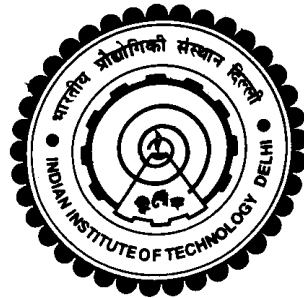


**LANDFILL MINING:
CHARACTERIZATION OF SOIL-LIKE MATERIAL (SLM)
RECLAIMED FROM OLD MSW DUMPSITES AND
ITS SUITABILITY FOR GEOTECHNICAL RE-USE**

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INDIAN INSTITUTE OF TECHNOLOGY DELHI
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by

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Submitted

in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

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CERTIFICATE

This is to certify that the thesis entitled “**LANDFILL MINING: CHARACTERIZATION OF SOIL-LIKE MATERIAL (SLM) RECLAIMED FROM OLD MSW DUMPSITES AND ITS SUITABILITY FOR GEOTECHNICAL RE-USE**” being submitted by **Mr. Mohit Somani** to the **Indian Institute of Technology Delhi** is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements for **DOCTOR OF PHILOSOPHY** degree. The research report and results presented in this thesis have not been submitted, in part or full, to any University or Institute for the award of any degree or diploma.

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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 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°-38° in saturated conditions. The permeability of SLM is found to range between 8.9×10^{-6} to 7.7×10^{-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°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.

सार

विकासशील देशों में, पिछले कुछ दशकों में खुले डंपसाइट्स (अनलाइन लैंडफिल) में बड़ी मात्रा में ठोस अपशिष्ट (MSW) के संचय के परिणामस्वरूप ऐसे डंप भूमि के विशाल क्षेत्रों पर कब्जा कर लिए हैं और ५० मीटर या उससे अधिक की ऊंचाई तक पहुंच गए हैं। आंकड़े बताते हैं कि भारत में सालाना ३०-४० मिलियन मीट्रिक टन MSW डंपसाइट में डाला जाता है। लगभग २५,००० एकड़ शहरी भूमि भारत के ४७२ शहरों में १४० मिलियन टन से अधिक पुराने कचरे (५१७ डंपसाइट्स में) के साथ डंपसाइट्स में बंद है, जिससे आस-पास के पारिस्थितिकी तंत्र पर महत्वपूर्ण पर्यावरणीय प्रभाव पड़ता है। इन डंपसाइट्स का निराकरण करने के लिए, भारत में पिछले कुछ वर्षों में लैंडफिल खनन ने प्रमुख ध्यान आकर्षित किया है। लैंडफिल माइनिंग एक ऐसा दृष्टिकोण है जिसके तहत पहले लैंडफिल किए गए ठोस कचरे की खुदाई की जाती है और संसाधनों की वसूली के लिए संसाधित किया जाता है। वर्तमान अध्ययन में, ऑफसाइट भू-तकनीकी अनुप्रयोगों में वृद्ध नगरपालिका ठोस अपशिष्ट (MSW) की स्क्रीनिंग द्वारा प्राप्त मिट्टी जैसी सामग्री (SLM) के पुनः उपयोग की व्यवहार्यता को चिह्नित करने और उसका आकलन करने के लिए एक प्रयोगात्मक जांच की गई है। SLM पुराने डंपसाइट्स में कुल MSW का एक बड़ा हिस्सा है।

इस शोध में, वृद्ध MSW (१० वर्ष से अधिक पुराना) दिल्ली, हैदराबाद और कडपा में स्थित भारत के चार पुराने MSW डंपसाइट से एकत्र किया गया है। मिट्टी जैसी सामग्री (SLM, ०-४.७५ मिमी) को कुल वृद्ध एमएसडब्ल्यू का प्रमुख घटक (६०-७०%) माना जाता है। SLM पर निम्नलिखित प्रयोगात्मक जांच की गई:

- नमी सामग्री, कार्बनिक सामग्री, पीएच, विद्युत चालकता, अंतिम विश्लेषण आदि सहित भौतिक रासायनिक लक्षण वर्णन।
- भू-पर्यावरणीय लक्षण वर्णन (चिंता के संदूषक) जिसमें कुल घुलनशील ठोस पदार्थ, गहरे रंग के लीचेट का विमोचन, और भारी धातुएँ (कुल और साथ ही लीचेबल) शामिल हैं।
- आकार के वितरण, संघनन विशेषताओं, कतरनी ताकत, पारगम्यता और संपीड़ितता सहित भू-तकनीकी लक्षण वर्णन।

कुल वृद्ध एमएसडब्ल्यू और एसएलएम की विशेषताओं पर कचरे की गहराई के प्रभाव का आकलन १५० मिमी व्यास में ड्रिलिंग और नमूने के माध्यम से दिल्ली में भलस्वा डंपसाइट में शीर्ष स्तर से ३५ मीटर गहराई और मध्य ऊंचाई तक बोरहोल करके अबाधित नमूने एकत्र करके किया गया है।

