

COMPARATIVE STUDY ON THE USE OF CLAY AND CEMENTED CLAY AS LANDFILL LINER MATERIALS

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Abstract - Due to the massive increment in the amount of Municipal Solid Waste (MSW) generation, the disposal of these wastes became a major issue. Among all the methods for the disposal of MSW, land disposal is the most commonly adopted and safe method. Various studies conducted in landfills and its surroundings reveals that the leachate percolated from the waste to the deep soil is the major reason for the contamination of ground water resources in that area.

This problem can be overcome by installing a liner in landfills before and after the waste is dumped. Even though they can prevent penetration of leachate through the barrier to a large extent, there will be having escape of a small amount of leachate through the barrier through the cracks formed in them. Many materials are used as liners, among them clay, especially kaolinite clay is one of the best. It can remove large amount of pollutants from leachate. To avoid the failure of liners, clay should be stabilized by mixing it with cement and installed by providing enough compaction.

Here, in this study, a comparative study on the pollutant removal properties of clay and cement stabilized clay is carried out. Leachate is collected before and after passing through the liners and taken for laboratory analysis. In laboratory pH, turbidity, chloride content and COD analysis is carried out. 95% COD is removed by clay liner and 98% COD is removed by cemented clay liner.

Key Words: Municipal Solid Waste, Leachate, Landfill liner, Kaolinite clay, Cement stabilized clay, Laboratory analysis

1. INTRODUCTION

Due to the development in economy, the life quality of the people changed and this cause a massive increment in the amount of municipal solid waste (MSW) generation. This MSW contains both recoverable and reusable products and solid matters with which there is no further use. Information and data on the physical composition of the solid waste are important in the selection and design of the disposal facilities. Composition of MSW can be classified on dry basis and wet basis. Here in this study, wet composition of solid waste is preferred. Examples of the waste composition on wet basis for Kuala Lumpur, Malaysia, are tabulated in table-1 [5]

Table-1: Composition of Solid Waste (% weight, Wet Basis) in Kuala Lumpur (2002)

Composition	Typical (%)
Combustible	
Food waste & organic	56.3
Mix paper	8.2
Mix plastic	13.1
Textile	1.3
Rubber and leather	0.4
Wood	1.8
Yard waste	6.9
Fine	0.4
Non combustible	
Glass	1.5
Ferrous	2.1
Aluminium	0.3
Non ferrous	0
Other inorganic	
OBW	1.3
TOTAL	100

1.1 LANDFILL DISPOSAL PROBLEMS

Land disposal in the form of sanitary landfill is the most commonly adopted method of long term handling of MSW today. Solid wastes disposed in a sanitary landfill undergoes a number of simultaneous physical, chemical and biologic changes due to reactions. It mainly includes biological decay of organic putrescible materials, evolution of gases, chemical oxidation of materials, movement of liquids caused by

different heads, dissolving and leaching of the organic and inorganic materials by water and leachate movement through the fill, uneven settlement of the fill due to consolidation, etc. The decomposition and stabilization in landfill will depend upon many factors such as composition of waste, degree of compaction, amount of moisture present, rate of water movement, etc. [4]

The main problems associated with a landfill includes

- Evolution of gases
- Leachate percolation and
- Uneven settlement of the fill material.

1.2 LANDFILL LINER

The leachate which is formed due to the contact of the solid waste with water from rainfall and other sources can be controlled by installation of the landfill liner. If uncontrolled, landfill leachate can be responsible for contaminating ground water and surface water. Once ground water is contaminated, it is very difficult to clean it up.

