STUDIES ON LANDFILL MINING AT SOLID WASTE DUMPSITES IN INDIA

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SUMMARY: Thousands of old landfills and dumpsites exist throughout the developing countries representing a threat for human health for the next decades, unless appropriate measures are taken. Landfill mining, involving the excavation, screening and separation of material from landfills into various components including soil, recyclable materials and residues is central to the sustainable approach to prolong the landfill life and to remediate contamination from unlined open dumps. The focus of this paper is on the concept and utility of landfill mining as a key part of sustainable landfill management especially for the rehabilitation of the municipal solid waste dumpsites in developing countries. The paper would discuss the findings of the studies on mining of decomposed materials from the dumpsites at Kodungaiyur and Perungudi, near Chennai and compare with the results of similar studies in Deonar, near Mumbai in India, Europe and USA.

1. INTRODUCTION

Landfill mining, first reported in Israel as a process where solid wastes dumped at landfills are excavated, processed and reused, has the objectives of conservation of landfill space, reduction in landfill footprint, elimination of potential contamination source, rehabilitation of dumpsites, energy recovery from recovered wastes, reuse of recovered materials and reduction in the cost of post closure care and monitoring of landfill sites (Shual and Hillel, 1958; Savage et al., 1993).

With a view to achieve one or more of the above objectives six-landfill mining projects were carried out in the USA (Lee and Jones, 1990). Collier County, Florida landfill was mined in 1988 in order to reduce the potential for ground water contamination, recover and reuse cover material and reclaim landfill capacity (Lee and Jones, 1990). A comprehensive field test evaluation of the Collier county landfill mining system revealed that the soil fraction was 60% (USEPA, 1997). Lancaster county landfill mining between 1991 and 1993 resulted in 41% soil recovery and 56% of waste converted into fuel. A landfill mining project in Thomson Connecticut, aimed at recapturing the landfill volume to extend its life (Strange, 1998). A few case studies at Barre (Massachusetts), Bethlehem (New Hampshire) and Edinburgh (New York) were also reported (Strange, 1998). Burghot landfill (Germany) gained the first mining experience in Europe (Hogland et al, 1997). In Italy, the Sardinia landfill site was mined in 1994 (Cossu et al, 1995). During the summer of 1994, a 10 year old part of Filborna landfill in Sweden was excavated as a pilot test (Hogland et al 1997). Cossu et al (1996) have reported about the technical and practical experience gained on commercial basis by USA and pilot and research experience from Europe.

Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 6 - 10 October 2003

India as other developing countries follows the practice of open dumping of solid wastes causing environmental and health risks. The Deonar dumpsite near Mumbai was mined in 1989 on pilot scale basis to enable the recovery of decomposed waste as compost (Coad, 1997). The results of the mining studies carried out at the Kodungaiyur and Perungudi dumpsites near Chennai, India with a view to evaluate the degradation status of the solid waste and the feasibility of recovering the soil fraction as compost and/ or landfill cover material.

2. SITE DESCRIPTION

Chennai (formerly Madras) is one of the four metropolitan cities in India with a population of about 5 million. The current municipal solid waste generation from the city is about 3500 t/day. This waste is disposed by open dumping at the Kodungaiyur and Perungudi sites located in the densely populated suburbs of Chennai at a distance of about 10 km north and south of Chennai central (ERM, 1996). Both the sites are in operation since 1985.

The Kodungaiyur dumping ground (KDG) extends over 160 ha marshy lands adjacent to the Kodungaiyur Sewage Treatment Plant on the southern margins of flood prone alluvial lowlands of Korattalaiyar River. The Perungudi dumping ground (PDG) is low lying and poorly drained being occupied by extensive areas of marshy land permanently wet and seasonally inundated. The total area of this site is about 250 ha in which about 22 ha is used for dumping (ERM, 1996).

