EFFICIENCY OF THE COAGULATION-FLOCCULATION FOR THE LEACHATE TREATMENT

Lee Mao Rui [a], Zawawi Bin Daud [b]
[a], [b],Department of Water and Environmental Engineering,
Faculty of Civil and Environmental Engineering,, Universiti Tun Hussein Onn Malaysia.
[a] Corresponding author: maorui_86@yahoo.com.my

 ISSN 1923-6654 (print)
ISSN 1923-6662 (online). Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: Leachate will be treated by using coagulation-flocculation. Coagulation and flocculation are essential process in a number of diverse disciplines, including biochemistry, cheese manufacturing and in water and waste water treatment. It is effective for removing high concentration organic pollutant and heavy metals in wastewater. However, coagulation-flocculation examined the effectiveness of alum and ferric chloride as well as the use of cationic polymer and micro zeolite on removal of suspended solid (SS), color, COD and ammoniacal nitrogen (NH_3N) from leachate. The coagulant dosage has typically been determined through jar test, which requires a long experiment time in a field water treatment plant.

Keywords: coagulation-flocculation, leachate, polymers, micro zeolite

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. Physical-chemical treatments for removal of refractory pollutants from the leachate such as coagulation-flocculation, ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) have been employed worldwide (Li et al, 2010).

Coagulation-flocculation processes are widely used in wastewater treatment plant. The efficiency of the process depends on a few factors such as coagulant and leachate age. Coagulation-flocculation most of investigations the effect of different operating variables on the final conversion achieved, measured in term of COD and color (Rivas et al, 2004).

Chemical treatment systems generally have lower installation costs. Chemically enhanced wastewater treatment can handle higher hydraulic loads compared to conventional treatment methods. This treatment is more predictable and more subject to control by simple techniques. It proceeds rapidly and is most frequently amenable to automatic control (Semerjian et al., 2001). Principal disadvantages that might preclude a wholly physical-chemical solution to wastewater treatment are the problems associated with the highly putrescible sludge produced, and the high operating costs of chemical addition. However, much of the current interests in physical-chemical treatment stem from its suitability for treatment under emergency measures; for seasonal applications, to avoid excess wastewater discharges during storm events; and for primary treatment before biological treatment, where the above disadvantages become of lesser impact. Moreover, physical-chemical treatment has a well established position in tertiary wastewater treatment.

Physical-chemical treatments have been found to be suitable not only for the removal of refractory substances from stabilized leachate, but also as a improving step for biologically treated leachate. Physical-chemical treatments such as chemical precipitation, activated carbon adsorption and ion exchange can be carried out on site. According numerous previous researches, treatment of leachate using different types of physical-chemical treatment have been carried out worldwide in recent years. However, no attempt has so far been made the treatment mentioned above in terms of the polymers and micro sand for the removal of COD and NH_3-N from landfill leachate (Kurniawan et al., 2005).

The main objective of this research was to determine the efficiency of leachate treatment using coagulation-flocculation. This research examined the effectiveness of PAC, alum and ferric chloride as well as the use of synthetic polymers (cationic polymers, anionic polymers and polymer nonanionik) on removal of suspended solid (SS), COD, color, and ammoniacal nitrogen (NH_3N).

LEACHATE CHARACTERISTICS

Leachate of different age

The decomposition of solid urban waste in landfills is essentially a result of microbiological processes and, therefore, the production of biogas and leachate are both directly related to the activity of microorganisms. It has been demonstrated that large variations in leachate quality exist for different landfills, but also at different locations within the same landfill. New landfills generate more organic pollutants than older landfills. The BOD : COD (biochemical oxygen demand : chemical oxygen demand) ratio in young leachate is typically in the range of 0.5 to 0.7, which indicates higher biodegradability than that of mature landfills, which produce leachate with a BOD : COD ratio of less than 0.4 (Renou et al., 2007).

Leachate treatment

Leachate can be treated by three main methods that is physical, chemical and biological treatment. Treatment can be a combination of two or three of the above methods. Air stripping, adsorption are major physical leachate treatment methods, while the other methods such as coagulation-flocculation, chemical precipitation, chemical and electrochemical oxidation methods are the common chemical methods used for the landfill leachate treatment. This combination method is most popularly used to achieved excellent leachate treatment efficiency (Sartaj., 2010).

