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# Study of Geotechnical Properties of Organic Waste Materials as Landfill Cover

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**Abstract -** *The natural $CH_4$ oxidation which is carried out through the use of landfill covers (biocovers) is the most suitable method for reducing $CH_4$ emissions from landfills. Oxidation process takes place by the activity methanotrophic bacteria, which oxidize $CH_4$ into $CO_2$. Organic soil supports the growth and activity of methanotrophic bacteria. Materials should conduct less heat and provides better temperature insulation, which can ensure an appropriate and stable temperature for methanotrophic bacteria within the biocover. The article presents an evaluation of the geotechnical behaviour of organic materials as cover liner (fibrous paper mill sludge, sludge-rice husk mixture 3:1,1:1,1:3 and rice husk) and to introduce a suitable landfill liner with the best property to reduce methane emission and rain water infiltration. The geotechnical properties of different organic materials including compaction, consolidation, hydraulic and thermal conductivities were analyzed. The obtained result is that both sludge and rice husk show low dry density, specific gravity, thermal and hydraulic conductivities. The materials studied have a very high water and organic content. Thus both materials show favored properties for biocover. Sludge and rice husk in 1:1 ratio is more suitable as landfill liner. The results showed that the sludge and rice husk are materials with reduced hydraulic and thermal conductivity and less $CH_4$ emission. These materials have multiple applications, such as in the construction of bottom liners, cover liners and steep side-slope liners for solid waste landfill.*

***Key Words***: Biocover, Fibrous paper mill sludge, Landfill, Landfill cover, Methane, Methanotrophic bacteria.

## 1. INTRODUCTION

Methane is a GHG with a global warming potential that is 25 times than that of $CO_2$.The anaerobic biodegradation of municipal solid waste (MSW) in landfills is one of significant global sources of anthropogenic $CH4_4$ emissions. It has also been estimated that 627.34 tonnes $CO_{2\text{-e}}$ ($CO_{2\text{-e}}$ or equivalent $CO_2$ is the concentration of $CO_2$ that causes the same level of radiative forcing as a given type and concentration of GHG) per year is generated in landfills worldwide, of which more than 85% is emitted into the atmosphere[1]. Therefore, mitigation actions are urgently required in light of the significant levels of $CH_4$ found in the atmosphere.[8]

Therefore, one of the most promising methods that would reduce $CH_4$ emissions from landfills is the natural processing of microbial $CH_4$ oxidation through active biological soil covers or biocovers. This oxidation process principally relies on the activity of a group of bacteria known as methanotrophs, which are able to use molecular oxygen ($O_2$) to oxidize $CH_4$ into $CO_2$. Biocovers are an alternative effective option for the mitigation of $CH_4$ emission[5]. Organic soil supports the growth of methanotrophic bacteria.

Increase in the cost of solid waste disposal and environmental regulations lead to the introduction of alternative industrial wastes as raw materials in the field of civil engineering. Fibrous paper mill sludge and rice husk are commonly available organic waste materials. Suitability of these materials as landfill liner is evaluated in this article. Good knowledge of geotechnical properties of cover materials is necessary for the proper design of biocover. Therefore, the goal of this paper is to provide insight into the geotechnical properties of sludge and rice husk-based biocover materials and assess their suitability for use as biocover media from a geotechnical point of view.

## 2. MATERIALS USED

### 2.1 Fibrous Paper Mill Sludge

The paper industry is responsible for the generation of high amounts of sludge every day, and it deserves attention by researches that are searching for technical solutions using alternative materials instead of natural resources. When employed in cover liners, the paper mill sludge seems to have a satisfactory performance in terms of geotechnical parameters because it is an economic and attractive alternative for clayey liners in conventional cover systems of sanitary landfills[1]. Fibrous Paper Mill Sludge used in this study is shown in Fig -1.

**Fig -1**: Fibrous Paper Mill Sludge

### 2.2 Rice Husk

Rice husk is the outermost layer of protection encasing a rice grain. Rice is the most commonly eaten daily foodstuff for more than 2/3of the world population. Rice husk is a waste product and its volume is about 20% of total rice crop. Rice husk used in this study is shown in Fig -2.

**Fig -2**: Rice Husk

## 3. RESULTS AND DISCUSSION

### 3.1 Organic Content

The organic content is determined as per ASTM D 2974. The sample is kept at 440°C. At this temperature organic matter is burned off and only the mineral constituents remain. Muffle furnace is used to maintain this temperature. The organic content is the ratio, expressed as a percentage, of the mass of organic matter in a given mass of soil to the mass of the dry soil solids[10]. Table 1 shows the organic content of fibrous paper mill sludge and rice husk.

**Table1:** Organic Content Result

| Material | Organic Content(%) |
|---|---|
| Fibrous paper mill sludge | 59.55 |
| Rice husk | 87.15 |

### 3.2 Specific Gravity

The knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc. Soils containing organic matter and porous particles may have specific gravity values below 2.0[11]. Table 2 shows the specific gravity results. As the specific gravity of rice husk is the least, it contain more organic content than sludge. Material with more organic content is suitable for the growth of methanotrophic bacteria.

