Contaminants in soil-like material recovered from mining of an MSW dumpsite in Delhi

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Abstract. Soil-like material ("SLM") was mined from an old municipal solid waste (MSW) dumpsite located in New Delhi to assess its potential reuse as construction material in earthwork projects. The process consisted of excavating 10-25 years old MSW, drying it and segregating it into different particle sizes through screens. The contamination levels of SLM (< 4.75 mm) were analyzed on the basis of organic content, total soluble solids, release of dark colored leachate and heavy metals. Local soil was considered as the reference material for obtaining the background level of all the contaminants.

In the SLM, organic content was found to be 4.0-8.8% whereas in the local soil it was found to be 1.0-1.2%. Total soluble solids were found to be in the range of 0.8 to 1.5% almost four times higher than 0.2-0.4% in the local soil. The intensity of color in the water extract from SLM was observed to be 380-400 Hazen while in the water extract of local soil it was found to be 25-30 Hazen highlighting the potential for release of colored leachate from SLM. Heavy metals including chromium, copper, zinc, cadmium, and lead were found to be elevated with reference to the local soil.

Though SLM from aged landfills appears to be an attractive option for filling low lying areas and for constructing embankments, however, presence of contaminants indicate that use of SLM requires suitable pre-treatment measures or design measures to prevent their release to the local ecosystem.

Keywords: Dumpsites; Soil-like material; Contamination, Leachate, Heavy metals, Soluble solids.

1 Introduction

There are so many issues prevailing in the contemporary society in terms of mismanagement of waste, over occupancy of land, depletion of natural resources etc. In past few decades, dumpsites have become a serious threat for the local civic authorities particularly in the developing countries like India. Generation of toxic gases, leachate, fire, and foul odour are few major challenges faced by the nearby localities of dumpsites. The improper segregation, or complete absence of segregation facility at the waste generation site, causes the accumulation of toxic waste in landfills and subsequently, these sites pose a great risk to environment and the human health [18]. In a recent report on the solid waste scenario of world by ISWA [6] it was highlighted that

40 % of the world's waste directly goes to dumpsites. 50 biggest dumpsites of the world are directly affecting daily lives of 64 million people. All these problems associated with dump sites have gained the attention of researchers to determine an effective and sustainable solution.

Landfill mining is one of the possible alternatives for reducing accumulated old waste at a dump site and reclaiming the site for other purposes or expanding landfill capacity [15]. It involves excavation of aged waste from a dump or sanitary landfill, separation into different fractions by screening (Fig. 1) and re-use of separated material – coarse fraction for recycling or processing to recover energy and fine (soil-like) fraction as cover material or fill material or compost. The recoverable fractions from landfill mining primarily include soil-like material, which requires extensive study, not only about the overall composition but also about the pretreatment before use [8]. Soil-like fraction (often defined as finer fraction of size less than 10 to 60 mm) have been identified as 40-80% of the mined materials in previous studies [3,4,8,13].