3. METHODOLOGY

Municipal solid waste (MSW) samples were collected from 6 locations in PDG and 18 locations in KDG. The sampling locations were identified in consultation with the municipal authorities responsible for operation of the sites so that the wastes at these locations were dumped about 10 years back. Sampling was done with a 150 mm diameter manual auger and samples were collected for every one-meter intervals (0-1, 1-2 and 2-3 m) up to the full depth of the dump of about 3m. Approximately 100 kg of sample was collected per location. For comparison purposes, bulk sampling at selected locations was carried out using JCB excavator machines and about 100 kg was collected by quartering method.

Sample temperatures were measured immediately with a thermometer. Each sample was bagged in double plastic bags and labeled. All samples were transported to the laboratory where pH (of 1:10 water extract) and moisture content (at 105ºC) were determined. Then the samples were air dried by spreading on polythene sheets. The dried samples were screened into > 20 mm, 20-2 mm and <2 mm fractions with a mechanical vibrating screen. The first two fractions were further segregated manually into individual constituents. The soil fraction (<2 mm) was analysed for density, Volatile Organic Matter (VOM) at 550º C, and ash content. Total Organic Carbon (TOC) of these samples was determined using a solid mode TOC Analyzer (Micro C, Analytik Jena. Germany).

Aqua–regia digest (DIN 38402, 1996) of MSW fine fraction was subjected to the heavy metal analysis using Atomic Absorption Spectrophotometer Vario model (Analytik Jena, Germany) in flame (Cu, Cd, Ni, Pb and Zn), hydride (As), graphite (Cr) and cold vapor (Hg) modes of operation.

Monthly monitoring of leachate was also done at these locations. The leachates were analysed for heavy metals and compared with that of the water extract of the soil fraction.

4. RESULTS AND DISCUSSION

The composition of the solid samples from PDG and KDG are presented in Table 1. The results are compared with reported results of Deonar, Filborna and Edinburg landfills for combustible, non-combustibles and soil.

Table 1. Composition of mined samples of municipal solid wastes.

Constituents (%) Category	Particulars	Perungudi, India*	Kodungaiyur, India**	Deonar, India[a]	Filborna, Sweden[b]	Edinburg, USA[c]
Combustible	Textile	2.3	0.6	NA	4.5	NA
	Wood	11.6	0.5	0.6	14.2	5.0
	Plastic	11.0	1.9	1.5	18.1	22.0
	Rubber and Leather	14.5	0.5	0.6	1.5	NA
Non combustible	Metal	0.2	0.1	0.4	7.9	17.0
	Glass	0.8	0.4	NA	0.5	8.0
	Stone	18.5	28.3	31.5	19.0	NA
Soil	Coarse	40.1	67.8	63.5	55.0	NA
	Sieve size	< 20 mm	< 20 mm	< 8 mm	< 40 mm	NA

* - Average of 12 samples

** - Average of 46 samples

NA – Not available

a – Lessons from India in Solid waste management (Ed. Coad), pp. E1.7, 1997

b – Sardinia, 95', 5th landfill symposium, pp.783-794, 1995

c – Seminar on waste management and the environment, Kalmar, Sweden, pp.1-14, 1997

The combustible constituents such as textiles, wood, rubber and plastics are less in Kodungaiyur and Deonar landfills, indicating the stabilized status of the sampled site of the landfill. In Perungudi, the combustible constituents are higher, indicating the incomplete degradation, which is further supported by the percentage of soil fraction (40-55 %). The non-combustible constituents for these landfills range from 20 to 30 %. Soil fraction for the landfill in Kodungaiyur and Deonar are around 65 % and is comparable to the soil to waste ratio summarized from different landfill mining studies in Table 2.