The leachate treatment processes have different effectiveness depending on the leachate from landfill of different ages. The biological treatment process has been found to be effective on leachate from young landfills. Sometimes leachate can be treated by traditional package treatment plants on site, but this kind of treatment is the biological process, especially for young leachate which has mainly volatile fatty acids, but it is not effective on old leachate because in many cases high COD value was found in leachate after biological treatment.

Leachate control

Cleaning of polluted ground water is very expensive. Hence, using the best ways for leachate treatment in order to keep the ground water safe and clean is very essential. Currently, landfill management is governed by strict rule, design, and construction instructions in order to prevent the migration of leachate into the ground water. The design of the lining systems offers less permeability in the movement of leachate into ground water. The lining materials are mostly made of low permeability soils (typical clays) or synthetic materials (e.g plastic). Sometimes the landfill design has more than one liner. Leachate collection systems (LCS) consist of several layers with different types of materials.

Reduction and collection of leachate

To control long-term leachate flow and reducing treatment costs the reduction of infiltration could be helpful and sometimes necessary (especially for old landfills without bottom sealing). The strategy for water input control is strictly related to the quality of the waste to be landfilled. In the case of non-biodegradable waste and according to its hazardous potential for the environment, prevention of water infiltration can be adopted as the mainoption (normally by means of top sealing). On the contrary, in the case of biodegradable waste, a water input must be assured until a high degree of biostabilization is achieved. In this case the water input should be limited to the strictly necessary amount and minimization techniques should be applied.

Monitoring

Monitoring works need to be carried out periodically on various aspects such as the landfill waste, leachate, underground water, discharged water, gas generation and bad odour in order to achieve proper management and control of the sanitary landfill system. The main function of carrying out monitoring works is to observe and understand the changes condition of the landfill sites from various aspects such as changes in landfill waste layers, leachate quality, odours and environment impacts.

Monitoring the landfilled waste*:* the monitoring of landfilled wastes layers shall be carried out during the operation as well as after landfill completion, particularly on its changes in the solid waste compositions, settlement rates in the waste layers. The data obtained from monitoring of lanfilled waste will be useful for designing future leachate treatment plants as well as planning of future use after landfill completion.

Monitoring the leachate and discharge water: as part of the management and maintenance of the sanitary landfill system, the quality and frequency of the discharged water shall be monitored. In the case of leachate, monitoring shall be done for the water flowing into the leachate treatment facility. The amount of pollutants and harmful substances in the leachate flowing out of a landfill site shall also be measured particularly at the discharge point where the treated leachate is released to the environment.

Monitoring groundwater: the monitoring of groundwater in areas surrounding the landfill site shall be carried out for the quality of the groundwater to ensure that the liner systems of the landfill site are functioning well without any leakage. This monitoring was detected any pollution at earliest possible so that remediation works can be carried out immediately to prevent the extant of the impacts of pollution on the groundwater and the surrounding environment. Therefore, the groundwater monitoring wells established is crucial in order to determine the quality and possible usage of the groundwater in the areas around the landfill sites. The number of wells, positions and depth required are of primary important and shall be determined carefully.

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. To increase the particles size, coagulation is usually followed by flocculation of the unstable particles into bulky floccules so that they can settle more easily. This technique facilities the removal of suspended solids and colloid particles from a solution. The general approach for this technique includes pH adjustment and involves the addition of ferric/alum salts as the coagulation to overcome the repulsive forces between the particles.
The removal of heavy metals from stabilized leachate containing high concentration of organic and inorganic matter was investigated using coagulation with $FeCl_3$. The metal removal performances were reported to be higher at pH 9.0 than at pH 4.0. The results demonstrated the effectiveness of precipitation at basic pH for the removal of heavy metals (M.Plattes et al., 2007).

Coagulation-flocculation studies are carried out in usual jar test equipment. The jar test has been the typical technique used in wastewater and drinking water industry to improve the addition of coagulant and flocculants (Galvez et al., 2005). The speed and duration of mixing are significant factors in both the first and second steps. For example if the mixing strength is too high, it could be a reason to split up the aggregated floc. The other important factor is the duration of settlement.