**Table2:** Specific Gravity Result

| Material | Specific Gravity |
|---|---|
| Fibrous paper mill sludge | 1.75 |
| Rice husk | 1.4 |

### 3.3. Thermal Conductivity Test

The thermal conductivity of a bad conductor can be found using Lee's method. Thermal conductivity, *k*, is the property of a material that indicates its ability to conduct heat. Conduction will take place if there exist a temperature gradient in a solid (or stationary fluid) medium. Energy is transferred from more energetic to less energetic molecules when neighbouring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy[9]. The thermal conductivity of the material is shown in Table 3.

**Table 3:** Thermal Conductivity Result

| Material | Thermal Conductivity (W/m/K) |
|---|---|
| Fibrous paper mill sludge | 0.0513 |
| Fibrous paper mill sludge:Rice husk (3:1) | 0.0474 |
| Fibrous paper mill sludge:Rice husk (1:1) | 0.0426 |
| Fibrous paper mill sludge:Rice husk (1:3) | 0.0387 |
| Rice husk | 0.0348 |

The obtained results indicate that the thermal conductivity of the studied materials is strongly influenced by the rice husk content such that the thermal conductivity significantly decreases with increasing rice husk content. It can be concluded that all the materials, specially rice husk conducts less heat and thereby provides better temperature insulation, which can ensure an appropriate and stable temperature for methanotrophic bacteria within the biocover, an especially important factor for cold climates when the atmospheric temperature is low[1].

### 3.4. Compaction Test

The compaction curve of fibrous paper mill sludge, rice husk and its combinations is in Chart 1. The maximum dry density decreases as the rice husk content is increased. Pure sludge shows the highest dry density and lowest water content, whereas pure rice husk shows the lowest dry density and higher water content values. Material with low dry density shows low specific gravity value[12]. During the compaction process, samples with lower sludge content required the addition of more water but were still compactable while those with higher sludge content required less water and were less compactable[1]. Table 4 shows optimum moisture content and maximum dry density of the selected samples.

**Table 4:** Compaction Result

| Material | Optimum Moisture Content(%) | Maximum Dry Density(kg/m³) |
|---|---|---|
| Fibrous paper mill sludge | 54.06 | 874.61 |
| Fibrous paper mill sludge:Rice husk (3:1) | 100.07 | 648.92 |
| Fibrous paper mill sludge:Rice husk (1:1) | 154 | 458.25 |
| Fibrous paper mill sludge:Rice husk (1:3) | 206.02 | 335.79 |
| Rice husk | 244.33 | 224.77 |

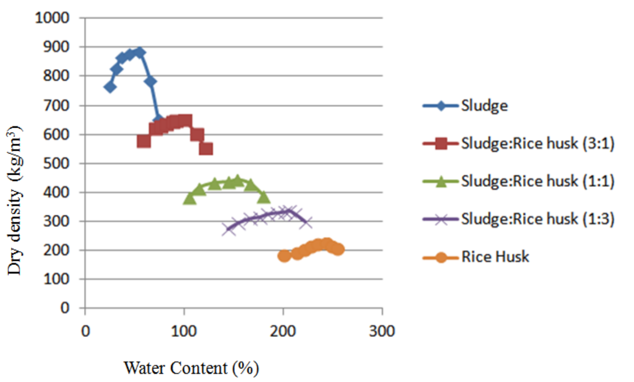


**Chart -1**: Compaction Curve

### 3.5. Consolidation Test

Consolidation can change the porosity of biocovers. The gas transport process in biocovers (e.g. advection flux of $CH_4$ (upward) and diffusion flux of oxygen (downward) into the $CH_4$ oxidation zone) and the performance ($CH_4$ oxidation capacity) of biocovers is strongly affected by their porosity [1]. These cracks provide the preferential pathways for the escape of $CH_4$ into the atmosphere. Thus, there is a need to understand the consolidation characteristics of the biocover materials[7]. Table 5 shows the consolidation test results of the sample. Initially when sludge alone was tested the settlement was high. When rice husk was added, the settlement is increased[13].

**Table 5:** Consolidation Result

| Material | $C_v$ (mm²/s) | $C_c$ |
|---|---|---|
| Fibrous paper mill sludge | 5.28 | 1.14 |
| Fibrous paper mill sludge:Rice husk(3:1) | 5.44 | 1.22 |
| Fibrous paper mill sludge:Rice husk(1:1) | 5.61 | 1.28 |
| Fibrous paper mill sludge:Rice husk(1:3) | 5.79 | 1.31 |
| Rice husk | 5.83 | 1.39 |

### 3.6. Hydraulic Conductivity Test

Biocovers should have very less hydraulic conductivity so as to reduce rain water infiltration. Hydraulic conductivity of a specific specimen is reduced as the moisture content and dry density are increased. Table 6 shows the hydraulic conductivity of the materials. Hydraulic conductivity increases on adding rice husk, for sludge it shows the least value. When rice husk alone is tested, hydraulic conductivity increases. The interlinked fibrous structure of sludge is the reason for low hydraulic conductivity of the material[1]. The sludge will occupy the small pores in between rice husk, and reduces the hydraulic conductivity[14].

