The Use of Alum, Ferric Chloride and Titanium tetrachloride as Coagulants in Treating Landfill Leachate

Pushpalatha T N, Lokeshappa B

***Abstract*—Coagulation is a relatively simple physico–chemical technique in the treatment of old and stabilized landfill leachate. A variety of conventional coagulants has been widely used. Titanium tetrachloride ($TiCl_4$) showed better performance for the turbidity, colour and COD removal compared to the ferric chloride and alum coagulants. The optimum dose for alum is 0.8 g/L and for ferric chloride 0.4 g/L. whereas optimum dose for titanium tetrachloride is 0.6 g/L. From this experiment titanium tetrachloride showed best removal of turbidity, colour and COD than ferric chloride and alum chemical coagulants. Therefore it is found as effective new coagulants in landfill leachate treatment.**

***Index Terms*— Alum, Ferric chloride, Landfill leachate, Titanium tetrachloride.**

I. Introduction

Management of solid wastes has become a great concern. Disposing waste on open dumping ground may create environmental pollution problems (soil and ground water contamination, health problems etc.). When solid wastes are incinerated they reduce the waste to ash and release potentially hazardous gases into the air causing public health risks. These wastes can be dumped into landfills, which are the source of large emissions of methane to atmosphere. Methane gas has a global warming potential that is over 20 times of CO_2 [1].

Water has become the most commercial product; the main sources for supplying water are groundwater and surface water. Water is a basic necessity of life for both animal and plants. Water covers over 70.9% of the Earth's surface, of which 97% of the total water is covered by oceans, 2.4% by polar ice caps and 0.60% by other land surface water bodies like river, lakes. The quality of ground water is depending on the aquifer, human activities and also the utilization of dumping sites. Groundwater has a high risk of being polluted around areas near landfills because of the potential pollution source of landfill leachate. Hence, the study of landfill leachate has become a special issue in recent years [2].

***Manuscript received June, 2014*.**

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Continuing development of population and industrialization around the world has resulted in increasing production of municipal solid wastes (MSW). The major method of municipal solid waste management is land filling work. It was one of the most important issues of a concern in landfill leachate and its potential for downgrading water resources systems [3].

Solid waste generated in urban areas has been increasing year by year due to the rapid urbanization and diversity of lifestyles. Disposal and solid waste collection is an important issue in public health and it will affect a human life. Global environmental issue is a disposal of the growing quantities of solid waste, the waste generation rates are currently among the highest worldwide with the growth in population and the increase in per capita [4].

Wastes cause two types of pollution, which correspond to the migration into the natural environment of:

- Leachates, defined as water that has percolated through the wastes (rainwater or ground water seepage), a source of soil and groundwater contamination,
- Biogas produced by the fermentation of organic matter, a source of air pollution. With regard to leachates, controlling the pollutant loading means reducing its quantity by containing or treating the waste to comply with certain discharge characteristics which are compatible with the receptor medium (river, sea, municipal treatment plant)[4].

In most climates rain and snowfall will either infiltrate the cover soil or leave the site as surface runoff, depending on surface conditions. The infiltrated water that is not subsequently lost by evapo-transpiration or retained as soil moisture will percolate down through the waste deposit and generate the leachate. Leachate generation (flow) varies from site to site and over time at the same site [5]. The water content of the waste being land filled is usually below saturation (actually field capacity) and will result in absorption of infiltrating water before drainage in terms of leachate is generated. The water absorption capacity of the land filled waste and its water retention characteristics are very difficult to specify due to the heterogeneity of the waste. Furthermore, these characteristics may hange over time as the waste density is increasing and the organic fraction, which dominates the water retention, is degraded in the landfill [6].

ISSN: 2278 – 7798

Garbage, refuse, sludge, and other discarded solid materials resulting from industrial and commercial operations and from community activities. It does not include solids or dissolved material in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial wastewater effluents, dissolved materials in irrigation return flows or other common water pollutants [7].

In order to implement cost-effective management strategies that are beneficial to public health and the environment, it is practical to classify wastes. For example, wastes can be designated by generator type, i.e., the source or industry that generates the waste stream. Some major classes of waste include [8]:

- Municipal waste
- Hazardous waste
- Industrial waste
- Medical waste
- Universal waste
- Construction and demolition waste
- Radioactive waste
- Mining waste
- Agricultural waste

Leachates are the result of the biochemical decomposition of the solid waste's organic or biodegradable part, under aerobic and anaerobic conditions, plus the percolation of rain water through the wastes. This liquid filtrates into the wastes dragging and dissolving some materials that make it toxic and contaminant. The leachate generated in any kind of dump place is the aggregate of water, microorganisms and dissolved and suspended substances of the wastes. Leachates are characterized by dark colour, bad smell and high organic and nitrogen loads; its treatment is difficult because also contents heavy metals, human substances and recalcitrant compounds [9].

