Retardation of Iron Oxide Concentration using Coir Pith Amended Landfill Liner

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***Abstract*— Industrial activities generate large quantities of wastes. Contamination of the environment with heavy metals has increased beyond the recommended limit and is harmful to all life forms. Landfills play a vital role in the whole waste treatment or disposal process of wastes. The greatest threat to groundwater posed by landfills is leachate, that accumulates as water moves through the landfill. This study involves investigation on the suitability of using naturally available sand as a liner material, incorporated with montmorillonoite based clay bentonite. The use of waste fibres like coir for the retention of iron oxide contamination through the liner system can be evaluated in this study, so that it brings an alternate way for the disposal of these waste fibres. The efficiency of sand bentonite liner and coir pith amended sand bentonite liner in the removal of heavy metal waste, iron oxide is evaluated through column study**.

Keywords—Bentonite, Coir Pith, Column study, Iron Oxide

I. INTRODUCTION

The containment of wastes is certainly one of the most urgent problems faced by civil engineers. The most frequently used disposal options for solid waste is to dump in the landfill because of its low cost and efficiency. Landfill plays a vital role in the whole waste treatment/disposal process. Soil liners are preferred because of their low cost, large leachate attenuation capacity and resistance to damage and puncture. Clays also possess sorptive or attenuative capacity and reduce the concentration of contaminants in leachate. Soils generally have large capacity to sorb materials of different types, but some soils do not provide an impermeable boundary. Clay is the most important component of soil liners because the clay fraction of the soil ensures low hydraulic conductivity. It should have the following properties:

1. Permeability, a measure of the materials ability to contain the leachate. A low permeability generally 10-7 cm/sec is required.
2. Durability and resistance to weathering is the quality of the material to withstand the forces of alternating wet/dry and freeze/thaw cycle.
3. Constructability, which means the material, should be reasonably workable in terms of placement and compaction under field conditions.
4. Compatibility with leachate: the liner material must maintain its strength and low permeability even after prolonged contact with leachate.

Sand-clay mixtures have been utilized as a barrier material in several engineering applications. Bentonite-sand mixtures are comprised of two truly contrasting soils with regard to grain size, permeability, chemical activity and strength which, when combined in optimum proportion, can form an excellent seepage barrier that is dimensionally stable and possess a low hydraulic conductivity. Bentonite is contained within the voids between sand particles and in the presence of water hydrates and swells. When the void ratio of bentonite is less than its free-swell capacity, bentonite completely fills the space and presses lightly against the sand particles. If the void spaces in the sand exceeds free-swell capacity of the bentonite, the space will not become completely filled with hydrated bentonite, and so, will contain free water, forming holes or if connected to other water filled holes, channel.

Kerala is the largest producer of coconut in India. Coir is a natural fiber extracted from coconut husk. Coir pith is a agro waste generated from the process of coir fiber and considering as a renewable resource. Coir pith is a spongy, peat like residue from the processing of coconut husks form coir fiber known as cocopeat, it consists of short fibers (<2cm), around 2% - 13% of the total coir particles ranging in size from granules to fine dust. Coir pith consists of lignocellulosic compound. Due to its low carbon (pentosan) to lignin ratio of less than 0.5%, the total degradation of this material is impossible. The spongy structure of coir pith facilitates retention of water. It absorbs over eight times its weight of water. Lignin and cellulose are biopolymers bearing multiple phenolic, hydroxyl, carboxyl and amino groups which are reported as responsible for the removal of pollutants from waste water. The low values of bulk density and high values of pore space volume of coir pith are found to be favourable for the process of adsorption. Coir pith has, up to now, the least use and is still considered waste and nuisance, for which no important industrial uses have been developed, and they are normally incinerated or dumped without control. Nowadays, several studies are being carried out to utilize coir pith based adsorbents for contaminant treatment used them in modified forms. The major properties of coir pith were:

1. High water holding capacity, i.e. 6-8 times than its weight.
2. Slow degradation due to high lignocellulose content.
3. Excellent moisture retention even after drying.
4. Porosity is high, stores and releases nutrients over extended periods of time
5. Acceptable electrical conductivity (EC), pH, and Cation exchange capacity (CEC).
6. Greater physical resiliency that withstands compression better.
7. Being a poor conductor of heat, helps keep soil temperature under control.

