Biomining: An Innovative and Practical Solution for Reclamation of Open Dumpsite

S. Mohan and Charles P. Joseph

Abstract Many of the developing nations practice open dumping as a final disposal method for municipal solid waste (MSW) generated. These dumpsites of MSW create the surface water pollution through the leachate discharge from the dumpsite, pollute the groundwater by leaching of heavy metals from the dumped solid waste over the years and also create air pollution in terms of release of CO_2, CH_4, thus contributing to climate change and other toxic gases. Thus, dumpsite becomes an eyesore and it is the need of the hour to find an alternate way of environmentally friendly disposal method of MSW. A feasible solution for the reclamation of these large sites is by biomining in which different groups of materials are extracted from the dumpsite and recycled or reused in a proper way thus resulting in the monetary value and resource flow. Biomining concept is a simple, innovative, economically feasible, practical, quick, and environmentally acceptable measure to remediate the old open dumpsite to achieve zero emission of landfill gases and leachate, and also reclaim the land reusability and zero maintenance. An integrated approach has been incorporated in which the stabilization part in biomining is carried out through bioreactor landfill treatment and then followed by biomining concepts. A conceptual framework for Biomining of the MSW dumpsite at Chennai has been developed and the implementation of the same in a site has been discussed. Also, a detailed framework for future management of open dumpsites has been developed and discussed.

Keywords Municipal solid waste · Open dumpsite · Biomining · Leachate · Sustainable environment

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1 Introduction

Open dumping is the common disposal practiced in most of the developing countries. The quantum of waste load generated is increasing day by day and is sent to the open dumping as an ultimate method for solid waste disposal. According to the Central Pollution Control Board 2012, the total quantum of waste generated in India is 127,486 tons per day (TPD) out of which a total amount of 89,334 TPD (70.07%) is collected and only 15,881 TPD is treated, which accounts to only 12.45% of the total quantum generated. The major problem associated is that in most of the Asian cities, open dumping is being carried out for the last 40–50 years and this had greatly expanded alarmingly, posing major havoc in the near future. Also, the groundwater and surface water have been greatly affected due to dumping practices carried out in the last few decades. Thus, it is the need of the hour for the reclamation of the existing open dumping grounds in many of the Asian cities. Biomining in combination with bioreactor landfill technology will be the most viable solution for the reclamation of the same. Biomining refers to the process of excavating the MSW and reclaiming the previously disposed material fractions like metals, glass, plastic, soil, fine materials, and other combustible materials [1]. The major factors which have contributed to the rising need of biomining concepts are reducing the greenhouse gas emissions, avoiding the surface water and groundwater contamination due to open dumps since it is unlined, reducing the footprint area of landfill, i.e., increasing land value and economic costs associated with it, rising energy demand, improving reuse and recycling concepts especially the variety of metals available which have a market value, and reducing the post-closure operation and maintenance costs.

Biomining concept was first implemented at Hiriya Landfill in 1953 by the Dan Region Authority, next to Tel Aviv, Israel. The waste contains many resources with high resource value and the most notable are the nonferrous metals such as aluminum cans and scrap metal. A study conducted by Zee et al. [2] revealed that the concentration of aluminum in many landfills is higher than the concentration of aluminum in its ore, i.e., from bauxite.

The most practiced or implemented method of waste management in developing and developed countries are landfill biomining [3–6] and this technology is reported in several Indian cities [7]. During 2002–03, the first biomining experiment was adopted at Panchavati in Nashik city, where a 28-acre site with an average 4–7 m depth of garbage was engulfed by expanding the existing facility. The old waste was cleared off in 120 days costing around 6.4 million rupees. To enhance the windrow composting process of old waste, composting bioculture was used at the rate of 250 g/m^3. Understanding the importance and proven benefits of the biomining process of reclaiming the old dumpsite/landfill, the Government of India is now considering funding for dumpsite bioremediation projects [7]. Landfill Biomining is the best approach for landfill reclamation since it is very important to address the contamination of groundwater posed by the old and new wastes, to increase the area of the existing facility for future expansion and to reduce the post-closure operational expenses.