Leachate treatment strategy is not easy to define due to the high variability in its composition and characteristics that depend of several variables like the place of the dump and the age of the wastes. Around the world, many researchers had dedicated to study the most effective processes for leachate decontamination and in this way can find and chose the appropriated technology for its treatment depending on its characteristics. Young leachates have a high biodegradability due to the high ratio BOD/COD, contrary to the old ones, which have a low ratio and therefore a low biodegradability. The biological treatments have shown to be very effective for young leachates, while for old or partially stabilized leachates[10].

The physicochemical and advanced biological systems are being implemented for leachate treatments with high initial inversion and operation costs, reason why its implementation in developing countries has been limited. Taking this into account and due to the landfill leachate treatment problem is urgent to solve, there is a need of work with systems more flexible and low cost both in investment and operation and maintenance; in this vein, natural systems have began to be investigated since early 90´s as leachates treatment alternatives[11].

The study aimed at meeting the following objectives:

- The determination of the optimum coagulant.
- Comparing the removal efficiency of the different coagulants at their optimum dosages namely titanium tetrachloride, ferric chloride and alum.

II. MATERIALS AND METHODS

A. Background

This chapter deals with the sampling, materials used, experimental procedure and methods adopted for treatment of municipal solid waste landfill leachate to meet the objective of the work.

B. Materials

The following materials were used in the study the behaviour of titanium tetrachloride, ferric chloride and alum by treating municipal solid waste landfill leachate.

- Volumetric flask (1,000 mL)
- Analytical balance
- Coagulants and coagulant aids
- Magnetic stirrer (optional)
- A stirring machine with six paddles capable of variable speeds from 0 to 100 revolutions per minute (RPM).
- Beakers (1,000 mL)
- Pipettes (10 mL)
- Watch or clock
- Turbidometer and sample tubes.

C. Municipal solid waste landfill leachate

Leachate was collected from a landfill site. The type of sampling adopted in this study was grab sampling also known as a catch sample, consists of a single sample taken at a specific time. Samples were collected from the holding basin in 20-L plastic containers and the characterization of landfill leachate samples was conducted immediately after the sample arrived to laboratory, then sample was stored in refrigerator at temperature of 4^0C. Leachate samples were removed from the refrigerator and left under ambient temperature for about 2 hrs before the jar test was performed.

D. Methodology

During this treatment, the dose of $TiCl_4$ is chosen; the coarsened concentration of $TiCl_4$ is dissolved in acidic solution. It is because the $TiCl_4$ is extremely volatile when exposed to the air and water. Hence hydrochloric acid (HCL) was used to dissolve the $TiCl_4$.The optimum dosage of coagulant is determined by using the same [12].

Jar test is most widely used experimental methods for coagulation-flocculation. A conventional jar test apparatus was used in experiments to coagulate sample of landfill leachate using alum, ferric chloride and titanium tetrachloride. It was carried out as a batch test, accommodating a series of six beakers together of 1 liter capacity with six spindle steel paddles. Before operating jar test, sample is mixed homogenously. Then analyze the parameters such as turbidity, colour, and COD for $TiCl_4$, $FeCl_3$ and alum. Then results are plotted on graphs than they are compared [13].

ISSN: 2278 – 7798

Batch Experiment involving rapid mixing, slow mixing and sedimentation. Apparatus consists of six beakers to be agitated simultaneously.1000ml of the Landfill leachate sample is put in to each 6 one-liter beakers and placed under jar test apparatus. The required dose of $TiCl_4$, $FeCl_3$ and Alum 1000ml was added simultaneously. The paddles were inserted in jars, apparatus was switched on and whole procedures in jar test were conducted in different rotating speed, which consist of rapid mixing (200 rotations per minute, rpm) for 5 minute and slow mixing (30rpm) for 40 minutes. After agitation has been stopped, suspensions are allowed to settle for 45 minutes. Finally, a sample was withdrawn using a pipette from middle of supernatant for physicochemical measurements, so that effect of coagulant dose on coagulation could been studied. Then, samples are measured for different parameters [14].

