toxic and Radioactive Waste Management, 2005, pp. 97-102.

[8] X, J, Wang, S, Chen, X, Y and Gu, K, Y, Wang, "Pilot study on the advanced treatment of landfill leachate using a combined coagulation, fenton oxidation and biological aerated filter process," Waste Management, 2009, pp. 1354-1358.

[9] K, Gnandi, G, Tchangbedji, K, Kili, G, Baba and O, Salim, "Processing of phosphate mine tailings by coagulation flocculation to reduce marine pollution in Togo: laboratory tests," *Mine Water and the Environment*, 24, 2005, pp. 215-221.

[10] A,A, Tatsi, A, I, Zouboulis, K, A, Matis and P, Samaras, "Coagulation-flocculation pretreatment of sanitary landfill leachates," *Chemosphere*, 53, 2003, pp. 737-744.

[11] V, Golob, A, Vinder and M, Simonic, "Efficiency of the coagulation/flocculation method for the treatment of dyebath effluents," *Dyes and pigments*, 67, 2005, pp.93-97.

[12] A, Gurses, M, Yalcin and C, Dogar, "Removal of remazol red by using Al (III) as coagulant-flocculant: effect of some variables on settling velocity," *Water, Air and Soil Pollution*, 146, 2003, pp. 297-318.

[13] T, J, casey, "Unit treatment processes in water and wastewater engineering," John Wiley & Son, Chichester, England.

[14] P, Y, Zhang, W, Zhen, G, M, Zhang, G, M, Zeng, H, Y, Zhang, J, Li, X, G, Song and J, H, Dong, "Coagulation characteristics of polyaluminum chlorides PAC-A130 on

humic acid removal from water, Separation and Purification Technology, 63, 2008, pp. 642-647.

[15] A, Y, Zahrim, C, Tizaoui and N, Hilal, "Coagulation with polymer for nanofiltration pre-treatment of highly concentrated dyes: A review," Desalination, 266, 2011, pp. 1-16.

[16] T, Sun, L, L, Liu, L, L, Wang and Y, P, Zhang, "Preparation of a novel inorganic polymer coagulant from oil shale ash," Journal of Hazardous Materials, 185, 2011, pp. 1264-1272.

[17] N, D, Tzoupanos & A, I, Zouboulis, "Characterization and application of novel coagulant reagent (polyaluminum silicate chloride) for the post treatment of landfill leachates," Water Treatment Technologies for the Removal of High Toxicity Pollutants, 2010, pp. 247-252.

[18] A, Maleki, M, A, Zazouli, H, Izanloo and R, Rezaee, "Composting plant leachate treatment by coagulation-flocculation process," American-Eurasian J. Agric. & Environ. Sci, 5(5), 2009, pp. 638-643.

[19] M, J, K, Bashir, H, A, Aziz and M, S, Yusoff, "New sequential treatment for mature landfill leachate by cationic/anionic and anionic/cationic processes: Optimization and comparative study," Journal of Hazardous Materials, 186, 2011, pp. 92-102.

[20] E, Durmusoglu & C, Yilmaz, "Evaluation and temporal variation of raw and pre-treated leachate quality from an active solid waste landfill," Waste, Air and Soil Pollution, 171, 2006, pp. 359-382.

[21] A, Baeza, M, Fernandez, M, Herranz, F, Legarda, C, Micro, A, Salas, "Elimination of man-made radionuclides from natural waters by applying a standard coagulation-flocculation process," Journal of Radionalytical and Nuclear Chemistry, 260, 2, 2004, pp. 321-326.

[22] S, Haydar & J, A, Aziz, "Coagulation-flocculation studies of tannery wastewater using combination of alum with cationic and anionic polymers," Journal of Hazardous Materials, 168, 2009, pp. 1035-1040.

[23] M, A, Aboulhassan, S, Souabi, A, Yaacoubi and M, Baudu, "Improvement of paint effluents coagulation using natural and synthetic coagulants aids," Journal of Hazardous Materials, B138, 2006, pp. 40-45.