MSW from PDG contains 40 % combustible, 20 % non- combustible and 40 % soil fraction. In the case of KDG combustibles constitute about 4 %, non-combustible 28 % and soil fraction 68 %. This large difference may be attributed to the age of MSW at the sampling locations. In Kodungaiyur, it was about 10 years old; whereas in Perungudi fresh wastes were also observed at the sampling points due to the unorganized dumping practices. A comparison of the constituents in the samples from PDG and KDG is presented in Figure 1. Variation in composition of samples obtained from auger sampling was compared with bulk sampling and depicted in Figure 2. Significant variation was not noticed in the results of auger and bulk sampling.

Table 3 presents the temperature, moisture content, pH, volatile organic matter, ash content, total organic carbon and dry density of the soil fraction of the solid wastes. These are compared with the results obtained from Deonar and Filborna landfills. In most cases, the TOC values are around 50% of the VOM. Low pH and high TOC values indicate incomplete biodegradation.

The results of heavy metal analyses of these samples are presented in Table 4. Comparison of the results with Indian Standards for compost shows that Cr, Cu, Hg, Ni and Pb are exceeding the limits. When compared with USEPA standards, all are within the standard limits for the compost. Hence, this fine fraction can be applied as compost to non-edible crops or as cover material after determining the geotechnical suitability.

Table 2. Soil-to-waste ratio (%) at various excavated landfills (Hogland, 2002).

Landfill	Soil-to-waste ratio %
Edinburg, NY, USA	75:25
Horicon, NY, USA	65:35
Hague, NY, USA	50:50
Chester, NY, USA	25:75
Coloni, NY, USA	20:80
Sandtown, Delaware, USA	46:54
Burghof, Germany	71:29*
Schoneiche, Germany	77:23*
Döbeln-Hohenlauft, Germany	62:38*, 21:79**
Schoneiche, Germany	20-80*, 30:70**
Dresden, Germany	74:26*, 19:81**
Sengenbühl, Germany	11:89*, 45:65**
Basslitz; Germany	50:50*, 34:66**
Cagliari, Italy	31:69*
Filborna, Sweden	65:35
Kodungaiyur, India	65:35
Perungudi, India	45:55
Deonar, Mumbai, India	70:30

* screen gauge 40 mm, **screen gauge 8-40 mm

The screen gauge was 24 mm unless otherwise indicated

In order to evaluate the environmental effects of heavy metals, a comparison was made between the leachates collected from PDG and the water extract (1:10) obtained by 24 hours shaking. The results are presented in Table 5. In general, the heavy metal concentrations in water extracts are less than that of leachate. This indicates the poor solubility and slower leachability of the heavy metals in water. The differences in heavy metal contents between leachate and water extract are high in the case of Cu, Cr, Ni, Pb and Zn. There is no significant difference between leachates and water extracts of other heavy metals (As, Cd and Hg), which may be due to the very low concentration.

Table 3. Physico-chemical characteristics of the soil fractions of MSW.

Particulars	Perungudi, India			Kodungaiyur, India				
	Min	Max	Ave	Min	Max	Ave	Deonar, India[1]	Filborna, Sweden[2]
Temperature (C^{o})	32	39	35	30	34	32	-	17
Moisture content (%)	21.4	52	39.5	15.5	46	24.4	14	30 - 38
pH	7.6	8.6	8.06	6.9	8.1	8.0	7.2	4.0 – 5.0
VOM (g/kg)	89	158	117	89	207	138	145	
Ash content (g/kg)	842	911	883	793	911	862	-	789
TOC (g/kg)	52.3	78.8	55.6	45	104	69	58	130
Dry density (kg/m^3)	745	1147	965	853	1254	1106	-	400 - 500