एसएलएम के लक्षण वर्णन के परिणामों की तुलना डंपसाइट्स के पास के कुंवारी क्षेत्र की पृष्ठभूमि की मिट्टी के साथ-साथ राष्ट्रीय और अंतर्राष्ट्रीय नियामक प्रथाओं के साथ की गई है। सभी चार डंपसाइटों के एसएलएम में जैविक सामग्री 5-18% पाई जाती है जो कि पृष्ठभूमि की मिट्टी से 5-15 गुना अधिक है। एसएलएम और पृष्ठभूमि मिट्टी में कुल घुलनशील ठोस क्रमशः 4880-25220 मिलीग्राम/किलोग्राम और 500-1000 मिलीग्राम/किलोग्राम की सीमा में पाए गए हैं। कुल घुलनशील ठोसों में से अधिकांश में सल्फेट और क्लोराइड होते हैं। सल्फेट और क्लोराइड पृष्ठभूमि की मिट्टी की तुलना में 10-25 गुना अधिक पाए जाते हैं। एसएलएम पृष्ठभूमि मिट्टी (25-40 पीसीयू) की तुलना में गहरे रंग का लीचेट (225-925 पीसीयू) जारी करता है। Cd, Cr, Cu, Pb, और Zn की कुल भारी धातु सांद्रता SLM में पृष्ठभूमि मिट्टी की तुलना में काफी अधिक (5 से 30 गुना) पाई गई है। लीचेबल हेवी मेटल्स (Cr, Ni, Cu, As, Cd, Pb) एसएलएम से लीचेट में पृष्ठभूमि मिट्टी से पानी निकालने की तुलना में 3-10 गुना अधिक पाया गया है। सीडी का लीचेबल अंश एसएलएम में पृष्ठभूमि की मिट्टी की तुलना में अत्यधिक उच्च सांद्रता (58-97 गुना) अधिक प्रदर्शित करता है। विषाक्तता विशेषता लीचिंग प्रक्रिया (टीसीएलपी) के परिणामों से पता चलता है कि मिट्टी जैसी सामग्री में भारी धातुओं का स्तर एसएलएम को खतरनाक के रूप में वर्गीकृत करने के लिए पर्याप्त नहीं है।

बोरहोल से 35 मीटर गहराई तक एकत्र किए गए कुल एमएसडब्ल्यू के अबाधित नमूनों में कुल इकाई वजन, जैविक सामग्री और नमी की मात्रा क्रमशः 1.25-1.90 ग्राम / सीसी, 10 से 25% और 15 से 40% पाई गई है। भलस्वा डंपसाइट पर शीर्ष और मध्य ऊंचाई। कुल MSW नमूनों के सभी मापदंडों की विशेषताओं में व्यापक भिन्नता देखी गई है जो सामग्री की विविधता को दर्शाती है। बोरहोल के निचले सिरे की ओर कार्बनिक सामग्री में थोड़ी कमी देखी गई है, जबकि, कचरे की गहराई में वृद्धि के साथ कुल इकाई वजन में वृद्धि देखी गई है। कचरे की गहराई में वृद्धि के साथ मिट्टी जैसी सामग्री (एसएलएम) के प्रतिशत में वृद्धि देखी गई है। घुलनशील लवणों (मुख्य रूप से सल्फेट्स और क्लोराइड्स) और लीच करने योग्य भारी धातुओं (Cr, Cu, और Zn) की सांद्रता में उल्लेखनीय वृद्धि अपशिष्ट की गहराई में वृद्धि के साथ देखी गई है।

SLM के आकार के वितरण विश्लेषण के आधार पर, सभी चार डंप साइटों से एसएलएम को पृष्ठभूमि की मिट्टी की तुलना में काफी मोटा पाया गया है जो एसएलएम में निर्माण और विध्वंस मलबे की महत्वपूर्ण उपस्थिति के कारण हो सकता है। एसएलएम प्रकृति में गैर-प्लास्टिक पाया गया है। एसएलएम का विशिष्ट गुरुत्व 2.10-2.60 के बीच भिन्न

पाया गया है। एसएलएम की अपरूपण शक्ति पृष्ठभूमि मिट्टी के समान या बेहतर पाई जाती है। एसएलएम संतृप्त स्थितियों में 340-380 की सीमा में कतरनी प्रतिरोध के कोण को प्रदर्शित करता है। एसएलएम की पारगम्यता 8.9×10^{-6} से 7.7×10^{-7} मीटर/सेकंड के बीच पाई जाती है जो दिल्ली (दिल्ली गाद) की पृष्ठभूमि मिट्टी के समान है। एसएलएम का संपीड़न सूचकांक 0.13-0.20 की सीमा में पाया जाता है।