1.1 Biomining Technology

Biomining (also referred to as landfill mining) refers to the process of digging out the previously dumped/disposed materials from a landfill (in our case open dumpsite) to recover metal, plastic, glass, combustibles, soil, and other fine materials [1]. It also refers to clearing the open dumpsites by segregating the prevailing waste into different constituents and converting the biodegradable portion into compost, methane gas or biodiesel and the remaining nonrecyclable plastic as refused derived fuels, which in turn can be used as an alternative fuel in industries. The compostable portion of the waste is removed through sieving and sold for use as soil enriches/fertilizers or for landscaping.

Landfill mining has been adopted at a number of landfill sites throughout the United States and is globally gaining interest [8–12]. The first step for landfill mining is the stabilization of the existing waste in the dumpsite. The mining of unstabilized or insufficiently decomposed wastes would result in an unacceptable generation of nuisances and will have a negative impact with regard to the health and safety of the people operating and also affects the ecosystem. The technology mainly targets to excavate the materials and process in such a way that the target materials can be separated from the excavated mass and further process to meet its required grade for any reuse or recycling operations. Generally, excavation is conducted using technologies used for open-cast mining, usually a front-end loader, a backhoe, a clamshell, a hydraulic excavator, or a combination of these. The excavated material may be directly processed in situ or will be stockpiled for later processing via different methodologies to segregate the components. Based on the extent of resource recovery, the quantum and number of streams of segregation of the excavated material varies. The process starts with the excavation of materials and the excavated materials are discharged into coarse screens and oversize, non-processible wastes are removed. The residual fraction is further sent to relatively smaller screens and the material fraction that passes through the second screen is considered as soil fraction. Further, to segregate the soil fraction from the excavated waste, an efficient unit process named trammel screen is widely used. In order to recover or retrieve the ferrous fraction in the composition, the remaining fraction is exposed to the magnetic field/force. After this, the nonferrous fraction is processed through an air classifier that separates the light organic materials from the heavy organics and commonly, this is used to recover waste-derived fuel (RDF). The processing at the landfill site is typically accomplished by means of equipment mounted on trailers, which usually consists of conveyor belts, a coarse screen, a fine screen, and a magnet. After the recovery of metals, plastics and combustible materials, the processing rejects and the inerts are disposed of as a backfilling material after ensuring the required geophysical properties.

1.2 Bioreactor Landfill Concept into Biomining Process

On average, 70% of solid waste generated throughout the South Asian region is a biodegradable organic mass with high moisture content [13]. Central Pollution Control Board (CPCB) in assistance with National Environmental Research Institute (NEERI) has conducted a survey of solid waste in 59 cities and found that the major fraction (40–60%) of the municipal solid waste is biodegradable [14], which provides an opportunity for composting or energy recovery processes. The excavated biodegradable fraction can be used as a potential resource for the bioreactor landfill technology. Energy conservation is a cornerstone of waste management. In most of the developing countries, the activities like open dumping have led to climatic change through Green House Gas (GHG) Emissions and other health-related impacts. A bioreactor landfill could be any permitted Subtitle D landfill or landfill cell where liquid or air is injected in a controlled fashion into the waste mass in order to accelerate or enhance biostabilization of the organic waste as defined by the Solid Waste Association of North America (SWANA). In order to recover the untapped energy from waste, an effective method of waste management which is environmentally and biologically sound has to be adopted and thus bioreactor landfill (BLF) comes into being.

Bioreactor landfill serves as a sustainable way of solid waste management and has the potential for recovery of methane (CH_4) and other resources. The leachate recirculation and the addition of other supplements into a landfill accelerate waste degradation and enhance gas production by stimulating the microbial activity. Several researchers performed small-scale laboratory tests, pilot-scale and full-scale investigations to study the effects of leachate recirculation in waste and noted the advantages of this concept [15–18]. These bioreactor landfills have several benefits over traditional landfills such as effective management of leachate generated, early waste stabilization, enhanced CH_4 production, and low post-closure monitoring costs. The biodegradation of municipal solid waste (MSW) is considered to be highly crucial as it greatly influences the other processes and in addition dictates the CH_4 production, the landfill settlement, and the stabilization time. BLF can serve in the potential extraction of metals from leachate by some selective adsorption techniques. Most of the developing countries have open dumpsites or uncontrolled dumpsites with no liners or gas collection system which poses an enormous health threat to the neighborhood by fetid, ground and surface water contamination and exacerbates the global climate change. The energy generated from BLF is biogas which in turn can be utilized for the production of electricity or heat or as a biofuel for automobiles or all of these.