1 – Lessons from India in Solid waste management (Ed. Coad), pp. E1.7, 1997

2 – Sardinia, 95', 5th landfill symposium, pp.783-794, 1995

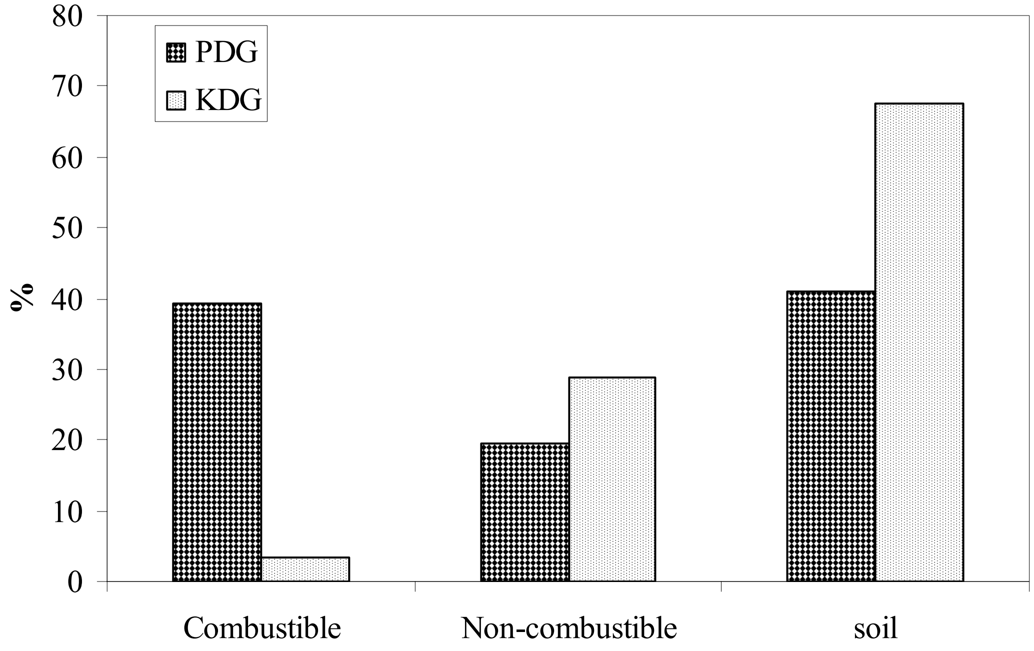

Figure 1. Comparison of constituents of MSW collected from PDG and KDG.

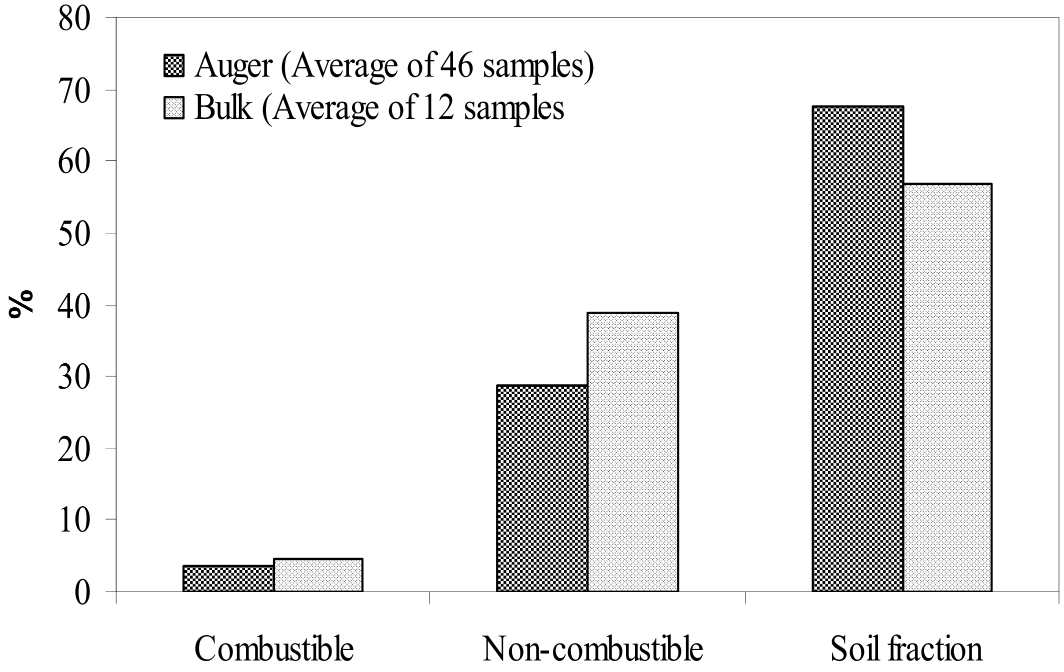

Figure 2. Composition of auger and bulk samples from KDG.