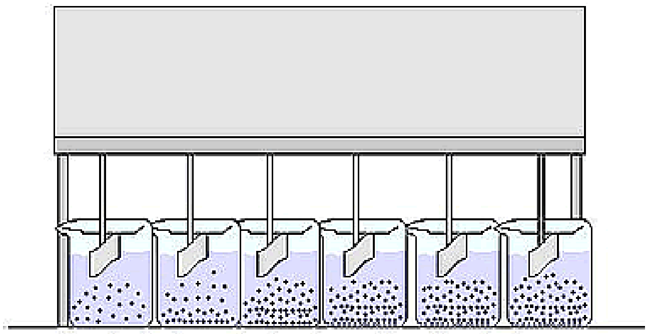

Fig. 1: Schematic view of conventional jar test apparatus.

III. RESULTS AND DISCUSSIONS

A. Turbidity

The variation in turbidity for $TiCl_4$, $FeCl_3$ and alum. About 35.3% of turbidity was removed with dosage of 0.8g of alum, about 52.1% was removed with $FeCl_3$ of dosage of 0.4g and about 72.6 % was removed with $TiCl_4$ of dosage of 0.6g. The trend reveals that removal of Turbidity is slightly more with $TiCl_4$ compared to $FeCl_3$ and alum is as shown in below bar chart.

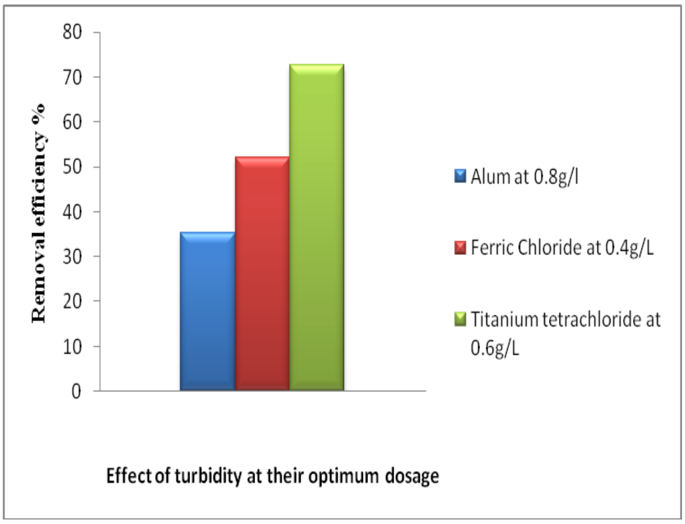

Fig.2: Percentage reduction in turbidity with $TiCl_4$, $FeCl_3$ and alum.

B. Colour

The variation in colour for $TiCl_4$, $FeCl_3$ and alum. About 45.3% of colour was removed with dosage of 0.8g of alum, about 59.8% was removed with $FeCl_3$ of dosage of 0.4g and about 75.4 % was removed with $TiCl_4$ of dosage of 0.6g. The trend reveals that removal of colour is slightly more with $TiCl_4$ compared to $FeCl_3$ and alum is as shown in below bar chart.

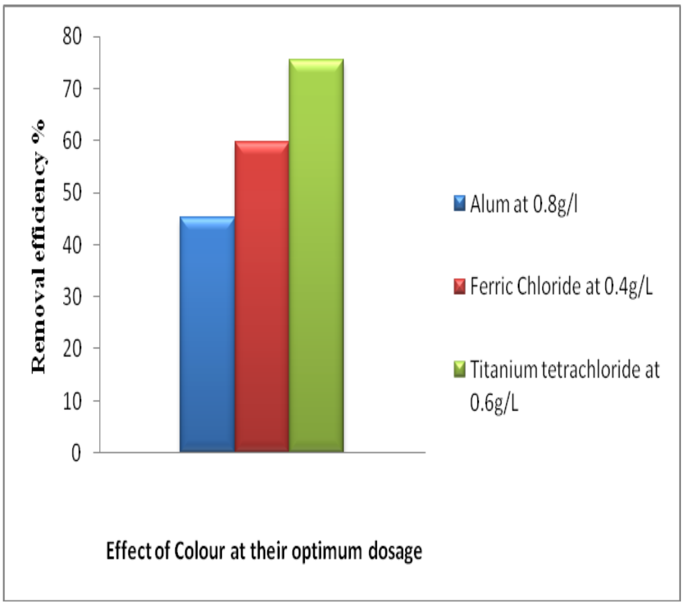

Fig.3: Percentage reduction in colour with $TiCl_4$, $FeCl_3$ and alum.