II. MATERIALS REQUIRED

A. Sand

Locally available sand was collected from MEC campus for the study. Fig.1 shows a photograph of the soil used for the study. The properties of the collected sand is shown in Table 1.

Fig 1: Sand

Table 1: Properties of Sand

Soil Properties	Values
Effective size D10 (mm)	0.35
Uniformity coefficient Cu	1.37
Coefficient of curvature Cc	1.25
In-situ bulk unit weight (kN/m3)	14.44
Dry Unit weight (kN/m3)	14.09
Specific gravity	2.6
Angle of internal friction , Ø(degree)	31
IS designation	SP

B. Sodium Bentonite

The commercial available sodium bentonite was used for the study. It was collected from KINFRA Kazhakoottam. Fig.2 shows a photograph of sodium bentonite used for the study. Table 2 shows the properties of sodium bentonite obtained.

Fig.2: Sodium Bentonite

Table 2: Geotechnical properties of Sodium bentonite

Soil Properties	Values
Specific gravity	2.6
Maximum dry density (kN/m^3)	12.6
Optimum moisture content (%)	38
Liquid limit (%)	332
Plastic limit (%)	40.6
Plasticity index (%)	291.4
Shrinkage limit (%)	13.2
Free swell (ml/2g)	23
UCC strength (kN/m^2) at OMC	114.7
IS designation	CH

C. Iron Oxide Waste

The heavy metal used in this study was Iron Oxide. Iron Oxide is collected from KMML, Chavara, shown in fig 3. The initial percentage of iron oxide was 76.5%

Fig 3: Iron Oxide Waste

D. COIR PITH

The stabilizer used in the study was coir pith shown in Fig.4, consisting of flaky particles along with short and baby fibers. The air-dried coir waste that passed through the 4.75 mm sieve was designated as coir pith. The sieved coir pith consists of baby fibers which were difficult to remove manually. Chemically treated air-dried coir waste was used for the study. Table 3 shows the properties of coir pith.

Fig 4: Coir Pith

Table 3: Properties of coir pith (Ross et al.,2012)

Constituents	Values
Lignin %	38.5
Cellulose %	26.4
Nitrogen	0.24
C:N ratio	123:1
pH	5.4-5.8
Moisture%	20-30
CEC (meq)	15-20

E. SODIUM HYDROXIDE

Chemical treatment was done by soaking the additives in a solution of 1% of NaOH. Sodium hydroxide was most commonly used chemical for cleaning for cleaning the surface of fibers. The reaction of fibers with sodium hydroxide with cellulose was as follows.

Cell – OH + NaOH ---> Cell – O- Na+ H2O + Surface impurities The treatment removed lignin hemicellulose and other soluble compounds on the surface of the fibers. The reason for the improved mechanical properties was the removal of impurities on the fibers during alkali treatment. The level of interfacial adhesion was improved on alkali treatment.

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III METHODOLOGY

3.1 Preparation of sand bentonite liner

Compaction tests (IS 2720 Part7-1980), Unconfined Compression Strength tests (IS 2720 Part 10-1991) and Permeability tests (IS 2720 Part 17-1986) were conducted to prepare the sand bentonite mix for landfill liner. Bentonite used for this study was kept in a moisture controlled environment. Different proportions of Bentonite i.e., 18%, 20%, 22%, and 24% were added with the sand.

3.2 Treatment of coir pith

The additives are treated with sodium hydroxide flakes in order to remove the organic content present in the coir pith and to slow down the process of bio degradation. Chemical treatment was done by soaking the additives in a solution of 1% of NaOH. Alkali treatment involved soaking 1% solutions of NaOH maintained at 27°C for 24 hours. After alkali treatment the coir pith were rinsed thoroughly in water to remove unreacted NaOH before drying under the sun for about 2 days (Bwire et al, 2007). Only 1% of solution is used because more amount of alkali disintegrates the lignin content of natural additives. Colour variations were seen in the additives before and after treatment and this may be due to the removal of organic content. The reaction of sodium hydroxide with cellulose as follows,