The major constraints of the biomining process are as follows:

- During biomining process, methane will escape into the atmosphere resulting in odur problems, health risks, and air emissions. This can be captured by operating the existing dump as a bioreactor in the initial period and then after stabilization leaving it as the former condition.
- In uncontrolled dumpsites, the degradation process is not uniform, hence, recovery of fine fractions is not possible; recovery of fractions like plastics, wood, etc., will be very difficult and those recovered will be contaminated. So in order to remove the contaminated plastic and wood fraction, bioreactor landfill technology helps in removing the same and finally, the leachate has to be pumped out for treatment and the same has to be sent to the open dump and after stabilizing, we need to stop the entire process.
- Typical quantity reduction achievable is between 28 and 32% (based on the study undertaken at Gorai by MCGM in Mumbai). The large quantity of unprocessed biomining rejects will need an area within the site for disposal.

2 Case Study—Hyderabad City

The Municipal Solid Waste Composition of Hyderabad City is as follows (Fig. 1):

Steps carried out are:

- Loosening of waste for drying the material
- Transportation of waste to the trammel site

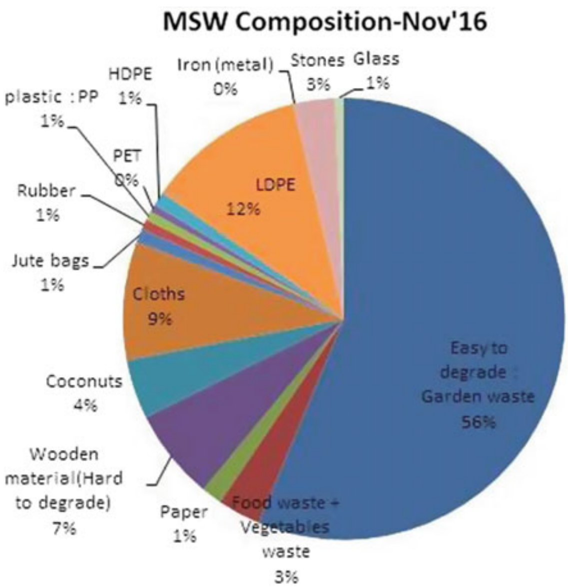

Fig. 1 Municipal solid waste composition in Hyderabad city (*Source* Ramky Enviro Engineers Ltd.)

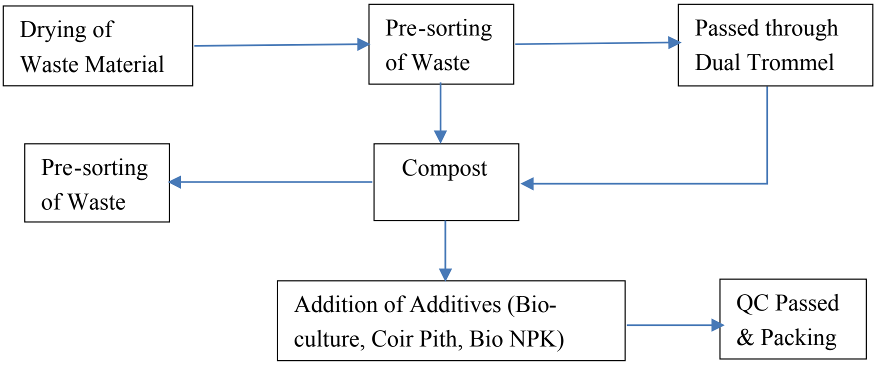

Fig. 2 Process flow diagram of the biomining process operational cost per ton

- Presorting of waste—Removing large size stones, tires, coconut shells, etc.
- Feeding the waste to the DUAL Trammel having sieve size of 35 mm and 3 mm
- Transportation of sieved material (compost) to the packing shed
- Mixing of the compost by adding additives—Bio culture, Rich soil, Coir pith, Tobacco, and Jaggery and maintaining 15 to 25% of moisture
- Before packing, the material should pass the Fertilizer Control Order (FCO) specification
- After passing Quality Control, material is weighed, packed and sent to the market (Fig. 2, Table 1).