METHOD AND MATERIAL

Coagulant selection
The choice of coagulant chemical depends upon the nature of the parameter to be removed, the raw water conditions, the facility design, and the cost of the amount of chemical necessary to produce the desired result. Final selection of the coagulant (or coagulants) should be made following through jar testing and plant scale evaluation. Considerations must be given to required effluent quality, effect upon downstream treatment process performance, cost, method and cost of sludge handling and disposal, and net overall cost at the dose required for effective treatment (Amokrane et al., 1997).

Inorganic coagulants: inorganic coagulants such as aluminium and iron salts are the most commonly used. When added to the water, they furnish highly charged ions to neutralize the suspended particles. The inorganic hydroxides formed produce short polymer chains which enhance micro floc formation. Inorganic coagulants usually offer the lowest price, are widely available and quite effective in removing most suspended solids. They are also capable of removing a portion of the organic precursors which may combine with chlorine to form disinfection by products. They produce large volumes of floc which can entrap bacteria as they settle. However, they may alter the pH of the water since they consume alkalinity. When applied in a lime soda ash softening process, alum and iron salts generate demand for lime and soda ash. They require corrosion resistant storage and feed equipment. The large volumes of settled floc must be disposed of in an environmentally acceptable manner. Delete the author and affiliation lines for the second affiliation (Wang et al., 2009).

Table:1 Acceptable Conditions For Discharge Of Leachate

No	***Parameter***	***Unit***	***Standard***
1	Temperature	ºC	40
2	pH value	-	6.0-9.0
3	BOD_5 at 20ºC	mg/L	20
4	COD	mg/L	400
5	Suspended solids	mg/L	50
6	Ammoniacal Nitrogen	mg/L	5
7	Mercury	mg/L	0.005
8	Cadmium	mg/L	0.01
9	Chromium, Hexavalent	mg/L	0.05
10	Chromium, Trivalent	mg/L	0.20
11	Arsenic	mg/L	0.05
12	Cyanide	mg/L	0.05
13	Lead	mg/L	0.10
14	Copper	mg/L	0.20
15	Manganese	mg/L	0.20
16	Nickel	mg/L	0.20
17	Tin	mg/L	0.20
18	Zinc	mg/L	2.0
19	Boron	mg/L	1.0
20	Iron	mg/L	5.0
21	Silver	mg/L	0.10
22	Selenium	mg/L	0.02
23	Barium	mg/L	1.0
24	Fluoride	mg/L	2.0
25	Formaldehyde	mg/L	1.0
26	Phenol	mg/L	0.001
27	Sulphide	mg/L	0.50
28	Oil and grease	mg/L	5.0
29	Colour	ADMI	100

ADMI-American Dye Manufacturers Institute

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. Polyelectrolytes are special classes of polymers containing certain functional groups along the polymer backbone which may be ionizable. If present, when the ionizable groups dissociate, the polymer molecules become charged either positively or negatively, depending on the specific functional groups present, and are thus referred to as cationic or anionic polyelectrolytes, respectively. Polymers are effective over a wider pH range than inorganic coagulants. They can be applied at lower doses, and they do not consume alkalinity. They produce smaller volumes of more concentrated, rapidly settling floc. The floc formed from use of a properly selected polymer will be more resistant to shear, resulting in less carryover and a cleaner effluent. Polymers are generally more expensive than inorganic coagulants.

Ferric Chloride ($FeCl_3$)

Experiment were first carried out without prior adjustment of pH (8.3) using different coagulant dosages (0.2,0.3,0.4,0.5 and 0.6 g Fe^{3+}/L). The reductions in COD were very low, ranging between 9.5 % and 11%. However, using a dosage ≥0.5 g/L, the reduction in turbidity reached values of 6.9 for a dosage of 0.6 g Fe^{3+}/L and 7.4 for a dosage of 0.2 g Fe^{3+}/L. experiments were subsequently conducted at different pH employing the same dosage of ferric chloride, 0.5Fe^{3+}/L, with the aim of determining the optimum pH. The optimum pH was found to be 3.8, obtaining reductions in COD, color and turbidity of 26%, 84%, and 90%, respectively. The next goal was to determine the optimum reagent dosage. Dosages ranging between 0.3 and 0.7 g Fe^{3+}/L were tested, obtaining an optimum value of 0.4 mg/L with reduction in COD, color and turbidity of 28%, 78% and 90% respectively. After settling periods of 30min and 24 hour, the sludge produced in the coagulation process represented approximately 32% and 30% of the total volume of sample used in the experiment. After centrifugation for 30 min at 4350 rpm, the volume of sludge was reduced to 4% of the total treated volume (Maranon et al., 2008).