All these problems can be overcome by establishment of an impermeable system as land fill liner. The most commonly used liner materials to be used in a landfill are soil, compacted soil, clay, synthetic barriers etc. The use of clay, due to its suitability and availability to be used as a liner material can be installed in the landfill. But tropical clay soils are normally associated with volumetric changes when they subjected to changes in the water content due to seasonal water fluctuations. Kaolinite clay is one among such clays which is effected by these kind of problems. So they need some modifications [6]. If these minerals are treated before its use, desired properties can be achieved. Chemical stabilization techniques have proven to be the most effective method in such clays. The commonly used materials for the stabilization of such clay are cement, lime, fly ash and blast furnace slag. Addition of small amount of cement will improve the strength and anti-seepage character of the clay. The low cost and easy availability of cement makes it suitable to be used as clay stabilizing agent.

The establishment of such an anti-seepage clay liner can remove large amount of pollutants in leachate. Clay have more capacity than the natural soil to absorb and remove pollutants from waste water than that of soil. Thus, these properties of clay and stabilized clay can be analyzed and compared to suggest the best composition of a good landfill barrier. Even though these liners can prevent penetration of leachate through them to a large extent, there will be having escape of a small amount of leachate through the barrier. But this escaped leachate will contain very small amount pollutants as compared to the initial leachate. So, laboratory analysis of leachate can be done before and after passing through the liners.

1.3 OBJECTIVES OF THE STUDY

The major objectives of the study includes

1. Evaluating removal rate of pollutants in leachate.
2. To compare the efficiency of clay and cemented clay as land fill liners.

2. MATERIALS AND METHODS

Two reactors were prepared separately. In the first one (R1), clay is installed as liner material and in the second one (R2), cement stabilized clay is the liner material. Leachate was synthetically prepared inside the reactors. Characteristics of leachate before and after passing through the liner is also analyzed. Various testes conducted on leachate includes

- COD removal analysis
- pH
- Turbidity test
- Chloride removal

2.1 MATERIALS

Kaolinite clay, which was easily available in Kerala was collected from "Kerala clays & ceramic product limited (A Government of Kerala undertaking) – Pappinissery, Kannur". This clay have good capacity to remove pollutants from the waste water. Ordinary Portland cement was purchased to be used as stabilizing agent. Leachate was synthetically prepared inside the reactor by filling the reactor with wet composition of MSW.

2.2 SYNTHETIC LEACHATE PREPARATION

The leachate was prepared synthetically. For the preparation of synthetic leachate, a condition of the solid waste disposal site were created inside the reactor artificially by adding different solid waste materials in different proportions. The standard composition of a municipal solid waste duping site was identified by referring different resources and the site condition was prepared in a chamber. In this study, for the preparation of the synthetic leachate, Wet composition of the MSW is preferred. This composition of the municipal solid waste used is shown in table-1. For the formation of leachate, presence of water is essential. So that the water was added into the chamber periodically and the leachate can be collected separately through the pipe provided with a control valve.

2.3 PREPARATION OF REACTOR

The reactor can be prepared by using glass columns made with a dimension of about 0.25m x 0.25m x 1m. An artificial condition of the landfill site were prepared in a reactor. For the preparation of the reactor, scale of the site was reduced in to 0.25m x 0.25m x 1m. Two reactors were prepared. One

with clay as the liner material and the other with cement stabilized clay as liner material. The reactor were filled with different layer of clay, sand, cemented clay and MSW as shown in fig-1, fig-2 The clay and the cement treated clay are established with in the reactor by giving proper compaction. Since leachate contains large amount of suspended and dissolved solid, there is a chance of clogging of the pores of the liner material. To avoid this, a layer of sand in small thickness is placed above the compacted liner. When leachate passes through this layer, the large suspended solids will get removed. Provisions for the collecting the leachate after passing through the liner are provided at the bottom side of the reactor. Two holes were provided in each reactor, one at the bottom for collecting the leachate after passing through the liner and other on the side of the reactor to collect the initially formed leachate (before it passes through the liner). Then laboratory tests are conducted on initially formed leachate and on the leachate passed through the barrier and also leachate produced in each week were quantified.



