A STUDY ON SOIL-LIKE MATERIAL OBTAINED FROM LANDFILL MINING

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ABSTRACT
This study aims at understanding the engineering properties of soil-like-material (SLM) obtained from landfill mining and its feasibility to be reused in multiple potential directions. The engineering properties of the material are taken from the researchers. This study compares the properties of soil-like material (SLM) with the properties of local soil. Leaching of heavy metals from soil-like material is analyzed to understand the contamination levels. Properties like organic content, release of dark colour leachate and amount of soluble salts are analyzed in comparison to local soils. From geotechnical characterization of SLM, it is found that SLM is non-plastic with low specific gravity due to presence of organic material. The strength properties are found to be satisfactory and permeability is similar to that of local soil. From the laboratory test results, it is found that the SLM is not hazardous. It is not similar to local soil. It is not inert and hence the unrestricted re-use of SLM is avoided. Treatment techniques and design measures can be adopted and SLM can be used in various applications.

Keywords: Landfill mining, Re-Use, Soil-Like-Material (SLM), Treatment.

INTRODUCTION
Landfill mining is a rapidly growing area of waste management. Statistics show that around 30-40 million tons of municipal solid waste is disposed in dumpsites annually in India (Downtoearth, 2019). Landfill mining operations extract and reprocess materials from older disposal sites. The ultimate aim of the process is to mine the landfills for recyclable or reusable materials which can be refined for further use. It is generally been employed as a means of waste management and also to increase space to meet disposal capacity needs. A landfill needs to be at least 15 years old before planning mining activities (Joseph et al., 2008). Soil-like material (SLM) is the largest component obtained from landfill mining. This is due to the deposition of silts, street sweepings, construction and demolition waste at the landfill site. It is possible to re-use this material in various on-site applications according to its suitability. Hence, it justifies the economic viability of mining projects. Large scale use of SLM as earth-fill in off-site applications has not been widely reported. Depending upon the composition, quality of the material and market demand, many options for re-use are available. As it is obtained from dumpsites, it is tested for strength parameters, hazardous nature and spread of contaminants. There is no universally adopted definition of 'soil-like material' and it is defined based on the size of screens used by different researchers.

OBJECTIVES
1. To study if SLM is Hazardous.
2. To compare SLM with local soil.

3. To study geotechnical characterization of SLM – grain size distribution, compaction, shear strength, permeability and compressibility characteristics.
4. To study the treatment techniques for re-use of SLM.

REVIEW OF LITERATURE

Geotechnical properties of SLM have been studied by Song et al. (2003); Oettle et al. (2010), and Hyun et al. (2011). The strength properties have been found acceptable by all except Song et al. (2003) who reported a reduction in strength with an increase in organic content. Concerns regarding long-term settlements due to high organic content have been indicated by Oettle et al. (2010). Use of SLM for off-site applications in roads and in embankments after washing and blending have been suggested by Oettle et al. (2010) and Wanka et al. (2017) respectively. Scheu and Bhattacharya, 1997; Kurian et al., 2003; Prechthai et al., 2008; Zhou et al. (2015) have reported the feasibility of using SLM as compost. Mukhopadhyay et al. (2016) has observed the effect of reclaimed coal mine spoils on the soil. The major attention of the previous research is focused on the heavy metals as contaminants in the soil-like material recovered from mining of dumpsites. The leaching of total soluble solids can increase the salinity of sub-soil (Somani et al., 2019). Leaching of colored liquid can cause the coloration of the surrounding water bodies which may affect consumer perception towards drinking water (Somani et at., 2019). Organic content is not a contaminant, but if the levels are too high, long term settlements can occur when the material is used in earthworks.
The present study deals with analyzing the properties of SLM obtained from old municipal solid waste dumps located in Delhi. The main objective of the study is to identify if the soil-like material is similar to local soil, to study its nature and identify its re-use as earth-fill based on the presence of heavy metals, soluble salts and release of leachate.

RESEARCH METHODOLOGY

Data Collection: The study is based on the data taken from the webinar, "Mining of Large-Sized Old Landfills for Recovery of Resources and Geotechnical Re-use of Soil-Like Material" presented by Prof.Manoj Datta, Indian Institute of Technology (IIT) Delhi at KCT International Webinar series on Advancement in Geotechnical Engineering. Numerical data is taken from the research scholars (Mohit Somani and D.Parida - MSW mined waste; Aali Pant - Coal Ash; Garima Gupta and D.Bansal - MSW Ash from WTE plants and Apoorva Agarwal - processed waste from C&D plants) and Geo-Environment Group working on Re-use of Waste at IIT Delhi.