Table 1 Operational Cost of Biomining (*Source* Ramky Enviro Engineers Ltd.)

REQUIRE MACHINERY/EQUIPMENT	UNIT COST	QTY.	TOTAL COST		
25 TPD Capacity of Trammel	500000	1	500000		
SHED	1500	1250	1875000		
EXCAVATOR	1300	20	26000	26000	
TIPPER	100	20	2000	2000	
JCB	550	20	11000	11000	
OPERATOR	15000	1	15000	500	
POWER	10	400	4000	150	
			1YR	DAY 39650	
		TRAMMEL	100000	273.9726	
		SHED	187500	513.6986	
		COMPOST	500	40437.67	
			50	808.7534	PER TON

3 Case Study—Kumbakonam Model

The dump yard was an eyesore with no place left to dump the future MSW. The average height of the heaps was 7 m from the ground level. Out of the total area of 10.5 acres, around 7.5 acres of land was dumped indiscriminately with MSW and others being utilized as green cover and other utilities.

The municipality contacted Service Providers for understanding the solutions to clear their dump in the landfills. The Urban Local Body awarded the contract to Zigma Global Environ Solutions Pvt. Ltd. after considered two points: the quantity of the prevailing waste and time required to clear the entire dump yard. Zigma conducted a contour mapping survey before the presentation to assess the quantity of waste dumped. Zigma then assessed the time required to clear the entire dump yard. There was a Questions and Answers session specific to Kumbakonam Dump Yard, among Municipal Employees, Sanitary Inspectors, Pollution Control Board Representatives, and Municipal Health Officers, among others.

The plant is designed to segregate around 14 different aggregates enabling efficient and responsible disposal of all of them. The plant disposes of all its aggregates responsibly to the tune of 100%. The plant has achieved 0% rejects which means none of the aggregates is considered as rejects and dumped back into sanitary landfill [19].

The different ways that it has been used as resources are 17% for cement companies and power plants, 15% for pyrolysis plants, 6% for recyclers, 2% for reclaimers, 3% for recycling companies, 0.5% for steel plants, 5% for pipe-making companies, 6% for soil enricher to sugarcane farmers, and 6.5% consisting of wood cloth and other organic items are shredded and sold as refuse-derived fuel to cement companies and power plants.

Out of 131,250 m^3, more than 100,000 m^3 has been processed and aggregates successfully disposed of. Out of 7.5 acres dumped with garbage, more than 5 acres have been reclaimed. The ULB has built an RCC Compost Plant and a 70 MT per day MSW Processing plant in the 2 acres land reclaimed. As of now, the entire quantity is processed and the dump yard is a site to see.

4 Proposal for the Reclamation of Perungudi Open Dumpsite, Chennai

Chennai Corporation has two major dumping sites; Perungudi and Kodungaiyur located south and north of Chennai. These are open dumpsites, which stink and the surface water percolates through these waste dissolves or release harmful chemicals and heavy metals in the waste contributed to environmental pollution. Human health is very well affected when they consume the groundwater contaminated by heavy metals. Therefore, the bore wells and tube wells near the dumpsite threatens the lives of people living near it.

Perungudi dumpsite extends around 230 acres and the dumping has been carried out for the last 40 years. The average height of the MSW is 5–7 m and the total quantum of waste will be around 2.5 million metric tons. At first, the entire open dumpsite will be operated as anaerobic bioreactor landfill and after the stabilization; biomining concepts have to be incorporated. This, in turn, helps in energy recovery and less GHG emissions, less health hazards, and so on. The aerobic bio-reactor has to be operated in the following method:

a. The entire area has to lessen for reducing the horizontal area. This is in order to reduce the plan area because we have to provide a final covering over the dumpsite. The entire area has to be reduced to lessen the horizontal area of final covering over the dumpsite. Soil parameters like bearing strength, safe bearing capacity, etc., and landfill stability parameters like slope stability, density, etc., have to be ensured while doing so.
b. After this, we have to encapsulate the entire area by providing sheet piles until a hard stratum which does not allow the leachate within the encapsulated zone to move out. The geology of the location has to be studied for determining the depth of the sheet piles.
c. Then the water level inside the encapsulated zone is kept below the water level just outside the encapsulated zone thereby creating a gradient toward the landfill (encapsulated zone). This is to ensure that no water/leachate moves out of the encapsulated zone. This can be achieved by pumping the water/leachate inside the encapsulate zone; for this, there are existing leachate drains from which the leachate can be pumped. This leachate pumped out has to be treated and a part can be sent back for recirculation and some part can be sent to the marshland. The treatment plant can be set next to the dumpsite since there is already a wastewater treatment near it, but for the treatment of leachate, separate treatment methods have to be adopted.
d. For the degradation of different organic and inorganic compounds, oxidation has to be provided. This can be achieved by two different processes: one is by purging the air into the top layers of the landfill. Second is by oxidizing using hydrogen peroxide (H_2O_2) because, at the bottom layers of the landfill where it is saturated by leachate, the air addition will not be having enough pressure to move through the saturated zone and also the oxidation efficiency would be less (Fig. 3).

The quantification and monetization costs and benefits associated with the rehabilitation of a dumpsite in Chennai have been studied by Anna University, Chennai, Asian Institute of Technology and University of Kalmar [20]. The total quantity of waste mass has been analyzed totally and it is estimated to have 3.5 million tones with a density of 700 kg/m^3. About 50% of the waste mass accounts for soil fraction, 10% recyclables, and the remaining 40% requires landfilling. The disposal of residuals in a landfill with a height of 15 m will require about 17.3 ha of land and the remaining land of 82.7 ha could be reclaimed, of which at least 90% of it will be available for future landfilling applications. The project would cost 147

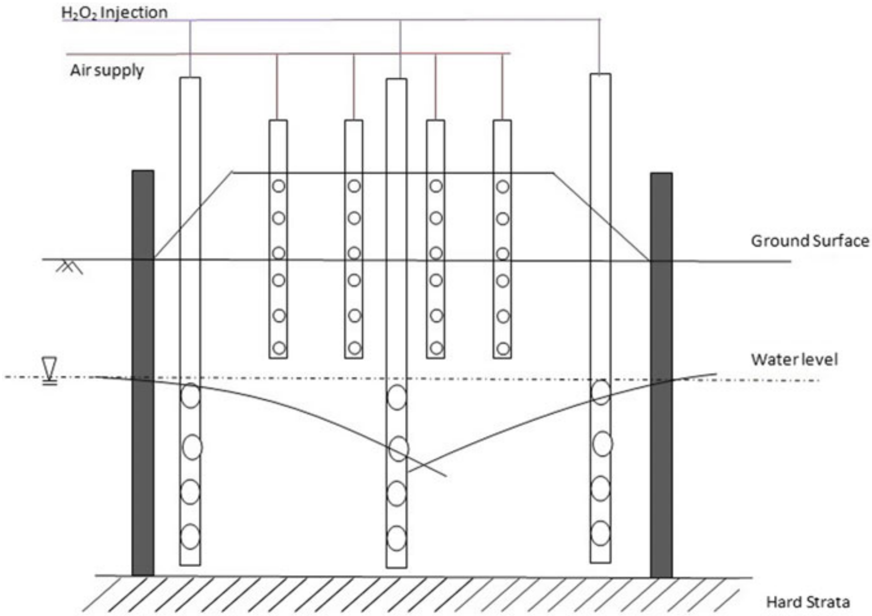

Fig. 3 A conceptual proposal for the remediation of an existing open dumpsite

million rupees as against a benefit of 162 million rupees resulting in a positive benefit to cost ratio of 1.1 and it is economical to take up the project for implementation.