Fig -2: reactors prepared

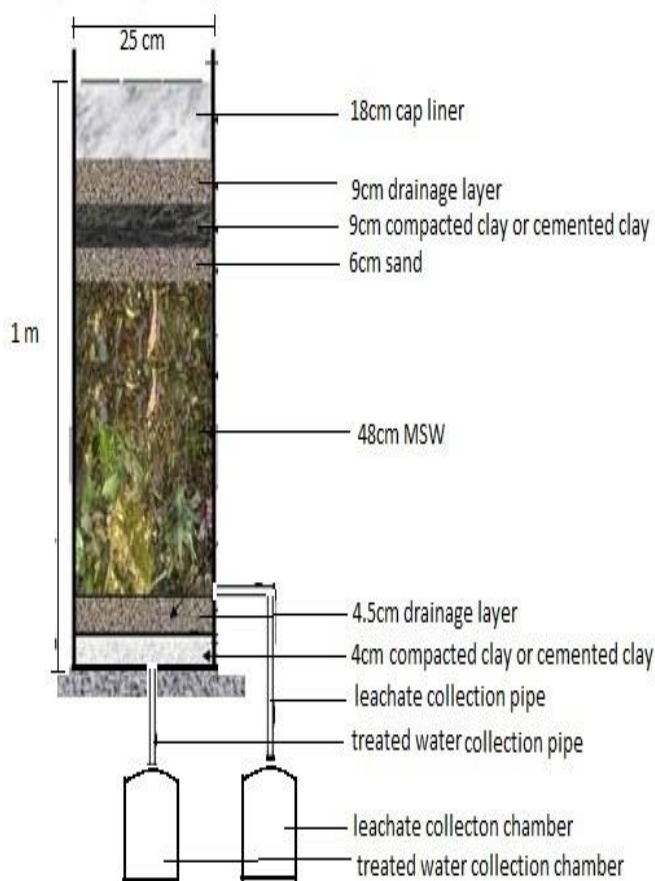


Fig -1: schematic diagram of the reactor

2.4 LEACHATE ANALYSIS

Leachate was developed inside the reactor within about 14 days after preparation. The leachate was collected outside through leachate collection pipe provided at the side of the reactor and taken for analysis. The properties of leachate are initially analyzed. The leachate was allowed to pass through the clay barrier installed at the bottom of the reactor. This passed leachate was collected outside the reactor through the collection pipe provided under the reactor. This passed leachate is also taken for laboratory analysis. Testes conducted includes

- pH
- turbidity
- chloride content
- COD analysis

3. RESULT AND DISCUSSIONS

The properties of initially developed leachate after 14 days was initially analyzed. The leachate that passed through clay barrier and cement stabilized clay barrier are also taken for laboratory analysis.

The results obtained are tabulated below.

Table -2: characteristics of leachate before and after passing through liners

Parameter	pH	Turbidity (NTU)	Chloride (mg/l)	COD (mg/l)
Initial leachate	6.94	129	685.15	13440
7 th	L	7	120	687.5

day	R ₁	5.81	32	507.65	12960
	R ₂	12.16	2	401.15	12000
14 th day	L	6.83	119	679	
	R ₁	5.69	26	447.3	8000
	R ₂	11.4	1	358.5	6200
21 st day	L	6.72	122	648	
	R ₁	5.62	12	426	3200
	R ₂	8.9	0	259.15	1290
28 th day	L	6.96	132	672.3	
	R ₁	6.52	11	372.75	700
	R ₂	7.1	0	252.05	300

3.2 TURBIDITY ANALYSIS

The leachate produced was black in color with an extreme pungent smell (Fig 4.5). When it passed through clay liner in first reactor, it became clearer with a small turbidity. While passing through the second reactor with cement stabilized clay liner, it became non turbid (Fig 4.6, fig 4.7). Both the effluents had pungent smell. But, as time passes, its smell also get reduced.



Fig -4: Leachate before passing through liner

3.1 pH ANALYSIS

The pH of the leachate before and after passing through the liners for a period of 30 days can be graphically represented as below.