Table 4. Heavy metals in soil fractions at Perungudi and Kodungaiyur.

Heavy metal	Content in soil fraction (mg/kg)		Compost standards (mg/kg)			
	Perungudi dumpsite	Kodungaiyur dumpsite	India[a]	USEPA[b]	Canada[c]	Germany[d]
As	0.077-1.561	0.83-5.6	10	41	10	-
Cd	0.82-1.77	0.9-3.07	5	39	3	1.5
Cr	110-261	191-657	50	1200	50	100
Cu	75-217	127-968	300	1500	60	100
Hg	0.039-0.78	0.61-2.73	0.15	17	0.15	1
Ni	21-50	31-247	50	420	60	50
Pb	53-112	81-320	100	300	150	150
Zn	167-503	205-1070	1000	2800	500	400

a – MSW Management and Handling Rules, 2000
b, c & d – Hogland *et al.*, Landfill mining tests in Sweden. Sardinia '95, pp 783-794.

Table 5. Heavy metals in Leachates and water extracts of fine fractions from Perungudi.

Sample	Heavy metal (µg /L)							
	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Leachate	2.50	16.13	75.63	69.80	5.20	407.4	319.9	101.7
Water extract	1.83	9.5	17.2	53.1	8.7	134.4	139.5	48.3

5. CONCLUSIONS

This study indicates that about 65% of the samples recovered from the dumpsites of about 10 year old was fine particles. The fill at these dump sites were shallow with a depth of about 3 m and no significant variation in waste characteristics was noticed with depth of the fill. This fine fraction of the samples can be used as compost for non-edible crops or as cover material to future landfills after determining the geotechnical suitability. In dumpsites with uncontrolled dumping, the degradation process is not uniform and the recovery of fine fractions is not possible. A few heavy metals in the recovered material exceed the Indian standard for compost but well within the USEPA limits for compost. There is significant difference in the concentration of heavy metals such as Cu, Cr, Ni, Pb and Zn between leachate from the dump sites and water extract of the fine fraction of solid samples. However, this is not significant in the case of As, Cd and Hg.

The studies support the feasibility of dump site mining for lifetime expansion and remediation. Site-specific conditions will determine whether or not landfill mining and reclamation is feasible for a given location. The key conditions to be considered include

- composition of the waste initially put in place in the landfill
- historic operating procedures
- extent of degradation of the waste
- types of markets and uses for the recovered materials.

Landfill mining is a developing technology and method of waste management. Based on the analyses reported thus far, the heavy metal content and other characteristics of the recovered soil fraction indicate that the fraction can be suitable for landfill cover material. The compost standards are met for most parameters in the soil fraction of most studies. However it is possible that high concentrations of hazardous substances and heavy metal could be found in local pockets. The concept of landfill mining and related technology merits serious consideration in the rehabilitation of dumpsites. It may be relevant to consider the incorporation of the concept into the design of future landfills so that the landfilled waste can be degraded faster and made available for mining.

ACKNOWLEDGEMENTS

The Authors wish to thank the financial assistance from Swedish International Development Agency (SIDA), Sweden under the Asian Regional Research Programme on Environmental Technologies co-ordinated by Asian Institute of Technology, Thailand. Guidance provided by Dr. William Hogland, Department of Environmental Engineering, University of Kalmar, Sweden, in the preparation of the manuscript is also acknowledged with thanks.

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