मिट्टी के भराव और खाद जैसे ऑफसाइट अनुप्रयोगों में एसएलएम के पुनः उपयोग की व्यवहार्यता का आकलन एसएलएम की विशेषताओं की पुनः उपयोग के लिए राष्ट्रीय और अंतरराष्ट्रीय नियामक सीमाओं के साथ-साथ पृष्ठभूमि मिट्टी के साथ तुलना करके किया गया है। मिट्टी के भराव में मिट्टी के उपयोग के लिए एसएलएम में कार्बनिक सामग्री अधिकतम अनुमेय सीमा (1-5%) से अधिक पाई गई है। जर्मन प्रोटोकॉल (LAGA, 2012) के अनुसार कुल घुलनशील ठोस (सल्फेट और क्लोराइड सहित) मिट्टी के अप्रतिबंधित उपयोग की अनुमेय सीमा से काफी अधिक पाया गया है। एसएलएम से गहरे रंग के लीचेट की रिहाई पर साहित्य में ज्यादा ध्यान नहीं दिया गया है, हालांकि, इसमें आस-पास के जल निकायों के रंग का कारण बनने की एक बड़ी क्षमता है जो पानी की खपत के प्रति उपभोक्ता धारणा को प्रभावित कर सकती है। एसएलएम में लीच करने योग्य भारी धातु (डीआई पानी के साथ सिंगल बैच लीचिंग पर आधारित) को एलएजीए, 2012 के अनुसार मिट्टी के अप्रतिबंधित उपयोग के लिए नियामक थ्रेसहोल्ड में दी गई सीमा से काफी अधिक पाया गया है। कुल भारी धातु (Cd, Cr) मिट्टी के अप्रतिबंधित उपयोग के लिए अधिकतम स्वीकार्य सीमा से थोड़ा अधिक पाया गया है। यद्यपि टीसीएलपी परीक्षण के आधार पर एसएलएम को गैर-खतरनाक प्रकृति का पाया गया है, एसएलएम का ऑफ-साइट अनुप्रयोगों में अर्थ-फिल के रूप में खुला और अप्रतिबंधित उपयोग एक व्यवहार्य विकल्प नहीं है। एसएलएम में पोषक तत्व (N, P, और K) स्तर, कुल मिलाकर, एसएलएम के खाद के रूप में उपयोग के लिए एसडब्ल्यूएम नियम (2016) में निर्धारित आवश्यकताओं को पूरा करते हैं, हालांकि, कम कुल कार्बनिक कार्बन और उच्च भारी धातु इसकी अनुमति नहीं देते हैं। कृषि अनुप्रयोगों में प्रत्यक्ष उपयोग। अधिक से अधिक अखाद्य वनस्पति के लिए गैर-कृषि अनुप्रयोगों में इसका उपयोग करने की क्षमता है।

ऑफसाइट भू-तकनीकी अनुप्रयोगों में एसएलएम के पुनः उपयोग की व्यवहार्यता जैसे सड़कों, रेलवे और जल प्रतिधारण संरचनाओं के लिए तटबंधों में मिट्टी भरना; निचले इलाकों को भरना; गहरे गड्ढों को भरने के लिए जैविक सामग्री (थर्मल ट्रीटमेंट आदि के माध्यम से) में कमी/निकालने की आवश्यकता होगी। इसके अलावा, लीचेट संग्रह

कुओं (जैसे गहरे गड्ढों के लिए मिट्टी के भराव में) और क्षैतिज लीचेट ड्रेनेज पाइप (जैसे तटबंधों के लिए अर्थ-फिल में) के साथ सीलिंग परत की आवश्यकता का आकलन करना होगा। एसएलएम का उपयोग अखाद्य पौधों के साथ पुनः वनस्पति, भूनिर्माण आदि से जुड़ी बड़ी सतह क्षेत्र परियोजनाओं के लिए स्थानीय शीर्ष मिट्टी के साथ सम्मिश्रण करके सीधे पतली परतों में किया जा सकता है।

एसएलएम के ऑफसाइट पुनः उपयोग के लिए अधिकतम स्वीकार्य सीमा से नीचे दूषित पदार्थों के स्तर को कम करने के लिए इलेक्ट्रोकेनेटिक उपचार, फाइटोरेमेडिएशन, थर्मल उपचार और धुलाई सहित उपचार तकनीकों का पता लगाया गया है। विद्युत क्षेत्र के अनुप्रयोग ने एसएलएम से भारी धातुओं और घुलनशील लवणों की उल्लेखनीय कमी दिखाई है। हालांकि, कार्बनिक सामग्री और गहरे रंग के लीचेट की रिहाई पर इलेक्ट्रोकेनेटिक उपचार का कोई प्रभाव नहीं देखा गया है। फाइटोरेमेडिएशन प्रयोगों ने SLM में भारी धातुओं की सांद्रता में कमी दिखाई है। हालांकि, कार्बनिक सामग्री, घुलनशील लवण और गहरे रंग के लीचेट की रिहाई पर कोई प्रभाव नहीं देखा गया है। 500°C और उससे अधिक पर SLM के थर्मल उपचार ने कार्बनिक सामग्री को हटाने और रंग की रिहाई में उल्लेखनीय कमी दिखाई है, हालांकि, घुलनशील लवण और कुल भारी धातुओं के लीचिंग पर थर्मल उपचार का कोई प्रभाव नहीं देखा गया है। अल्ट्राप्योर पानी से एसएलएम की धुलाई ने रंग छोड़ने, घुलनशील लवणों की लीचिंग और एसएलएम से भारी धातुओं के लीचिंग की तीव्रता में उल्लेखनीय कमी दिखाई है, हालांकि, धोने से कार्बनिक सामग्री और कुल भारी धातुओं पर न्यूनतम प्रभाव नहीं दिखा है।

वर्तमान अध्ययन के निष्कर्षों से पता चलता है कि पुराने एमएसडब्ल्यू डंपों के खनन के बाद पुनः प्राप्त सामग्री के बड़े हिस्से में मिट्टी जैसी सामग्री (एसएलएम) होती है। हालांकि, एसएलएम घुलनशील लवणों की अत्यधिक उपस्थिति, गहरे रंग के लीचेट की रिहाई, उच्च कुल भारी धातुओं और काफी अधिक लीच करने योग्य भारी धातुओं के आधार पर दूषित पाया जाता है, इसलिए, ऑफसाइट भू-तकनीकी अनुप्रयोगों में इसका अप्रतिबंधित (प्रत्यक्ष) पुनः उपयोग है। संभव नहीं है। कोई एक व्यापक उपचार तकनीक नहीं है जो सभी दूषित पदार्थों को हटा / कम कर सके। इसलिए, एसएलएम का पुनः उपयोग केवल उपयुक्त डिजाइन उपायों जैसे सीलिंग परतों, रिसाव को अपनाने के बाद किया जा सकता है।