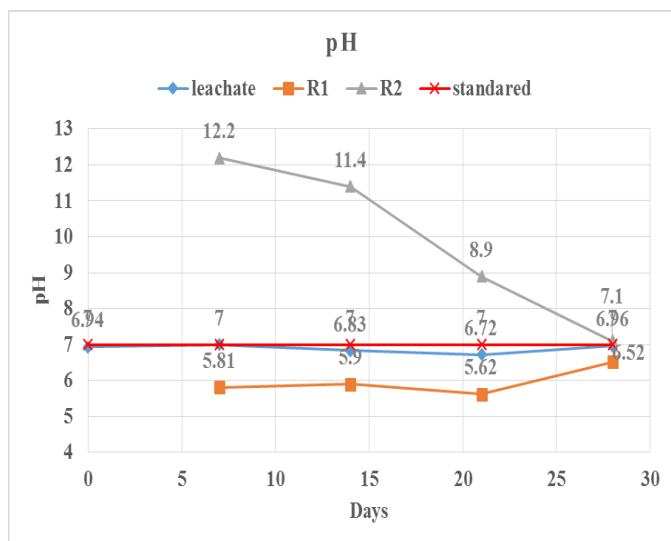


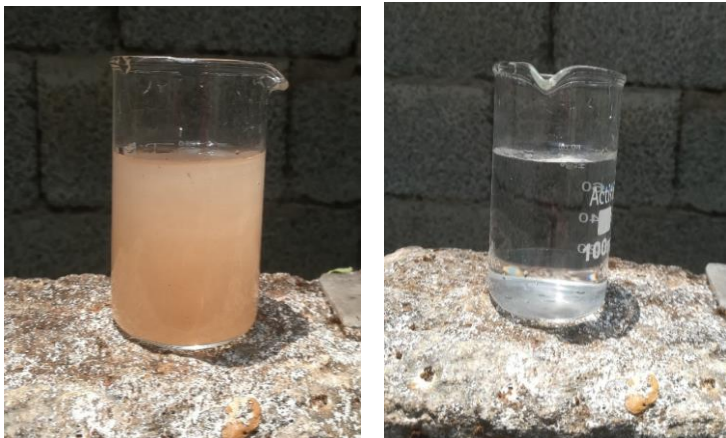
Fig -3: variation of pH with time

It can be seen from the graph that pH of leachate is within the standard limit of potable water (6.5 – 8.5). But, when the leachate passes through the clay liner in first reactor (R₁), its value reduces to about 5.81. i.e., it becomes slightly acidic. When the same leachate passes through the cement stabilized clay barrier installed in the second reactor (R₂), its pH rises to 12.2 which indicate that the leachate becomes highly alkaline. But, as the time passes, leachate through both the liners again approaches to the limit of potable water. So, it is proven that both the liners do not alter pH of leachate.



(a) (b)

Fig -5: Leachate after passing through (a) clay liner (b) cemented clay liner after 7 days



(a)

(b)

Fig -6: Leachate after passing through (a) clay liner (b) cemented clay liner after 28 days