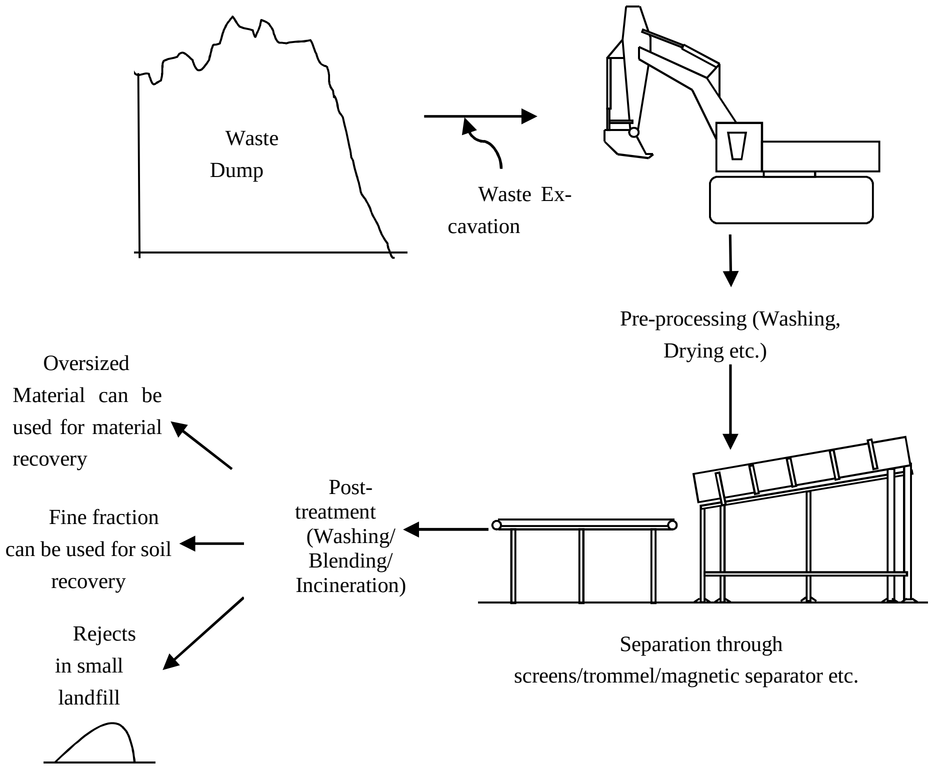

Fig. 1. Schematic diagram of landfill mining process

This study deals with soil-like material (SLM) of aged MSW collected from an old dumpsite located at New Delhi. The main objective was to determine the contaminants in SLM in terms of organic content, total soluble solids, release of dark colored leachate, and total heavy metals. The secondary objective was to undertake a comparison of contaminants in SLM with those in background soil collected from the nearby areas of the dumpsite.

2 Materials and Methods

2.1 Study area and sampling

Soil-like material (from now on referred as to "SLM") was recovered from the dumpsite located at New Delhi, India. The site is operating since mid to end of the 1990s till date and has a height larger than 50 m. Test pits of a size of one by one meter (in plan) were carried out using a backhoe excavator. Samples were taken from a depth of approx. five meters to get older and more decomposed material. Three composite samples have been prepared using samples from ten test pits, i.e. one composite sample consisted of samples from three to four test pits (Fig. 2). The age of waste samples was determined on the basis of recovered food packets, newspapers clips etc. and also on tentative information was provided by the operator of the dumpsites. The overall age of dumpsite was identified as 25-30 years old.

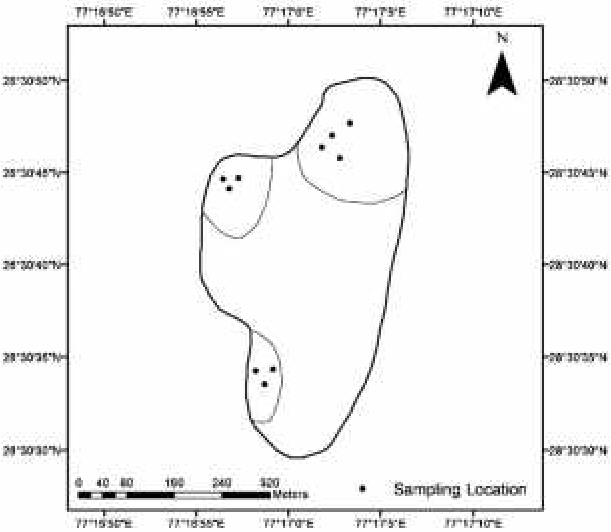

Fig. 2. Sampling location at Delhi dumpsite

To compare the characteristics of SLM with those of local soil, soil samples were collected in the vicinity of dumpsite. These samples were taken from a depth of 50 cm below the surface at five locations. The quantity of all the local soil samples collected was 5 kg (approx.) from all the locations. The local soil samples were collected beyond the periphery of the dumps up to a distance of 0.5-5 km.

2.2 Sample preparation and chemical analyses

Composite samples were dried in the sunlight (approx. 30-35°C) for five days before being manually homogenized using a trommel and screened at 4.75 mm in line with the Indian Standard [5]. The unders (<4.75 mm) were defined as SLM and had an approximate proportion of 55-65%. Subsamples were taken by coning and quartering SLM samples. Very small quantity (0.2-0.5 g) of SLM was required for the analysis of heavy metals. Therefore, it was further ground using ball mill to a size less than 0.075 mm. Moisture content, organic content, total soluble solids, release of dark colored leachate, single batch leaching and heavy metals were analyzed in order to assess the contamination potential of SLM.

Batch leaching test: Swedish Standard Method [17], batch leaching tests were performed. Liquid to solid ratio of 10 L/kg was maintained in a rotary shaker for 24 hours using deionized water. Leaching analysis were conducted on all the samples as mentioned in 2.1 on triplicate basis. The water extract was digested using HNO_3 following [14]. Heavy metals were analyzed using an ICP-MS (Agilent 7900 ICP-MS) with ultra-high matrix introduction (UHMI) technology in accordance with [19]. Other physicochemical parameters were determined using *standard method* [1].

Total soluble solids: Total soluble solids were determined as per [6] (1:10 dilution). In brief, 10 g of SLM was mixed with 100 ml ultrapure water ("UPW") followed by shaking for 24 hours at 100 rpm using a mechanical rotary shaker. After shaking, it was allowed to settle for 10 hours, the solution was then filtered through 2.5 μm filter paper (Whatman no. 42) and further centrifuged (REMI, R-24) at 8000 rpm for ten minutes. Total soluble solids was then determined gravimetrically after keeping 50 ml of water extract in a temperature controlled oven at 105^{o}C. To analyze the components of total soluble solids; volatile dissolved solids, anions, cations, and ammonia were determined using *standard method* [1].