TABLE OF CONTENTS

CERTIFICATE	i
ACKNOWLEDGEMENTS	ii
ABSTRACT	iv
TABLE OF CONTENTS	xii
LIST OF FIGURES	xx
LIST OF TABLES	xxiv
LIST OF NOTATIONS AND ABBREVIATIONS	xxix
CHAPTER 1: INTRODUCTION	1
1.1 Background	1
1.2 Need for the Present Study	2
1.3 Terminologies Used	3
1.4 Objectives	4
1.5 Scope of Work	4
1.6 Methodology	5
1.7 Organization of Thesis	7
CHAPTER 2: LITERATURE REVIEW	9
2.1 Introduction	9
2.2 Landfill Mining: An Engineered Approach	9
2.3 International Scenario of Landfill Mining	13
2.4 National Scenario of Landfill Mining	16
2.5 Total Aged MSW	18
2.5.1 Compositional Analysis	18
2.5.2 Particle Size Distribution	20
2.6 Soil-Like Material (SLM) Screened from Total Aged MSW	22
2.6.1 Physicochemical Characteristics	23
2.6.2 Geoenvironmental Characterization (Contaminants of Concern)	26
2.6.3 Geotechnical Properties	33
2.7 Regulatory Thresholds for Various Applications	35
2.7.1 Earth-Fill	35
2.7.2 Compost	37

2.8	Heavy Metals Contamination Indices	39
2.8.1	Contamination Factor and Degree of Contamination	39
2.8.2	Geo-Accumulation Index	39
2.8.3	Enrichment Factor	40
2.9	Treatment of SLM Before Re-Use in Offsite Applications	41
2.9.1	Electrokinetic Remediation	43
2.9.2	Phytoremediation	46
2.10	Concluding Remarks	51
2.11	Research Gaps	52
	CHAPTER 3: SAMPLE COLLECTION AND EXPERIMENTAL INVESTIGATIONS	54
3.1	Introduction	54
3.2	Study Sites	54
3.3	Sample Collection	55
3.3.1	Aged MSW	55
3.3.1.1	Sampling through trial pits	55
3.3.1.2	Sampling from boreholes through percussion drilling	57
3.3.1.3	Sampling from stockpiles of mined MSW	60
3.3.1.4	Age of waste	60
3.3.2	Background Soils	61
3.3.3	Leachate	61
3.4	On-Site Screening (Sieving) of Aged MSW	61
3.5	Experimental Investigations	65
3.5.1	Testing Program	65
3.5.1.1	Total aged MSW	65
3.5.1.2	Soil-like material (SLM)	65
3.5.2	Testing Methodology	70
3.5.2.1	Characterization of total aged MSW	70
3.5.2.2	Characterization of soil-like material (SLM)	73
3.5.2.3	Treatment of soil-like material (SLM)	77
3.6	Concluding Remarks	79
	CHAPTER 4: CHARACTERIZATION OF TOTAL AGED MSW	81
4.1	Introduction	81

4.2	Age of Waste	81
4.3	Physical Characterization	82
4.3.1	Compositional Analysis	82
4.3.2	Particle Size Distribution	85
4.3.3	Water Content and Organic Content	86
4.4	Concluding Remarks	87
CHAPTER 5: GEOENVIRONMENTAL AND GEOTECHNICAL CHARACTERIZATION OF SOIL-LIKE MATERIAL (SLM) INCLUDING CONTAMINANTS OF CONCERN		88
5.1	Introduction	88
5.2	Physicochemical Characterization	88
5.2.1	Water Content	89
5.2.2	Organic Content	90
5.2.2.1	Effect of aeration on organic content	91
5.2.2.2	Fast and slow biodegradable organic content	92
5.2.3	pH	92
5.2.4	Electrical Conductivity	93
5.2.5	Ultimate Analysis	94
5.2.6	X-Ray Diffraction	94
5.2.7	X-Ray Fluorescence	97
5.2.8	Scanning Electron Microscopy Studies	98
5.3	Geoenvironmental Characterization (Contaminants of Concern)	100
5.3.1	Total Soluble Solids and Associated Ions	100
5.3.1.1	Inorganic anions	101
5.3.1.2	Inorganic cations	103
5.3.2	Release of Dark-Colored Leachate	103
5.3.3	Heavy Metals	105
5.3.3.1	Total heavy metals	105
5.3.3.2	Leachable heavy metals	110
5.3.3.1	Sequential extraction of heavy metals	113
5.3.3.4	Discussions	117
5.4	Geotechnical Characterization	123
5.4.1	Grain Size Distribution	123