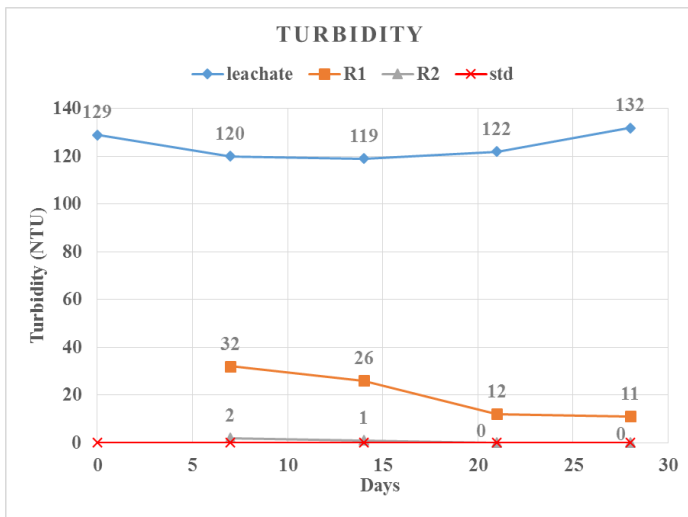


Fig -7: variation of turbidity with time

Leachate is black in color and seems to be highly turbid. Potable water should be least turbid. (i.e., turbidity should be 0-5). When this leachate passes through the clay liner, its turbidity reduces up to 11 within 30 days. But it is not within the drinking water limit. When the leachate passes through the cement stabilized clay liner, it become highly clear, i.e., turbidity is between 0-2. This is within the potable water limit. So, it is understood that both clay and cement stabilized clay can absorb large amount of suspended particles in leachate so that both can be used as a barrier in landfills.

Clay liner can remove 92% of suspended particles and the stabilized clay can remove 100% suspended particles. i.e. Among both the liners, cement stabilized clay liner can remove almost all suspended particles, so that it is highly efficient.

3.3 CHLORIDE CONTENT TEST

The results of chloride content test are graphically represented in Fig.4.9.

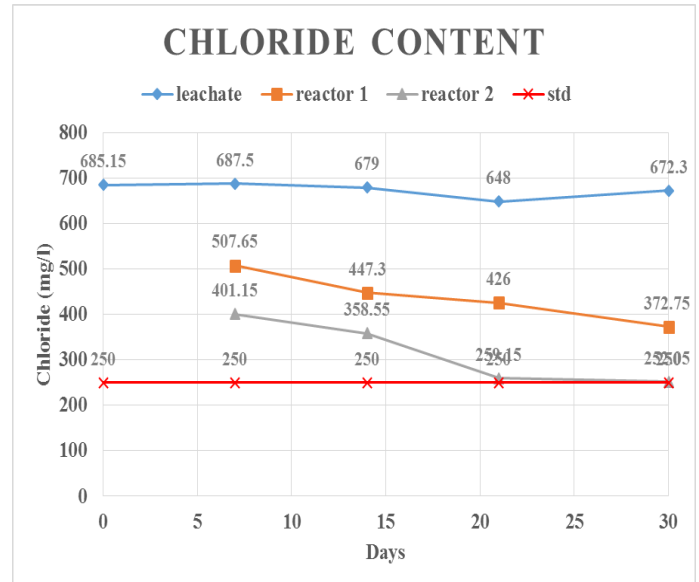


Fig -8: Removal of chloride with time by both barriers

The allowable chloride content in potable water is 250mg/l. chloride content in leachate was very high than this limit. When the leachate passes through the barriers, the chloride was adsorbed and removed by the liner materials. In the first reactor with clay barrier, when the leachate passes through this barrier, chloride content is reduced up to 372.75 mg/l on 28th day of testing. i.e., 44.5% of chloride is removed by clay barrier.

In the case of second reactor with cement stabilized clay liner, the leachate passed through the barrier contains 252 mg/l of chloride, which is very nearer to the drinking water standard, i.e. cement stabilized clay liner removes 62.5% of chloride. Thus, there is a trend by stabilized clay liner to remove chloride content and it can be expected that the chloride content will be within drinking water limit within one month.

3.4 COD ANALYSIS

The COD of the initial leachate and the leachate after passing through both liners are tested separately. COD of leachate was very high. It is about 13440 mg/l. when the leachate passes through the liners, this value get decreases. This is graphically represented in Fig.4.10.