Release of colored leachate: Deionized water was mixed with 10 g of SLM and the intensity of color of filtered liquid after centrifugation (1:10 dilution) was measured in Platinum-Cobalt Scale (PCU) using a Lovibond Tintometer. Standard liquids (EC 2000 Pt-Co15 and EC 2000 Pt-Co0) were used to calibrate the instrument.

Total heavy metal analysis: To determine heavy metals in solid matrix of SLM, 0.2-0.5 g of SLM (grounded to below 0.075 mm) was digested using aqua regia (mixture of HNO_3 and HCl in a molar ratio of 1:3) using a microwave digester (Multiwave GO, Anton Paar) following [14,15]. After digestion, it was cooled down to room temperature and the digested mixture was filtered through Whatman No.42 filter paper into a 50 ml volumetric flask and diluted to required volume. Heavy metals (Cr, Ni, Cu, Zn, As, Se, Ag, Cd, and Pb) were analyzed using an ICP-MS as mentioned in the above section. In addition, samples with high metal concentrations were diluted to fit within the linear region of the calibration curve. All the samples mentioned in 2.1 were performed on triplicate basis.

Moisture content and organic content: In the present study moisture content was determined by drying waste at 60^{o}C to a constant mass (36 to 48 hours) and organic content was determined by loss on ignition at 550 (±20^{o}C) which is in accordance with [21] and [13].

3 Results and Discussions

3.1 Batch leaching test

Single batch leaching test was performed in order to assess the flow of contaminants through water. The comparison of water extract from SLM with local soil and drinking water standards is shown in Table 1.

Table 1. Characterization of water extract prepared from SLM (1:10 dilution)

Particular	Soil-like material	Local soil	Drinking water standards
pH	7.12-7.41	7.07-7.17	6.5-8.5
EC (µS/cm)	1558-2293	120-143	-
TDS (mg/L)	916-1753	80-100	500
Calcium (mg/L)	18-92	42-46	75
Magnesium (mg/L)	28-44	5-8	-
Sulfate (mg/L)	178-580	30-40	200
Chloride (mg/L)	195-285	70-100	250
Fluoride (mg/L)	0.1-0.73	0.58-0.67	1
Bromide (mg/L)	0.18-0.20	BDL	-
COD (mg/L)	170-280	25-35	Nil
Bicarbonates (mg/L)	195-420	68-72	200
Ammoniacal nitrogen (mg/L)	15-18	3.2-3.4	-
Chromiun (µg/L)	188.66-201.95	36.57-43.17	0.05
Nickle (µg/L)	110.79-130.2	20.42-21.4	0.02
Copper (µg/L)	121.19-156	14.06-14.6	0.05
Zinc (µg/L)	118.85-242.5	44.63-67	5
Arsenic (µg/L)	13.08-34.56	5.35-5.45	0.01
Selenium (µg/L)	1.27-1.6	3.84-4.8	-
Cadmium (µg/L)	6.9-7	0.09-0.09	0.003

The electrical conductivity, total dissolved solids, bicarbonates, sulfates, chlorides, and COD were found significantly higher in SLM extract in comparison with the local soil extract, however, metals were found elevated in water extract from SLM in comparison with the local soils. Very low leaching ratio of metal ranging between 0.01 to 1.0% was observed by [15].

3.2 Total heavy metal content

Chromium, nickel, zinc, copper, cadmium, lead, and manganese were found significantly higher in the SLM from all the dumpsites in comparison to their local soils (Table 2). The concentration of all the metals varied over a wide range. Higher concentration of chromium, copper, and zinc is also reported in the previous studies [9, 3 and 11].

Table 2. Total heavy metal content in SLM

Particular	SLM	Local soil	Regulatory standards	
			Canadian, 1999	Dutch, 2001
Chromiun (mg/kg)	89-230	36.5-43.2	64	-
Nickle (mg/kg)	39-53	20.4-21.5	50	100
Copper (mg/kg)	140-50	14-14.5	63	190
Zinc (mg/kg)	153-326	44-67	200	720
Arsenic (mg/kg)	5.7-7.8	5.3-5.4	12	50
Selenium (mg/kg)	3.2-5.4	3.8-4.8	-	1
Cadmium (μg/L)	0.28-1.2	0.09	10	13
Lead (mg/kg)	27-333	5.9-6.5	140	530
Manganese (mg/kg)	295-328	108-112	-	-

The metals level in SLM was compared with the Canadian [2] and Dutch [20] soil standards in India. On comparing the metals in SLM with the Canadian standards all the metals (except arsenic) were found higher. However, in comparison to the Dutch standards except copper and arsenic, all the metals were found below the limit. It can be noted that arsenic was found higher in local soils also.