5 Framework for Future Management of the Reclaimed Open Dump

After the reclamation of the open dumpsite, say 70% of the land can be reclaimed. This land has to be utilized in a proper manner for the future MSW practice within the city. A conceptual framework for the utilization of the reclaimed land is being discussed. The fresh unsegregated waste should be processed through a sequence of the process which will be a sustainable solution for MSW management. The incoming fraction of the waste is first spread in windrows with a maximum height of 2 m, where we are providing sufficient aeration for the partial degradation of waste. This is carried out on a concrete surface with channels for collecting the leachate generated from initial hydrolysis. After this, the waste is sent through a conveyer belt where form one side, the hot air is blown to remove the lightweight plastics, paper, and other light materials. Further on the conveyor, the material remaining is then exposed to the magnet to recover the ferrous metals and finally, the remaining is sent to the bioreactor landfill, where energy and compost can be

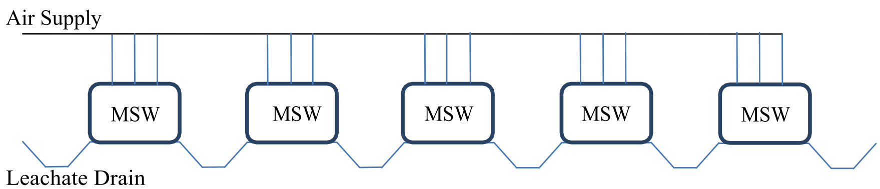

Fig. 4 Windrow operation of MSW in concreted/lined surface with leachate collection system

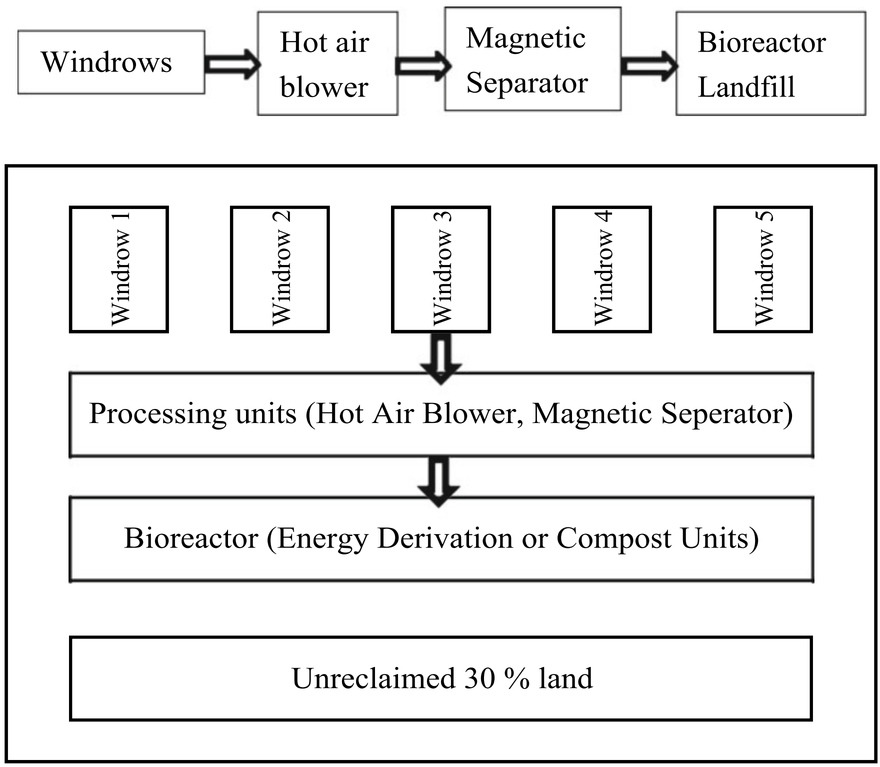

Fig. 5 Framework for future management of reclaimed open dump

produced, thus finding an economic benefit from the waste. The pictorial representation for the same is also shown below (Figs. 4 and 5).

Alternatively, if the waste is segregated at the source into biodegradable and nonbiodegradable; the process can be bypassed and the biodegradable fraction can be directly sent to the bioreactor facility and the nonbiodegradable fraction can be further segregated to different components.

6 Conclusions

Biomining will provide for exhumation that will not only reclaim landfill space but will definitely provide an opportunity to remediate existing public health and environmental quality problems associated with the existing or closed open dumpsite that would otherwise not be addressed until serious surface water or groundwater contamination is broadcasted. Further, it also emphasizes the regulatory bodies for ensuring a proper lining system and design at the bio-mined site so that future processing and MSW activities are undertaken at a manageable risk to the surrounding environs and public health. Biomining and bioreactor concepts have to be adopted in the reclamation of the old dumpsites in most of the Asian cities. We also have to take care of the reclaimed land and adapt facilities for further future management of MSW.

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