MATERIALS AND METHODS

Soil-like Material (SLM) is obtained from the municipal solid waste dumpsites. The soil like fraction obtained from landfill mining has to be screened for geotechnical characterization and tested further to confirm suitability for various applications.

Trommeling: It is a mechanical screening process to separate materials. A rotary screening machine with perforated cylindrical drum, elevated at an angle at the free end is loaded with material for size separation. Two sets of rotating screens (30mm and 60mm) were used.

Handpicking: Construction and demolition waste was handpicked and transferred to processing plants.

Laboratory tests: Tests for geotechnical characterization include compositional analysis, Grain Size Distribution, tests to determine compaction, shear strength, permeability and compressibility. Other tests performed are Toxicity Characteristic Leaching Procedure (TCLP) test, test for organic content, Total Heavy Metal Analysis, test for total soluble solids, test for intensity of colour, batch leaching test.

DATA ANALYSIS

Compositional Analysis: On screening of samples, the aged municipal solid waste composed of Soil-like material, Plastic, Gravel-like material, Textiles, Glass and miscellaneous material.

Table 1. Compositional Analysis

Material	Compositional analysis (%)
Gravel	40-55
Soil	20-25
C&D waste	18-24
Combustibles	3.2-4
Others	0.9-3

Combustibles include paper, plastic, wood and textiles.

Grain Size Distribution: Grain Size Distribution of the municipal solid waste include boulders (>80mm), coarse gravel (80mm-20mm), fine gravel (20mm-4.75mm), sand (4.75mm-0.075mm), silt + clay (<0.075mm).

Table 2. Grain Size Distribution

Size (in mm)	>80	80-20	20-4.75	4.75-0.075	<0.075
MSW (wt%)	2-8	8-15	12-20	45-50	20-25

TCLP (Toxicity Characteristic Leaching Procedure) leaching results for SLM:

Table 3. TCLP leaching results

Metals	mg/kg	TCLP levels	Metals	mg/kg	TCLP levels
Ag	0.02-0.48	100	Hg	0.01-0.1	4
As	0.1-0.2	100	Ni	1.6-2.3	-
Ba	6.4-11.2	2000	Pb	0.3-0.7	100
Cd	0.1-0.15	20	Se	0.02-0.03	20
Cr	2.1-2.5	40	Zn	19-40	-
Cu	4.2-5.7	-			

Leachate extraction and treatment systems should be implemented to handle the leachate which is generated.

Comparison of SLM with Local Soil

Organic Content:

Table 4. Organic Content

S.No.	Sample detail	Organic content (%)
1.	Soil-like material (from landfills)	6-18
2.	Local soil	1-1.2
3.	Regulatory limit for earthfills	1-5

Organic content is higher than the maximum prescribed limit for earth-fills and settlements can occur due to biodegradation.

Total Soluble Solids:

Table 5. Total Soluble Solids

Sample detail		Total soluble solids (%)	Sulphate (%)	Chloride (%)
Soil-like material		1.4-2.0	0.4-0.9	0.3-0.8
Local soil		0.08-0.1	0.02	0.11
Regulatory limits for earth fills	a) permits re-use without any restriction	-	0.05	0.01
	b) permits reuse if surface layer is sealed	-	0.6	0.15

Total soluble solids including sulphates and chlorides are significantly higher than the values prescribed for unrestricted use of soils.It can be observed that the SLM can be used for earth fills by taking additional design measures in the form of drainage layers at the base and the liners at the top.

Intensity of colour:

Table 6. Intensity of colour

S.No.	Sample detail	Intensity of colour (Pt-Co)
1.	Soil-like material	325-580
2.	Local soil	25 ± 3

Release of dark colored leachate from SLM in comparison to the background soil hampers the direct reuse of SLM as an earth-fill.

Total Heavy Metal Analysis (mg/kg):

Table 7. Total Heavy Metal Analysis (mg/kg)

Sample detail	As	Cd	Cr	Cu	Ni	Pb	Zn
Soil-like material	2.6-7.8	0.28-3.76	89-230	140-501	26-53	27-333	153-571
Local soil	0.4-2.2	Not detected	10-28	11-45	8-28	4-6	55-65

A large amount of heavy metal composition is detected in the SLM obtained from landfill mining. Hence, it makes SLM differ from local soil on a wide range preventing the unrestricted use of soils.