Aluminium sulphate (alum)

Experiments were once more conducted without prior pH adjustment for different dosages of aluminium sulphate (0.3, 0.4, 0.5 and 0.6 g Al^{3+}/L). It was found that the greater the dosage of aluminium sulphate employed, the higher the turbidity removal. Turbidity removal was similar for dosages of 0.5 and 0.6 g Al^{3+}/L (around 80.7%). The effluent pH ranged between values of 7 for a dosage of 0.3 g Al^{3+}/L and 6.4 for dosage of 0.6 g Al^{3+}/L. the dosage of 0.5 g Al^{3+}/L was employed to determine the optimum pH range, which is situated around 6, obtaining very high reduction in turbidity (92%) and color (77%), though not in COD (20%). The optimum dosage of aluminium sulphate was then determined for this optimum pH value. This was found to be 0.8g Al^{3+}/L, with removal percentages of COD, color and turbidity of 27%, 84%, and 93% respectively (Maranon et al., 2008).

Zeolite

Zeolite are natural or synthetic crystalline aluminosilicates that behave as cation exchangers. They are characterized by a rigid structure, made of cages and channels of molecular dimension, which gives rise to molecular sieving properties (size and shape selectivity).

The zeolite deposits in each of these environments have their own geochemical and mineralogical characteristics. The purest concentrations of zeolite are found in saline, alkaline lakes. A wide variety of materials including clay minerals, plagioclase, biogenetic silica, volcanic glass and quartz react to form zeolite in these settlings (Walcarius et al., 2003).

Jar test

The conventional jar test apparatus, in equipped with 6 beakers of 1L volume, was employed for coagulation-flocculation and precipitation processes. Chemicals reagents used as coagulants included alum ($Al_2(SO_4)_3 \cdot 18H_2O$) and ferric chloride ($FeCl_3 \cdot 6H_2O$). Leachate samples were thoroughly shaken, for re-suspension of possibly settling solids and the appropriate volume of sample was transferred to the corresponding jar test beakers. A jar test was set up at room temperature for each trial. The coagulant was added into the beakers and the pH values were immediately adjusted to the desired levels by the addition of appropriate amounts of NaOH and HCl solutions. The experimental process consisted of three subsequent stages: the initial rapid mixing stage took place for 3 min at 120 rpm, the following slow mixing stage for 15min at 20 rpm, while the final settling step lasted for another 45 min.

In order to determination of coagulant dosage (optimum dose) on removal efficiency, different concentrations (0 to 200% of initial dosage at stable pH) such as 0, 350, 700, 2100 and 2800 mg L^{-1} of alum and 0, 500, 1000, 2000, 3000 and 4000 mg L^{-1} of ferric chloride were added to 1 L leachate sample. pH was adjusted between 4 and 8 for determination of the optimum pH or pH effect on the efficiency process for alum and coagulant and between 3 and 11 for ferric chloride prior to tests. After the settling period, the supernatant was digested using standard methods to release its heavy metal contents and analyses were carried using atomic absorption spectrophotometer (Baeza et al., 2003).

RESULTS AND DISCUSSION

An analysis of leachate discharged or released onto or into any soil, or into any inlands waters or Malaysian waters shall be carried out in accordance with any of the methods contained in the publications as specified in the Environmental Quality Act 1974. This section exhibits and analyzes the results of the study performed on laboratory scale experiments. Landfill leachate composition varies widely among landfills. This variation makes a through characterization of leachate mandatory for each landfill before appropriate treatment schemes can be defined.

ACKNOWLEDGMENT

A very special thanks and appreciation to my supervisor, Dr Zawawi Daud for being the most understanding, helpful and patient. I would also like to express my deep gratitude to my co-supervisor, Prof Abd Aziz Abdul Latif for his encouragement throughout the study. I am also grateful to all my family members.

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