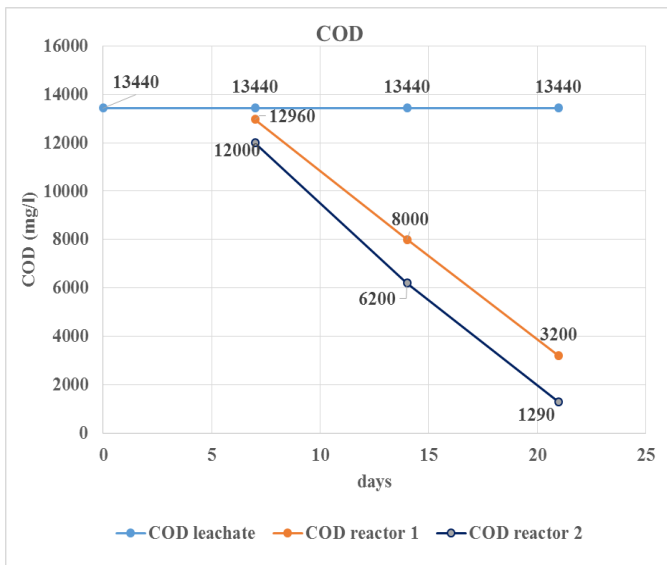


Fig -9: Removal of COD with time

COD of leachate when passing through clay liner falls from 13440 mg/l to 700 mg/l. This change happens within 28 days after preparation of reactor. i.e. clay can remove 95% COD from leachate.

In the case of second reactor with cement stabilized clay liner, the COD of leachate decreases into 300 mg/l. i.e. stabilized clay liner removes 98% COD.

So, both clay and cement stabilized clay are highly efficient in removing COD from leachate. So both can be used as landfill liner material.

4. CONCLUSIONS

There are many methods for the disposal of Municipal Solid Wastes. Among them, land disposal is the most accepted method. But in landfills, leachate penetration and gas evolution are the main problems. Leachate penetrating in to the deep soil layers will contaminate the ground water resources. Various studies conducted in landfills proves that leachate produced in these sites causes the contamination of wells near the sites. So it is essential to overcome this problem. Installation of landfill liners can resolve this problem to a large extent. Kaolinite clay, due to its easy availability and its ability to remove pollutants in leachate, can be used as landfill liners. To avoid the chance of failure of the clay liners, clay can be stabilized by mixing with small amount of cement and can be installed by providing proper compaction. Here, in this study, installation of clay and cement stabilized clay and their pollutant removal properties are studied.

Studies conducted on pollutant removal property of liners includes pH, turbidity, chloride content and COD analysis. When the leachate passes through clay liner, it become slightly acidic and become highly alkaline while passing

through cemented clay liner. As time passes, pH returns to initial value (nearly 7).

Leachate was highly turbid and when it passes through clay liner, 92% of suspended particles get removed and when passes through cemented clay, all the suspended particles get removed (100% efficiency) and reaches within the drinking water standard.

The allowable chloride content in potable water is 250 mg/l. Leachate had a large amount of chloride in it (about 687 mg/l) and when it passes through clay liner, it removes 44.5% of chlorides and reaches to 372.75 mg/l. When it passes through cemented clay liner, 62.5% of chloride get removed and it reaches 252 mg/l, which is very close to drinking water limit. So, it can be expected that, by the installation of cement stabilize clay liner, the chloride content of leachate will reach within drinking water standard within one month of installation. So, it can be concluded that cement stabilized clay is more efficient in chloride removal.

COD of leachate, when it passes through clay liner and cement stabilized clay liner get removed up to 95% and 98% respectively. By analyzing these values, it can be say that Kaolinite clay is highly efficient in removing COD of waste water. When this clay get mixed with cement, the removal efficiency increases. So, both can be used as landfill liner

All the leachate parameters analyzed in laboratory shows large decrease in their values and falls nearly into drinking water standard excluding COD. So, it can be expected that when the leachate continuously passes through these layers and when reaches in to the ground water sources located below deep soil, all the parameters will reach within drinking water standard. Thus the ground water contamination caused by leachate will be efficiently get removed.

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