Leachable heavy metals (mg/kg):

Table 8. Leachable heavy metals (mg/kg)

Sample detail	As	Cd	Cr	Cu	Ni	Pb	Zn
Soil-like material	0.01-0.2	0.001-0.003	0.004-0.1	0.08-2.0	0.01-0.46	0.01-0.4	0.2-1.5
Local soil	0.001-0.01	0.0003-0.01	0.02	0.008-0.11	0.02	0.03	0.27-0.6

The higher values of leachable heavy metals do not allow the unrestricted use of SLM. Leachate extraction and treatment systems should be implemented to handle the leaching of heavy metals into natural resources.

Geotechnical Characterization of SLM

GSD, Specific Gravity and Plasticity Index:

Table 9. GSD, Specific Gravity and Plasticity Index

Sample detail	Organic content (%)	Grain size distribution (%)			Plasticity index	Specific gravity
		Sand	Silt	Clay		
Soil-like material	9-18	54-55	39-42	9-10	Non-plastic	2.20-2.30
Delhi silt (Background soil)	0.9-1.2	15-16	79-82	5-6	5-7	2.70-2.75

The Soil-like material obtained from municipal solid waste dumpsite is found to be non-plastic with lower specific gravity due to presence of organic material.

Compaction characteristics:

The maximum dry density and OMC of SLM from the dumpsite is found to be in the range of 1.35-1.68g/cc and 16-28% respectively. In the local background soil (Delhi silt) maximum dry density and OMC was found to be 1.84g/cc and 14% respectively.

Shear strength characteristics:

Table 10. Shear strength characteristics

Sample detail	Organic content (%)	Compacted unit weight (g/cc)	Saturated unit weight (g/cc)	Cohesion intercept (c', kPa)	Angle of shearing resistance (ϕ', degree)
Soil-like material	15	1.34	1.68	24	36
Delhi silt (Background soil)	1	1.84	2.19	5	28

The samples of SLM are found to exhibit angle of shearing resistance in the range of 34°-38° in saturated conditions. The small value of cohesion intercept (7.5 to 24 kPa) could be attributed to the presence of a small amount of fine fibrous material in the SLM. No significant effect of organic content is observed on the shear strength parameters of SLM.

Permeability:

Table 11.Permeability

Sample detail	Permeability (m/sec)
Soil-like material	7.7×10^{-7}
Delhi silt (Background soil)	5.7×10^{-7}

Permeability of SLM sample from municipal solid waste dumpsite is found to be 7.7×10^{-7} m/sec which is closer to the permeability of local background soil.

Compressibility:

Table 12.Compressibility

Sample detail	Organic content (%)	Compression index (C_c)
Soil-like material	15	0.199

Compression index of SLM ranges between 0.133-0.199, effect of organic content can be easily seen on the compressibility characteristics of SLM. Higher organic content results in the high C_c and settlements can occur due to biodegradation.

Treatment Techniques:

As it is seen, the presence of high organic content, soluble salts, dark colored leachate, heavy metals in the soil-like material, it's employment in any field should be involving treatment methods before utilizing it directly.

Electro kinetic Remediation:

This technique uses electric potential to extract organic, inorganic compounds and heavy metal particles from soil. The application of electric field on SLM shows a significant effect on the movement of soluble salts and heavy metals towards the electrode ends. However, there is no effect on organic content and release of dark coloured leachate.

Phyto-remediation:

A promising approach for re-vegetation of heavy metal polluted land, Phyto-remediation is an eco friendly approach that could be a successful mitigation measure to revegetate heavy metal polluted soil in a cost effective way. It is a bioremediation process which uses various types of plants to remove, transfer, stabilize and destroy contaminants in soil. Its effect on SLM shows a decrease in the concentration of heavy metals where as no effect on organic content, soluble salts and color is observed.

Thermal treatment:

Thermal desorption is a remediation method used to clean contaminated soils by applying heat, the wastes with low boiling points are forced to turn into vapour which can be collected and treated in an off gas treatment unit. The thermal treatment of SLM after 500° C and above has shown removal of organics and a significant decrease in the release of color. However, no effect of thermal treatment is observed on the soluble salts and total heavy metals.