5.4.2	Specific Gravity	124
5.4.3	Plasticity Characteristics	124
5.4.4	Compaction Characteristics	125
5.4.5	Shear Strength Characteristics	126
5.4.6	Permeability	130
5.4.7	Compressibility	130
5.8	Concluding Remarks	132
CHAPTER 6: VARIATION OF CHARACTERISTICS WITH DEPTH UP TO 35 M FROM TOP SURFACE AND MID-HEIGHT OF A 65 M HIGH MOUND AT BHALSWA, DELHI		136
6.1	Introduction	136
6.1.1	About the Site	136
6.1.2	Site Investigation at Bhalswa Dumpsite	136
6.2	Location of Boreholes	137
6.3	Sampling Methodology and Nature of Samples Collected	137
6.4	Characteristics of Total MSW	139
6.4.1	Variation of Total Unit Weight with Depth of Waste	139
6.4.2	Variation of Organic Content with Depth of Waste	141
6.4.3	Variation of Water Content with Depth of Waste	142
6.5	Characteristics of Soil-Like Material (SL) Obtained from Sampling Tubes and Screened Through 4.75 mm Sieve	144
6.5.1	Variation of Percentage of SLM with Depth of Waste	144
6.5.2	Variation of Organic Content of SLM with Depth of Waste	146
6.5.3	Variation of Contaminants of Concern in SLM with Depth of Waste	147
6.5.3.1	Total soluble solids	147
6.5.3.2	Release of dark-colored leachate	149
6.5.3.3	Total heavy metals	150
6.5.3.4	Leachable heavy metals	152
6.6	Concluding Remarks	154
CHAPTER 7: SUITABILITY OF SOIL-LIKE MATERIAL (SLM) FOR RE-USE IN OFFSITE APPLICATIONS AND DESIGN OPTIONS		157
7.1	Introduction	157
7.2	Potential for Bulk Re-Use of SLM as Earth-Fill	157

7.2.1 Organic Content	158
7.2.2 Total Soluble Solids (Including Sulphates and Chlorides)	158
7.2.3 Release of Dark-Colored Leachate	159
7.2.4 Total Heavy Metals	160
7.2.5 Leachable Heavy Metals	162
7.2.5.1 Single batch leaching with DI water	162
7.2.5.2 Toxicity characteristics leaching procedure	165
7.3 Potential for Re-Use of SLM as Compost	166
7.3.1 Physicochemical Characteristics	166
7.3.2 TOC and Other Nutrients	167
7.3.3 Total Heavy Metals	168
7.4 Design Options for Bulk Re-Use of SLM as Earth-Fill	169
7.4.1 Embankments for Roads, Railways and Water Retaining Structures	170
7.4.2 Deep Earth-Fills in Open Pits	170
7.4.3 Shallow Earth-Fills for Raising Low-Lying Areas or for Landscaping	171
7.4.4 Large-area Surface Application for Re-Vegetation / Soil Conditioning / Eco-Forestry	171
7.4.5 Structural Fills for MSE Walls	172
7.6 Concluding Remarks	172
CHAPTER 8: TREATMENT OPTIONS OF SOIL-LIKE MATERIAL (SLM) PRIOR TO RE-USE	174
8.1 Introduction	174
8.2 Electrokinetic Remediation	174
8.2.1 Analysis of Leachate Collected from Electrode Chamber Every Week During the Experimental Run	175
8.2.1.1 Heavy metals	175
8.2.1.2 Cations and anions	177
8.2.2 Total Heavy Metals in SLM collected from anode, cathode, and central region in all three test conditions after the end of the experiment	180
8.2.3 Leaching Characteristics of SLM collected from anode, cathode, and central region in all three conditions after the end of the experiments	183
8.2.3.1 Leachable heavy metals	183
8.2.3.2 Total soluble solids and associated ions	184

8.3	Phytoremediation	186
8.3.1	Heavy metals in Excess Leachate Collected (After Watering) from All Pots Every Week During the Experimental Run	187
8.3.2	Total Heavy Metals in SLM Collected from All Pots After the End of Experiments	189
8.3.2.1	Mass balance of total heavy metals in SLM removed by the phytoremediation treatment	192
8.3.3	Leaching Characteristics of SLM Collected from All Pots at End of the Experiment	195
8.3.3.1	Leachable heavy metals	195
8.3.3.2	Total soluble solids and associated ions	196
8.4	Thermal Treatment	198
8.4.1	Organic Content	198
8.4.2	Release of Dark-Colored Leachate	199
8.4.3	Total Soluble Solids (Including Sulphates and Chlorides)	199
8.4.4	Total Heavy Metals	200
8.4.5	Leachable Heavy Metals	201
8.5	Sequential Washing	201
8.5.1	Release of Dark-Colored Leachate	202
8.5.2	Total Soluble Solids (Including Sulphates and Chlorides)	203
8.5.3	Leachable Heavy Metals	203
8.5.4	Total Heavy Metals	204
8.5.5	Organic Content	205
8.6	Concluding Remarks	205
CHAPTER 9: CONCLUSIONS		207
9.1	Major Conclusions of the Present Study	207
9.2	Significant Findings of the Present Study	209
9.2.1	Composition of Aged MSW	209
9.2.2	Characteristics of SLM	209
9.2.3	Contaminants of Concern in SLM	210
9.2.5	Suitability of Re-use of SLM and Design Options	211
9.2.6	Treatment Options for SLM Prior to Re-Use	213

9.3	Recommendations Based on the Findings of Present Study	213
9.4	Limitations of the Present Study	214
9.5	Suggestions for Future Research	214
	REFERENCES	215
	APPENDIX-A: Results of Characterization of Individual Sample of Total Aged MSW	237
	APPENDIX-B: Results of Characterization of Individual Sample of SLM	239
	LIST OF PUBLICATIONS BASED ON PRESENT STUDY	253
	BIO-DATA	256