**Table 6:** Hydraulic Conductivity Result

| Material | Hydraulic Conductivity(k) cm/s |
|---|---|
| Fibrous paper mill sludge | 6.97688E-06 |
| Fibrous paper mill sludge: Rice husk (3:1) | 6.9338E-06 |
| Fibrous paper mill sludge: Rice husk (1:1) | 6.57147E-06 |
| Fibrous paper mill sludge: Rice husk (1:3) | 6.46185E-06 |
| Rice husk | 5.25284E-05 |

## 4. CONCLUSIONS

Assessment and comparison of compaction, consolidation, hydraulic and thermal properties of sludge, sludge and rice husk mixtures with a mix ratio of 1:3, 1:1, 3:1 and rice husk for biocovers are made. The specific gravity of the materials where less, which shows its high organic content. The thermal conductivity values range from 0.03487W/m/K to 0.05131 W/m/K. As the selected materials showed low thermal conductivity, the materials provide suitable condition for the growth of methanotrophic bacteria. Organic contents result in higher compressibility of material. These materials show very high $C_v$ and $C_c$ value.

The optimum moisture content of the materials varies from 54% to 244.33% while the maximum dry density ranges from 224.7 kg/m$^3$ to 874.614 kg/m3. The maximum dry density and compatibility decrease with increasing rice husk content. The hydraulic conductivity values range from 6.97x10$^{-06}$cm/s to 5.25x10$^{-06}$cm/s. Least hydraulic conductivity and settlement was found for sludge. Sludge and rice husk in 1:1 ratio is the best to use as landfill liner. The results showed that the sludge and rice husk are materials with more organic content, reduced dry density, hydraulic and thermal conductivity. Organic materials can provide better temperature insulation and consequently a more stable temperature within biocovers which is particularly important in cold climates. Organic liners could have multiple applications, such as in the construction of bottom liners, cover liners and steep side-slope liners for solid waste landfill

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## REFERENCES

[1] Khoshand, Afshin, and Mamadou Fall. "Geotechnical characterization of peat-based landfill cover materials." Journal of Rock Mechanics and Geotechnical Engineering 8.5 (2016): 596-604.

[2] Reddy, Krishna R., et al. "Enhanced microbial methane oxidation in landfill cover soil amended with biochar." Journal of Geotechnical and Geoenvironmental Engineering 140.9 (2014): 04014047.

[3] Heineck, Karla Salvagni, Nilo Cesar Consoli, and Lidiane da Silva Ibeiro. "Engineering properties of fibrous paper mill sludge from southern brazil." Journal of Materials in Civil Engineering 23.9 (2011): 1346-1352.

[4] Pedersen, Gitte Bukh, Charlotte Scheutz, and Peter Kjeldsen. "Availability and properties of materials for the Fakse Landfill biocover." Waste management 31.5 (2011): 884-894.

[5] Scheutz, Charlotte, et al. "Evaluation of respiration in compost landfill biocovers intended for methane oxidation." Waste management 31.5 (2011): 895-902.

[6] Cabral, A. R., J. F. V. Moreira, and L-B. Jugnia. "Biocover performance of landfill methane oxidation: experimental results." Journal of Environmental Engineering 136.8 (2009): 785-793.

[7] Mesri, G., and M. Ajlouni. "Engineering properties of fibrous peats." Journal of Geotechnical and Geoenvironmental Engineering 133.7 (2007): 850-866

[8] Stern, David I., and Robert K. Kaufmann. "Estimates of global anthropogenic methane emissions 1860–1993." Chemosphere 33.1 (1996): 159-176.

[9] Lee's Disc Apparatus (Theory) : Heat & Thermodynamics Virtual Lab : Physical Sciences : Amrita Vishwa Vidyapeetham Virtual Lab(2017)

[10] ASTM, D. "2974." Standard test method for moisture, ash, and organic matter of peat and other organic soils (1987).

[11] IS: 2720(Part 3)-1980,“ Determination of Specific Gravity”, Bureau of Indian Standards, Manak Bhavan, New Delhi

[12] IS: 2720(Part 7)-1980,“ Determination of Water Content-Dry Density relation using Light Compaction”, Bureau of Indian Standards, Manak Bhavan, New Delhi.

[13] IS: 2720(Part 15)-1986,“Determination of Consolidation Properties”, Bureau of Indian Standards, Manak Bhavan, New Delhi.

[14] IS: 2720(Part 17)-1986,“ Determination of permeability of soil”, Bureau of Indian Standards, Manak Bhavan, New Delhi.