LANDFILL MINING: CHARACTERIZATION OF SOIL-LIKE MATERIAL (SLM) RECLAIMED FROM OLD MSW DUMPSITES AND ITS SUITABILITY FOR GEOTECHNICAL RE-USE

ABSTRACT

In developing countries, the accumulation of large quantities of municipal solid waste (MSW) in open dumpsites (unlined landfills) over the past few decades has resulted in such dumps occupying vast areas of land and reaching heights as tall as 50 m or more. Statistics shows that around 30−40 million metric tons of MSW is disposed in dumpsites annually in India. Around 25,000 acres of urban land is locked in dumpsites with more than 140 million tons of legacy waste (in 517 dumpsites) occupying valuable land in 472 cities of India causing significant environmental impacts on the nearby ecosystem. To reclaim these dumpsites, landfill mining has gained major attention in past few years in India. Landfill mining is an approach whereby solid waste that has previously been landfilled is excavated and processed for recovery of resources. In the present study, an experimental investigation has been undertaken to characterize and assess the feasibility of reusing soil-like material (SLM) obtained by the screening of aged municipal solid waste (MSW) in offsite geotechnical applications. SLM constitutes a major portion of the total MSW in old dumpsites.

Aged MSW (more than 10 years old) has been collected from four old MSW dumpsites of India located at Delhi, Hyderabad, and Kadapa. Soil-like material (SLM, minus 4.75 mm) is observed to be the major component (60-70%) of total aged MSW. The following experimental investigation was conducted on the SLM:

a. Physicochemical characterization including moisture content, organic content, pH, electrical conductivity, ultimate analysis etc.
b. Geoenvironmental characterization (contaminants of concern) including total soluble solids, release of dark-colored leachate, and heavy metals (total as well as leachable).

c. Geotechnical characterization including grain size distribution, compaction characteristics, shear strength, permeability, and compressibility.

The effect of depth of waste on the characteristics of total aged MSW and SLM has been assessed by collecting undisturbed samples through drilling and sampling in 150 mm dia. boreholes up to 35 m depth from the top level and mid-height at Bhalswa dumpsite in Delhi.

The results of the characterization of SLM have been compared with the background soil of the nearby virgin area of the dumpsites as well as with the national and international regulatory practices. Organic content in the SLM of all four dumpsites is found to be 5-18% which is 5-15 times higher than the background soil. Total soluble solids in the SLM and background soil have been found to be in the range of 4880-25220 mg/kg and 500-1000 mg/kg respectively. Majority of the total soluble solids consist of sulphate and chlorides. Sulphates and chlorides are observed to be 10-25 times higher than the background soils. SLM is found to release dark-colored leachate (225-925 PCU) in comparison to background soils (25-40 PCU). The total heavy metal concentration of Cd, Cr, Cu, Pb, and Zn has been found to be significantly higher (5 to 30 times) in the SLM than the background soils. The leachable heavy metals (Cr, Ni, Cu, As, Cd, Pb) have been found to be 3-10 times higher in leachate from SLM than the water extract from background soils. The leachable fraction of Cd is found to exhibit extremely high concentration (58-97 times) higher in SLM than the background soil. Toxicity characteristics leaching procedure (TCLP) results reveal that the level of heavy metals in soil-like material is not high enough to classify SLM as hazardous.

The total unit weight, organic content, and moisture content have been found to be 1.25-1.90 g/cc, 10 to 25%, and 15 to 40% respectively in the undisturbed samples of total MSW collected from boreholes up to 35 m depth from the top and mid-height at Bhalswa dumpsite. A wide variation has been observed in the characteristics of all the parameters of total MSW samples which reflects the heterogeneity of the material. A slight decrease in the organic content is observed towards the lower end of the boreholes, whereas, total unit weight is observed to increase with increase in the depth of waste. Increase in the percentage of soil-like material (SLM) with increase in the depth of waste has been observed. A significant increase in the concentration of soluble salts (mainly sulphates and chlorides) and leachable heavy metals (Cr, Cu, and Zn) has been observed with increase in the depth of waste.