LIST OF FIGURES

Figure No.	Figure Caption	Page No.
1.1	Present status of open dumps in India: (a) Gases, fire, and smog around a dumpsite, (b) Accumulation of contaminated water (leachate) around a dumpsite	2
2.1	A typical schematic of landfill mining process	10
2.2	Average composition of aged MSW reported in literature	18
2.3	Sequential extraction of heavy metals reported in literature	32
3.1	Location of trial pits for sampling at Okhla dumpsite	56
3.2	Location of trial pits for sampling at Bhalswa dumpsite	56
3.3	Location of trial pits for sampling at Hyderabad dumpsite	57
3.4	Collection of aged MSW through trial pits: (a) Trial pit of 1 m x 1 m at Okhla, (b) Excavation of aged MSW at Okhla, (c) Collection of aged MSW at Bhalswa, (d) Formation of trial pit at Bhalswa, (e) Excavation of aged MSW at Hyderabad, (f) Aged MSW from 4-5 m depth at Hyderabad	58
3.5	Collection of aged MSW through bore holes: (a) Sampling through percussion drilling from the top of the dumpsite, (b) Sampling through percussion drilling from the mid-height of the dumpsite, (c) Bailer operation at 20 m depth from the top of the dumpsite, (d) Sample in sampling tube, (e) Sample extrusion from the sampling tube in the laboratory, (f) Actual sample after extrusion	59
3.6	Collection of SLM from the stockpiles of mined MSW at Kadapa: (a) Trommel for the mining of aged MSW, (b) Separation of coarser and finer fraction, (c) Stockpiles of mined waste, (d) Collection of stockpiled waste	60
3.7	Overview of sampling procedure	62
3.8	On-site screening and segregation of aged MSW: (a) Sieves used at the site as per BIS classification, (b) Spreading of excavated MSW on the working platform at the site, (c) Drying of waste with turning at regular interval, (d) Screening of excavated MSW, (e) Screening of excavated MSW, and (f) Screening of excavated MSW	63
3.9	An overview of experimental investigations carried out on SLM	67
3.10	Schematic diagram of electrokinetic cell	78

4.1	Identification of age of MSW, (a) ~10 years old Tobacco packet found in MSW, (b) Degraded newspaper ~25 years old found in MSW, (c) ~15 years old food packet found in MSW, (d) ~20 years old food packet found in MSW	82
4.2	Components of aged MSW collected from all the four dumpsites, (a) Components of Aged MSW at Okhla dumpsite, (b) Components of Aged MSW at Bhalswa dumpsite, (c) Components of Aged MSW at Hyderabad dumpsite, (d) Components of Aged MSW at Kadapa dumpsite	84
4.3	Soil-like material from total aged MSW screened through 4.75 mm sieve	86
5.1	XRD patterns (a) SLM from Okhla, (b) SLM from Bhalswa, (c) SLM from Hyderabad, (d) SLM from Kadapa, (e) Background soil (Delhi), (f) Background soil (Hyderabad), (g) Background soil (Kadapa)	97
5.2	SEM images of (a) SLM from Okhla, (b) SLM from Bhalswa, (c) SLM from Hyderabad, (d) SLM from Kadapa, (e) Background soil (Delhi), (f) Background soil (Hyderabad), (g) Background soil (Kadapa)	100
5.3	Visual appearance of dark-colored leachate released by SLM	105
5.4	Comparison of heavy metals in the SLM with background soil: (a) Cd, (b) Cr, (c) Cu, (d) Pb, (e) As, (f) Ni, and (g) Zn	108
5.5	Comparison of heavy metals with the values reported in literature: (a) Cd, (b) Cr, (c) Cu, (d) Pb, (e) As, (f) Ni, and (g) Zn	110
5.6	Sequential extraction of heavy metals in SLM	117
5.7	Grain size distribution of SLM from all the dumpsites	124
5.8	Compaction characteristics of SLM from all the dumpsites	126
5.9	Variation of shear stress and vertical strain with horizontal displacement for SLM from all the four dumpsites: (a-1) Shear stress v/s horizontal displacement for SLM from Okhla, (a-2) Vertical displacement v/s horizontal displacement for SLM from Okhla, (b-1) Shear stress v/s horizontal displacement for SLM from Bhalswa, (b-2) Vertical displacement v/s horizontal displacement for SLM from Bhalswa, (c-1) Shear stress v/s horizontal deflection at for SLM from Hyderabad, (c-2) Vertical displacement v/s horizontal deflection for SLM from Hyderabad, (d-1) Shear stress v/s horizontal deflection for SLM from Kadapa, (d-2) Vertical displacement v/s horizontal deflection for SLM from Kadapa	129
5.10	Strength envelope for SLM from all the four dumpsites: (a) Okhla, (b) Bhalswa, (c) Hyderabad, (d) Kadapa	130
5.11	e – log (σ) curves of SLM from Bhalswa, Hyderabad, and Okhla dumpsites	132