C. Chemical oxygen demand

The variation in COD for $TiCl_4$, $FeCl_3$ and alum. About 26.2% of COD was removed with dosage of 0.8g of alum, about 42.3% was removed with $FeCl_3$ of dosage of 0.4g and about 78.3 % was removed with $TiCl_4$ of dosage of 0.6g. The trend reveals that removal of COD is slightly more with $TiCl_4$ compared to $FeCl_3$ and alum is as shown in below bar chart.

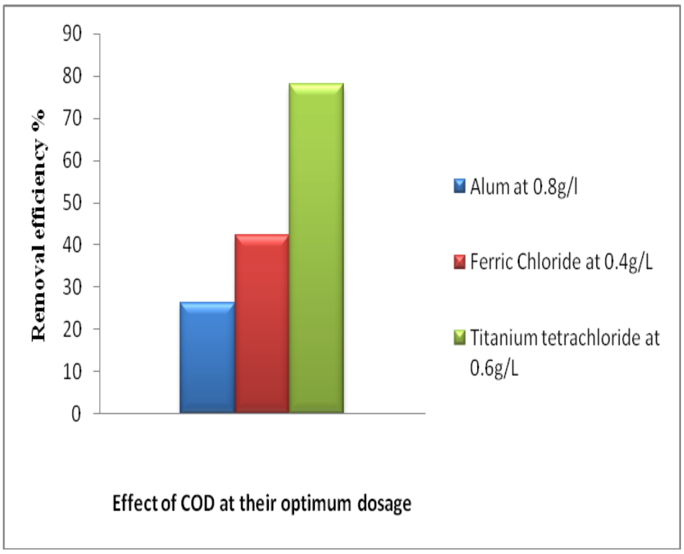

Fig. 4: Percentage reduction in COD with $Ticl_4$, $Fecl_3$ and alum.

ISSN: 2278 – 7798

D. *Average removal efficiency of all three coagulants*

Total average removal efficiency of all the parameters namely turbidity, colour and COD for $TiCl_4$, $FeCl_3$ and alum in treating municipal solid waste landfill leachate is plotted as below. From this graph it is proved that $TiCl_4$ coagulant is efficient in their working.

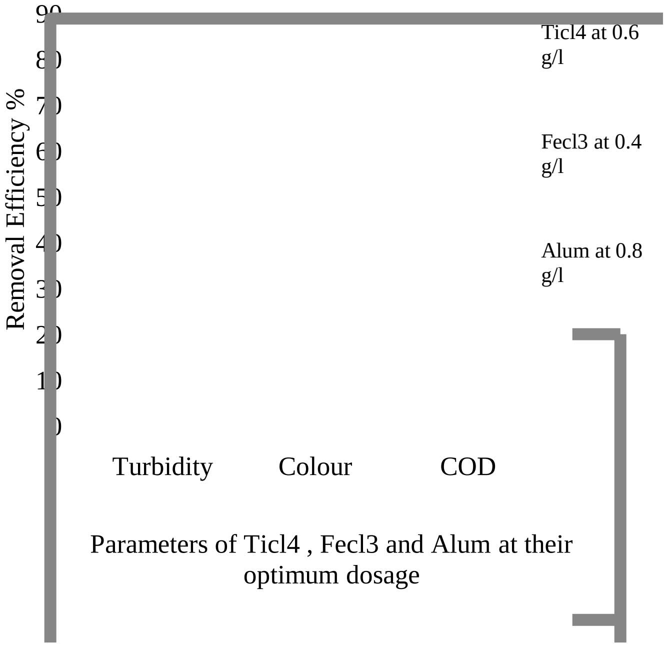

Fig.5: Average removal efficiencies of all parameters using alum, ferric chloride and titanium tetrachloride.

IV. CONCLUSION

- Titanium tetrachloride removed the parameters like COD- 78.3%, Turbidity-72.6%, Colour-75.4%, for optimum dosage of 0.6g/l.
- Ferric Chloride removed the parameters like COD-42.3%, Turbidity-52.1%, Colour-59.8%, for optimum dosage of 0.4g/l.
- Alum removed the parameters like COD-26.2%, Turbidity-35.3%, Colour-45.3%, for optimum dosage of 0.8g/l.

Thus the use of titanium tetrachloride is found as effective new coagulants in sewage treatment for the turbidity, colour and COD removal compared to the ferric chloride and alum coagulants.

ACKNOWLEDGMENT

We acknowledge the institution U.B.D.T College of Engineering, Davangere for providing lab facilities to do the experimental work.

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ISSN: 2278 – 7798