Cell – OH + NaOH ---> Cell – O – Na+ + H2 O + surface impurities

3.3: Column Test

3.3.1 Column test for 90cm soil

In order to model field conditions, laboratory soil leachate column experiments were conducted to study the removal efficiency of heavy metals like iron. The setup was prepared according to (Ghiani et al., 2001). The experimental set up consists of a PVC pipe of 90cm height and 14cm diameter columns are fabricated for conducting column test (fig. 5). The soil was kept at the bottom of the column by required density and optimum moisture content. In order to prevent the floating of soil on the top of the column and blocking of soil at the outlet collection tube a filter medium was placed. The water column was maintained to a height 10cm above the soil and it was kept constant throughout the saturation period. After attaining saturation, the water head was replaced by lead acetate and the column set up was kept for a week. The effluents were collected at regular intervals of time and it was given to NCESS, Trivandrum.

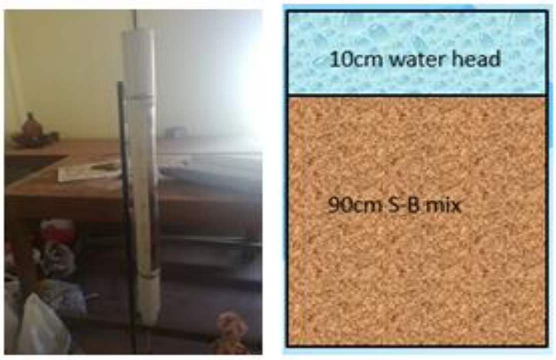

Fig 5: Fabricated 90 cm soil column

3.3.2 Treated coir pith as a barrier method for column study

For the soil leachate column experiments, first weighed amount of soil was transferred into a PVC column (90 cm height and 14 cm diameter) with the top portion (0-25 cm) being filled with clean soil , middle portion (40- 65 cm) and the lower portion (80-90cm) with clean soil to simulate the contaminant (Fe) distribution. Then placed 15 cm thick layer of NaOH treated coir pith barrier in between the soil sample (fig. 6). In order to prevent the floating of soil on the top of the column and blocking of soil at the outlet collection tube a filter medium were placed. After attaining saturation, the water head was replaced by replaced by iron oxide and the column set up was kept for a week. The effluents were collected at regular intervals of time and it was given NCESS,Trivandrum.

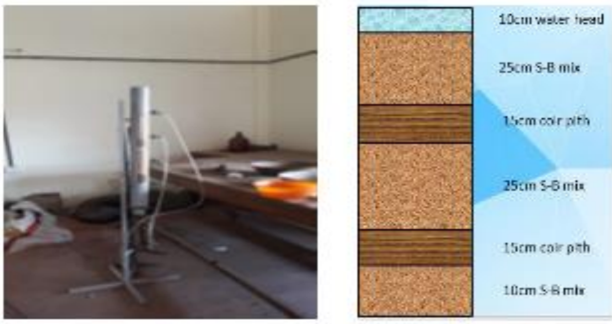

Fig 6: Fabricated 90 cm soil column

3.4: Chemical analysis

The collected effluent at regular intervals of time was given to NCESS, Trivandrum

IV. RESULT AND DISCUSSIONS

4.1: EFFECT ON COMPACTION AND STRENGTH CHARACTERISTICS OF SAND-BENTONITE MIXTURE

The results of Optimum moisture content and and Maximum dry density, and Unconfined Compression Strength of sand bentonite samples are presented in Table 4.

Table 4: Effect on compaction and strength characteristics of sand – bentonite mixture

Mix Combinations	MDD kN/m^3	OMC (%)	UCS kN/m^2
82%S+18%B	22.8	6.06	146
80%S+20%B	20.8	10.34	298
78%S+22%B	20.7	10.34	106.6
76%S+24%B	18.2	12.8	100.23

Fig 6 shows the variation of UCS at OMC for different percentage of bentonite used in the mix. The UCS value increases from 146 kN/m^2 at 18% bentonite mix to 298 kN/m^2 at 20% bentonite mix.