6.1	Pictorial view of Bhalswa dumpsite, (a) Front view, (b) Plan view	137
6.2	Sampling through drilling at Bhalswa dumpsite, (a) Drilling from the top level of dumpsite, (b) Sample in sampling tube retrieved from boreholes, (c) Sample extrusion in the laboratory, (d) completely disturbed sample after extrusion (collapsed)	139
6.3	Variation of total unit weight of total MSW with depth of waste	141
6.4	Variation of organic content of total MSW with depth of waste	142
6.5	Variation of water content of total MSW with depth of waste	144
6.6	Variation of average percentage of fractions of total MSW with depth	146
6.7	Variation of average percentage of organic content in SLM with depth of waste	147
6.8	Variation of average concentration of soluble salts in SLM with depth of waste	149
6.9	Average intensity of color in SLM with depth of waste	150
6.10	Variation of average concentration of total heavy metals in SLM with depth of waste	153
6.11	Variation of average concentration of leachable heavy metals in SLM with depth of waste	155
7.1	Use of SLM as an Earth-fills for Embankments	171
7.2	Use of SLM as an Earth-fills for Deep Pits	171
7.3	Use of SLM in filling of low-lying areas	172
7.4	Use of SLM for re-vegetation for non-edible crops	173
8.1	Variation of heavy metals in leachate samples collected every week from electrode chambers (located at anode and cathode end) in all three test conditions (a) Cr, (b) Cu, (c) Pb, (d) Ni, and (e) Zn	176
8.2	Variation of cations in leachate samples collected every week from the electrode chambers (located at anode and cathode end) in all three test conditions, (a) Na, (b) K, (c) Ca, and (d) Mg	179
8.3	Variation of anions in leachate samples collected every week from the electrode chambers (located at anode and cathode end) in all three test conditions. (a) SO ₄ ²⁻ and (b) Cl ⁻	180

8.4	Variation in percentage of metals at anode region, center region, and cathode region of each setup, (a) E-setup, (b) Ep-setup, and (c) control setup (percentage relative to the initial content)	181
8.5	SLM placed in the pots during the phytoremediation experiment	186
8.6	Roots and shoots extracted for the metal after the end of the experiment	187
8.7	Variation of heavy metals in leachate collected (after watering) from all pots every week during the experimental run, (a) Cr, (b) Cu, (c) Ni, and (d) Zn	189
8.8	Variation of total heavy metals in the SLM collected from control pots and pots with grass at end of phytoremediation experiments, (a) Cr, (b) Cu, (c) Pb, (d) Ni, and (e) Zn	191

LIST OF TABLES

Table No.	Table Caption	Page No.
2.1	Summary of landfill Mining studies reported in the literature	14
2.2	Feasibility study on landfill mining at open dumpsites in India reported in the literature	17
2.3	Recent bio-mining projects carried out at open dumps in India	17
2.4	Composition of Aged MSW reported in the literature	19
2.5	Particle size distribution of Aged MSW reported in the literature	21
2.6	Particle size of soil-like material adopted in the literature	22
2.7	Physicochemical characteristics of SLM reported in the literature	24
2.8	Ultimate analysis of SLM reported in the literature	25
2.9	Prominent minerals found in SLM reported in literature	26
2.10	Total heavy metal concentration in SLM reported in literature	27
2.11	Leaching characteristics of SLM reported in literature	30
2.12	Geotechnical properties of SLM reported in literature	34
2.13	Permissible organic content for use of soil as an earth-fill	35
2.14	Permissible limit of total heavy metals for use of soil as an earth-fill	36
2.15	Permissible limit of leachable heavy metals and soluble salts for earth-fill	36
2.16	Permissible limits of heavy metals for various applications of compost	38
2.17	Permissible limits of nutrients and other parameters in compost	38
2.18	Maximum compost application based on salt content (adopted from Brinton, 2000)	38
2.19	Heavy metal contamination indices	41
2.20	Treatment technologies for the removal of contaminants from SLM reported in literature	42
2.21	Laboratory scale electrokinetic remediation techniques reported in literature	44

2.22	Phytoremediation techniques reported in literature	47
2.23	Use of ryegrass for phytoremediation reported in literature	49
3.1	General information about all the dumpsites	54
3.2	Number of samples collected from all the dumpsites	64
3.3	Summary of testing program: characterization of aged MSW collected from all the dumpsites	65
3.4	Summary of testing program: characterization of SLM	68
3.5	Summary of testing program: variation of characteristics with depth	69
3.6	Summary of testing program: treatment of SLM	69
3.7	Techniques and standards adopted for the experiments	71
3.8	Sequential extraction method	76
4.1	Compositional analysis of total aged MSW carried out on visual basis	83
4.2	Particle size distribution of aged MSW	85
4.3	Water content and organic content of total aged MSW	87
5.1	Water content of SLM obtained by screening the aged MSW immediately after excavation	89
5.2	Water content of SLM obtained by screening partially air-dried (for 6-7 days) aged MSW after excavation	90
5.3	Organic content of SLM obtained by screening partially air-dried (for 6-7 days) aged MSW after excavation	91
5.4	Effect of aeration of SLM on organic content	91
5.5	Fast and slow biodegradable organic content in the SLM	92
5.6	pH values of SLM	93
5.7	Electrical conductivity of SLM	93
5.8	Ultimate analysis of SLM	94
5.9	Elemental composition (expressed in % oxides form) of SLM determined by XRF	98
5.10	Total soluble solids and associated ions in SLM (reported in mg/kg)	102

5.11	Release of dark-colored leachate from SLM	105
5.12	Water required to wash 1 g SLM to reduce intensity of dark-colored leachate	105
5.13	Total heavy metals in SLM determined after acid digestion	106
5.14	Leachable heavy metals (single batch leaching with DI water) in SLM	112
5.15	Leachable heavy metals (determined through SPLP) in SLM	113
5.16	Leachable heavy metals (determined through TCLP) in SLM	113
5.17	Heavy metals (determined through sequential extraction procedure) in SLM	115
5.18	Heavy metal contamination indices in SLM based on total heavy metal concentration	120
5.19	Total degree of contamination in SLM based on total heavy metals	121
5.20	Contamination factor for leachable metals in SLM	121
5.21	Total degree of contamination in SLM based on leachable heavy metals	122
5.22	Risk assessment code for heavy metals in SLM based on sequential extraction	123
5.23	GSD, specific gravity and plasticity index of SLM and background soil	124
5.24	Shear strength parameter of SLM and background soil in the saturated condition determined through direct shear test	127
5.25	Permeability of SLM and background soil	131
5.26	Compression index of SLM and background soil	132
5.27	Degree of compressibility of soil (Coduto et al., 1995)	133
6.1	Location of boreholes analyzed in the present study	139
6.2	Total unit weight of MSW collected at regular depth interval through boreholes	141
6.3	Organic content of MSW samples collected at regular depth interval through boreholes	142
6.4	Water content of MSW samples collected from regular depth interval through boreholes	144