Washing:

Soil washing is an ex situ remediation technique that removes hazardous contaminants from soil by washing the soil and then separating the clean soils from contaminated soils and wash water. The washing of SLM with pure water has shown a significant reduction in the intensity of release of color, leaching of soluble salts and leachable heavy metals. However, to achieve a significant reduction in the concentration of contaminants, a large quantity (100-120 mL/g) of water is needed. Also, it is noted that organic content is not eliminated by washing of SLM.

Re-use of soil-like material

A study based on the feasibility of re-use of SLM obtained from aged MSW landfills in India, suggests the bulk re-use of SLM in earth works as a replacement for local soil, in embankments for roads, railways and water retaining structures, filling low lying areas and abandoned deep mining pits. And also a potential for limited re-use of SLM as compost to re-vegetate barren lands. (Datta et al, 2020)

Critical issues in direct re-use of SLM due to the presence of high levels of organic matter, heavy metals and soluble salts indicate that the SLM requires treatment before offsite re-use or specific design measures are must before placing it as earth fill in embankments, low lying areas and deep pits. Some options are discussed hereafter

Large area fills of low height – These applications would be for non load bearing purposes with limited consequences of excessive settlement due to degradation of organic matter. The concerns are the contamination of shallow ground water table or nearby wells and plant root uptake of heavy metals. The design solutions would focus on restricting the height of fills, avoiding locations with shallow water table and allowing only non edible vegetative growth on the surface.

Embankments – In this case, the issue of long term creep settlements due to high organic content of SLM is of concern and its effect on road or railway track has to be addressed. Mixing SLM with local soil could reduce the organic content significantly. Uncontrolled emissions of soluble salts, color, soluble metals can be restricted by providing suitable impermeable covers at the top and on side slopes as well as liners on the base.

Filling of open pits – The base of open pits, usually at depths around 10-30m, are close to ground water table. As dissolved salts, dark colored leachate and soluble metals from soil-like material can harm the ground water quality, the design should focus on providing liners at the base and side slopes of such pits. Leachate collection systems should extract and send it for treatment till SLM becomes stable and emissions reduce to acceptable values.

Regeneration of barren land – A thin layer of SLM can be spread over the barren land / agro forestry to enhance the vegetative growth on the original soil. SLM can be used as low nutrient compost in non agricultural applications including parks, non edible crops etc. However, its direct use as compost in agricultural applications is not feasible.

RESULTS

From the study of laboratory test results, we confirm that soil-like material is not hazardous. It is not similar to local soil. It can be used in shallow earth-fills for raising low-lying areas for landscaping. It can be used as large area surface application for re-vegetation, soil conditioning and eco-forestry. It is non-plastic with low specific gravity due to presence of organic material. The strength properties are found to be satisfactory and permeability is similar to that of local soil. Although SLM is found to be non-hazardous in nature as per TCLP criteria, it is not inert and the direct re-use of SLM is not a feasible option.

DISCUSSION

In general, around the world, the soil like material from old landfills is retained at the landfill site itself or placed in new lined landfills. Lining of the new landfills/earthworks is essential in order to keep the soil and ground water in the surrounding areas safe from contamination. Recent NGT orders directed that mining of MSW dumps is leading to unrestricted earth filling. By undertaking large scale unrestricted re-use of SLM, slow spread of contamination over large area will take place. Design measures and treatments are required. Otherwise in 10-15 years the MSW dumps might disappear but the contaminants will not.

RECOMMENDATIONS

Nature has a powerful capacity to repair itself. So, can mix this soil-like material with natural soil and let the nature heal itself. However bad the damage, the nature's capacity to repair itself might prevent the unmitigated disaster that many fear on first sight.

LIMITATIONS

In this study, only a limited number of contaminants are examined. Other contaminants such as, persistent organic pollutants, pharmaceutical chemicals, microbial pathogens etc, are not studied. Hence, researchers cautioned that, a comprehensive site specific assessment should be made for other contaminants as well when examining the use of residues from old landfills in earthwork projects.

CONCLUSIONS

The present study compares the properties of soil-like material obtained from landfill mining with the properties of natural soil. The major conclusions are summarized below:
Soil-like material is non-plastic with low specific gravity due to presence of organic material. The strength properties are found to be satisfactory and permeability is similar to that of local soil.
The results indicate that high heavy metal concentrations do not allow its direct usage without design measures and treatment. Hence, it can find limited applications depending upon its suitability.
The researchers also mentioned that the future research can focus upon the possible remediation technologies to make the soil-like material suitable for offsite applications. The biological stability tests or degradation studies of SLM can also be taken into consideration in further studies.

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