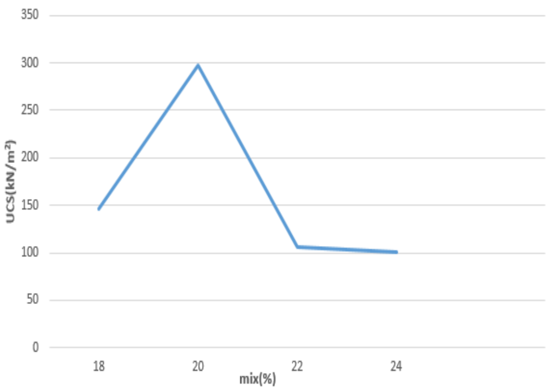

Fig 6: Variation in UCC strength on different mixtures

4.2: EFFECT OF PERMEABILITY ON SAND-BENTONITE MIXTURE

The results of permeability on sand bentonite samples are presented in Table 5.

Table 5: Effect of permeability on sand – bentonite mixture

Mix Combinations	Permeability (cm/sec)
82%S+18%B	1.7 x 10^ -8
80%S+20%B	1.6 x 10^ -9
78%S+22%B	1.6 x 10^ -8
76%S+24%B	1.8 x 10 ^-9

The increase in strength can be best explained by the change of soil structure due to the presence of bentonite. The bentonite occupies in the intergranular voids of the soil particles. Once the void spaces formed between the individual soil particles get completely filled by the bentonite, again the addition of bentonite replace sand particles and decreases the density after absorbing water, which results in decrease in UCC after an optimum content (20%). Bentonite content of 20% gives the maximum UCC strength and required permeability and was considered as the optimum mix for liner. The selected mix of 80%S +20% B was hence used for the remaining of the study.

4.3: SOIL COLUMN TEST ON IRON CONTAMINATED SOIL

Column test were carried out on sand-bentonite mix with and without the placement of treated coir pith. Required amount of soil was filled in the column at obtained optimum moisture content and maximum dry density. First test was conducted on contaminated soil and then that was correlated to compare the heavy metal removal efficiency of treated coir pith as a biosorbent. The effluents were collected from the bottom of the column at various time periods. Then the effluents were given to NCESS, Trivandrum.

4.4: CHEMICAL ANALYSIS

The collected effluent from soil column at regular intervals of time was given to NCESS, Thiruvananthapuram for conducting chemical analysis to find out the amount of iron oxide adsorbed by the soil, before and after the addition of coir pith as a barrier material. The results of chemical analysis are presented in Table 6.

Table 6: Results of chemical analysis

Time (hrs)	Percentage of iron oxide(%) in the collected sample	
	Sand bentonite liner	Coir pith amended liner
24	8.3	0.017
48	7.8	0.011
96	7.2	0.01

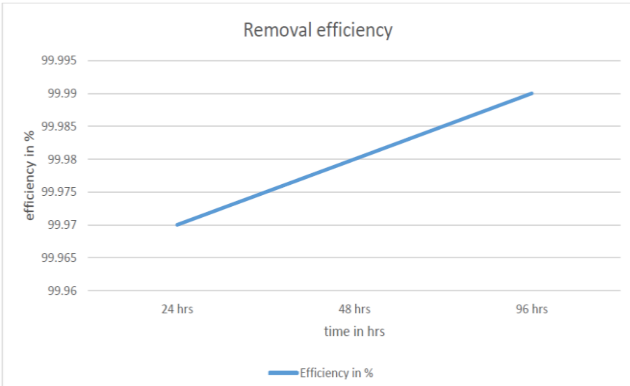

Fig 7: Removal of Efficiency

V. CONCLUSIONS

According to the test results, following are the conclusions which can be drawn from the study:

1. Properties of sand-bentonite mix confirm to the practical specifications of landfill liner, signifies that it can be used for the same

2. Sand- bentonite liner has a removal efficiency for Iron Oxide of about 90%.

3. Coir pith amended liner has a removal efficiency for Iron Oxide of about 99.9%, signifying that almost all of the heavy metal is absorbed on to the coir pith, so it can be suggested as an economically feasible technique for the retention of heavy metal in industrial landfills.

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