6.5	Percentage of various fractions of total MSW collected from regular depth interval through boreholes	146
6.6	Organic content in SLM collected from regular depth interval through boreholes	147
6.7	Total soluble solids in SLM collected from regular depth interval through boreholes	149
6.8	Release of dark-colored leachate from SLM collected from regular depth interval through boreholes	150
6.9	Total heavy metals in SLM collected from regular depth interval through boreholes	152
6.10	Leachable heavy metals in SLM collected from regular depth interval through boreholes	154
6.11	Leachable heavy metals as percentage of total heavy metals	154
7.1	Comparison of organic content of SLM with regulatory thresholds and background soils	159
7.2	Comparison of total soluble solids (including sulphates and chlorides) in SLM with regulatory thresholds and background soils	160
7.3	Comparison of release of dark-colored leachate from the SLM with background soil	161
7.4	Comparison of total heavy metals in SLM with the regulatory thresholds and background soils	162
7.5	Comparison of leachable heavy metals in SLM with the regulatory thresholds and background soils (Single batch leaching test with DI water)	165
7.6	Comparison of TCLP test results of SLM with background soil and regulatory standards	166
7.7	Comparison of physicochemical parameters of SLM with compost standards	167
7.8	Comparison of TOC and nutrients in SLM with compost standards	168
7.9	Comparison of total heavy metals in SLM with compost standards	169
8.1	Total heavy metal concentration in SLM after the end of the electrokinetic experiment in anode, central, and cathode region in all three test conditions	180
8.2	Leachable heavy metal concentration in SLM after the end of the electrokinetic experiment in anode, central, and cathode region in all three test conditions	184

8.3	Total soluble solids and associated ions in SLM after the end of the electrokinetic experiment in anode, central, and cathode region in all three test conditions	185
8.4	Total heavy metal in the SLM of control pots and pots with grass at the end of the phytoremediation experiment	190
8.5	Percentage removal and mass balance of total heavy metals from SLM after 4, 6, and 8 weeks of the phytoremediation experiments	194
8.6	Leachable heavy metals in the SLM collected from all the pots after the end of the phytoremediation experiment	195
8.7	Total soluble solids and associated ions in the SLM collected from all the pots after the end of the phytoremediation experiment	197
8.8	Organic content in the SLM after thermal treatment	198
8.9	Intensity of dark-colored leachate in SLM after thermal treatment	199
8.10	Total soluble solids (mg/kg) in SLM after thermal treatment	200
8.11	Concentration of total heavy metal in SLM after thermal treatment	200
8.12	Leachable heavy metal concentration in SLM after thermal treatment	201
8.13	Intensity of dark-colored in the SLM after every wash through sequential washing	202
8.14	Total soluble solids in SLM after every wash through sequential washing	203
8.15	Leachable heavy metals in SLM after every wash through sequential washing	204
8.16	Total heavy metals in SLM at the end of 10 th wash	204
8.17	Organic content in SLM after 10 th wash	205

LIST OF NOTATIONS AND ABBREVIATIONS

MSW = Municipal Solid Waste

NGT = National Green Tribunal

SLM = Soil-Like Material

MSE = Mechanically Stabilized Earth

BMP = Biochemical Methane Potential

XRD = X-Ray Diffraction

XRF = X-Ray Fluorescence

C&D = Construction and Demolition

CLO = Compost Like Output

LOI = Loss on Ignition

TOC = Total Organic Carbon

TN = Total Nitrogen

TP = Total Phosphorous

TK = Total Potassium

EC = Electrical Conductivity

C_f = Contamination Factor

EF = Enrichment Factor

I_{geo} = Geoaccumulation Index

C_d = Degree of Contamination

EK = Electrokinetic

EDTA = Ethylenediamine Tetraacetic Acid

RDF = Refused Derived Fuel

UDS = Undisturbed Sampling

APHA = American Public Health Association

ASTM = American Society for Testing and Materials

IS = Indian Standard

PCU = Platinum Cobalt Unit

ICP-MS = Inductive Coupled Plasma Mass Spectrometry

ICP-OES = Inductive Coupled Plasma Optical Emission Spectrometry

TCLP = Toxicity Characteristics Leaching Procedure

SPLP = Synthetic Characteristics Leaching Procedure

USEPA = United States Environmental Protection Agency

MDD = Maximum Dry Density

OMC = Optimum Moisture Content

SEM = Scanning Electron Microscopy

VDS = Volatile Dissolved Solids

FDS = Fixed Dissolved Solids

BDL = Below Detection Limit

RAC = Risk Assessment Code

GSD = Grain Size Distribution

OC = Organic Content

PI = Plasticity Index

c' = Cohesion Intercept

ϕ' = Angle of Shearing Resistance

C_c = Compression Index

L/S = Liquid to Solid

SWM = Solid Waste Management