Based on the grain size distribution analysis, the SLM from all four dumpsites has been found to be significantly coarser than the background soil which may be due to the significant presence of construction and demolition debris in the SLM. SLM is found to be non-plastic in nature. Specific gravity of SLM is found to vary between 2.10-2.60. The shear strength of SLM is found to be similar or better than the background soil. SLM exhibits an angle of shearing resistance in the range of 34^o-38^o in saturated conditions. The permeability of SLM is found to range between 8.9 x 10^{-6} to 7.7 x 10^{-7} m/sec which is similar to the background soil of Delhi (Delhi silt). The compression index of SLM is found to be in the range of 0.13-0.20.

The feasibility of reuse of SLM in offsite applications such as earth-fill and compost has been assessed by comparing the characteristics of SLM with the national and international regulatory thresholds for reuse as well as with the background soil. The organic content in the SLM is found to be higher than the maximum permissible limits (1-5%) for use of soil in earth-fills. The total soluble solids (including sulphates and chlorides) have been found to be significantly higher than the permissible limits of unrestricted use of soil as per German protocol (LAGA, 2012). Not much attention has been focused in the literature on the release of dark-colored leachate from SLM, however, it has a great potential to cause the coloration of the nearby water bodies which can affect the consumer perception towards water consumption. Leachable heavy metals (based on single batch leaching with DI water) in the SLM have been found to be significantly higher than the limits given in the regulatory thresholds for the unrestricted use of soil as per LAGA, 2012. Total heavy metals (Cd, Cr, Cu, and Zn) have been found to be slightly higher than the maximum allowable limits for the unrestricted use of soil. Although SLM is found to be non-hazardous in nature on the basis of TCLP test, the open and unrestricted use of SLM as earth-fill in off-site applications is not a feasible option. The nutrients (N, P, and K) levels in SLM, by and large, satisfy the requirements prescribed in the SWM Rules (2016) for use of SLM as compost, however, low total organic carbon and elevated heavy metals do not allow its direct use in agricultural applications. At best it has potential to be used in non-agricultural applications for non-edible vegetation.

The feasibility of reuse of SLM in offsite geotechnical applications such as earth-fill in embankments for roads, railways, and water retaining structures; filling of low-lying areas; filling of deep pits would require reduction/removal of organic content (through thermal treatment etc.). In addition, the requirement of sealing layer would have to be assessed along with leachate collection wells (as in earth-fills for deep pits) and horizontal leachate drainage pipes (as in earth-fills for embankments). SLM can be used directly in thin layers by blending with local top soil for large surface area projects involving re-vegetation, landscaping etc. with non-edible plants.

Treatment technologies including electrokinetic remediation, phytoremediation, thermal treatment, and washing have been explored to reduce the level of contaminants below the maximum allowable limits for the offsite reuse of the SLM. The application of the electric field has shown a significant reduction of heavy metals and soluble salts from SLM. However, no effect of electrokinetic treatment is observed on organic content and release of dark-colored leachate. The phytoremediation experiments have shown a decrease in the concentration of heavy metals in the SLM. However, no effect on organic content, soluble salts, and release of dark-colored leachate is observed. The thermal treatment of SLM at 500^{o}C and above has shown removal of organic content and a significant decrease in the release of color, however, no effect of thermal treatment is observed on the leaching of soluble salts and total heavy metals. The washing of SLM with ultrapure water has shown a significant reduction in the intensity of release of color, leaching of soluble salts, and leaching heavy metals from SLM, however, washing has not shown a minimal effect on organic content and total heavy metals.

The findings of present study shows that the bulk of the material reclaimed after the mining of old MSW dumps consists of soil-like material (SLM). However, SLM is found to be contaminated on the basis of excessive presence of soluble salts, release of dark-colored leachate, elevated total heavy metals, and significantly higher leachable heavy metals, therefore, its unrestricted (direct) reuse in offsite geotechnical applications is not feasible. There is no one comprehensive treatment technology that can remove/reduce all the contaminants. Therefore, SLM can only be re-used after adopting suitable design measures such as sealing layers, leachate collection system/drainage system.