3.3 Total soluble solids

It is important to highlight that not much focus has been given in the past research on the release of soluble salts from SLM to be used in offsite applications. However, the leaching of total soluble solids may increase the salinity of the surrounding sub-soil and can cause the contamination of the nearby ground water. The concentration of total soluble solids in SLM range between 9160-14520 mg/kg whereas in the local soil it was found to be 500-700 mg/kg (Table 3). Majority of soluble solids consist of anions (sulfates, chlorides etc.). Sulfates in the MSW were found to be 1750-5800 mg/kg, whereas chlorides were found to vary between 1950-2850 mg/kg.

There are no regulatory standards available in India for the reuse of mined waste in off-sites applications. Therefore, SLM was compared with the local soils (uncontaminated) and with the reuse criteria given in Dutch and Denmark regulations. All the parameters listed in Table 3 were found lower than the local soil. However, on comparing sulfates and chlorides with the Dutch reuse criteria of mined MSW, they were found to be higher than the limits for use in an open environment without any encapsulations, whereas, for using SLM to be used in isolated conditions (i.e. with proper cover and liner), sulfates and chlorides were found within the limits. Similarly on comparing SLM with the Denmark standards, it falls in Category 3 for the reuse of mined SLM in roads, paths, cable graves, and floors and foundations,

Table 3. Total soluble solids in SLM

Parameter	SLM	Local soils	Reuse criteria			
			Netherland		Denmark	
			Open	Isolated	Category 1&2	Category 3
Total soluble solids (mg/kg)	9160-14520	500-700	Not available			
Organic dissolved solids (mg/kg)	1460-3800	50-80	Not available			
Inorganic dissolved solids (mg/kg)	7700-10720	450-620	Not available			
Sulfates (mg/kg)	1750-5800	300-400	1730	20000	<500	500-8000
Chlorides (mg/kg)	1950-2850	700-1000	616	8800	<300	300-6000

3.4 Release of color

The intensity of color in the leachate released from SLM was observed to be 330-405 PCU whereas in the local soils collected from nearby areas of dumpsites, it was found to be 25-30 PCU.

The aspect of release of dark colored leachate from SLM has not been reported in the literature. However, if SLM is to be used in filling low lying areas or in embankments or subgrade, leaching of colored liquid can cause coloration of the surrounding water bodies and ground water. Presence of color in the water affects consumer’s acceptance towards drinking water. People aesthetically do not accept colored water [10].

3.5 Organic content

Organic content in the present study was found to be 4.8-8.2% for SLM reclaimed from all the dumpsite which is slightly lesser than 8.9-20.7% reported by [9] for Indian landfills. Organic content reported by [13] and [16] varied between 4.9-14.3% and 16.6% for Finland and Sweden landfills respectively. The low organic content observed at Delhi landfill may be the result of high content of C&D waste present in the waste reaching landfill [16].

Organic content in SLM was found to be significantly high (5-15 times) in comparison with the local soils collected from the nearby areas of the dump sites. Organic content is one of the important parameters for use of SLM in earthworks. High organic content may cause long-term creep settlement. Indian code of practice for road construction [12] do not allow organic content to be more than 2.5% for soil to be used as subgrade.

4 Conclusions

The analysis carried out in the present study are the indicators of the presence of contaminants in the soil-like materials reclaimed from the dumpsites. However, depending upon the waste intake, socio-economic conditions near the dumpsites affects the properties of the waste to a great extent. The age and depth of waste also affect the presence of contaminants. The major conclusions of the study can be summarized as follows:

1. The results of batch leaching test (with deionized water) indicate that high concentration of TDS, anions (sulfates and chlorides), cations (calcium and magnesium), bicarbonates, COD were found in water extract from SLM in comparison to the local soil. Slightly elevated level of metals was also observed.
2. High concentrations of total soluble solids (9160-14520 mg/kg) indicate that the use of soil-like material with such high concentration can increase the salinity of the surrounding soils and lead to the contamination of nearby ground water.
3. Release of dark colored leachate is the most important factor when it comes to public acceptance. SLM is found to release dark colored water (330-405 PCU) in comparison to local soils (25-30 PCU). Not much attention is focused on this in the literature but its potential to cause the coloration of the nearby water bodies cannot be overlooked.
4. In most of the previous studies heavy metals are highlighted as the major source of contamination. The present study shows that the heavy metals (chromium, copper, zinc, cadmium, and lead) are found at elevated level in SLM with respect to the local soils.
5. High organic content in the soil-like material is found to be a cause of concern for use of SLM in earthworks. Organic content was found to be 5-15 times higher in SLM in comparison to the local soils.

Overall, it can be concluded that mined materials from dumpsites appear to be an attractive source of material for reuse in earthworks. However, its reuse without pretreatment can cause the contamination of the nearby natural resources.

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