A COST-BENEFIT ANALYSIS OF BIOMINING AT SOLID WASTE DUMPSITE IN TAMILNADU

N.Pradheep[1*], Mr. K. C. Vinu Prakash[2]

Abstract

Open dumping is a common ultimate disposal strategy for municipal solid waste (MSW) in underdeveloped countries. Due to the leachate discharge from the dumpsite, heavy metals from the deposited solid waste over time damage the groundwater, and these dumpsites of MSW also pollute the air, which contributes to climate change and the release of other harmful gases. Biomining is the practice of removing previously discarded items from a landfill in order to recover metal, plastic, glass, combustibles, soil, and other fine materials. Due to its tremendous environmental and economic potential in material recycling, energy recovery, land reclamation, and pollution avoidance, biomining is an environmentally benign technique that integrates the ideas of material recycling and sustainable waste management. This study used a cost-benefit analysis methodology to determine whether biomining was economically feasible, which is crucial for its promotion.

Keywords: Municipal solid waste (MSW), cost- benefit analysis, biomining

---

[1]*Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur- 603203.
(E-mail: pn5608@srmist.edu.in)
[2]Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur- 603203.
(E-mail: vinuprac@srmist.edu.in)

***Corresponding Author:** N. Pradheep
*Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur- 603203.
(E-mail: pn5608@srmist.edu.in)

DOI: - 10.48047/ecb/2023.12.si5a.031

1. INTRODUCTION

Our entire world is dealing with waste and its disposal due to the rise in living standards and technological advancement. The treatment of trash was not formerly a top priority for the world. Municipalities or other local organizations collect the garbage produced by various resources, which is then disposed of in landfills or other disposal areas. With time, though, these landfills have grown to resemble enormous mountains or waste piles. By polluting the air, water, and land, these trash or rubbish mounds are causing global warming[1]. As per the study by the worldbank, A minimum of 33 percent of the 2 billion metric tons of MSW produced annually around the world is not managed in a manner that respects the ecology. Whereas MSW generation is 62 million tons in India in the year 2021 (0.16 million TPD). Management of solid waste begins with generation and continues with collection, transport, treatment, and disposal of waste. The difficulties in managing solid waste include, for instance, inadequate garbage collection and incorrect disposal, such as in unsupervised dumpsites with insufficient safeguards for soil or groundwater. Solid waste generation per capita per day, percentage of solid waste treated, and percentage of solid waste landfilled in India from 2015-16 to 2020-21 is given in Figure 1(a),1(b),1(c) respectively[2].

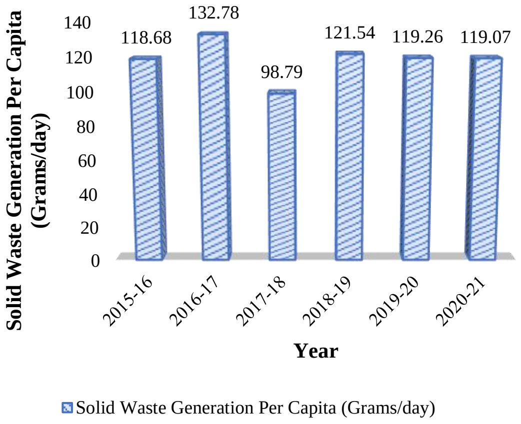

Fig.1(a) Solid waste generation per capita per day

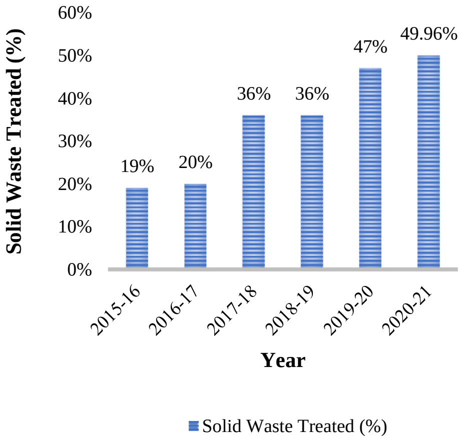

Fig.1(b) Percentage of solid waste treated

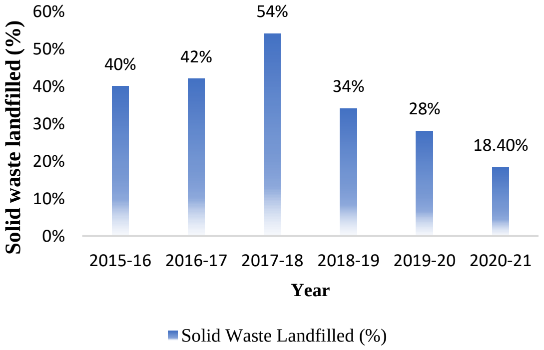

Fig.1(c) Percentage of solid waste landfilled

A revolutionary change in the management of waste has recently occurred in India, clearing the way for the cleanup of old waste dumpsites and hollowing out the justifications and arguments for not doing so. Although managing legacy waste through biomining may present particular difficulties, it can also result in technologically based approaches for recovering valuable land from landfills and revenue-generating fractions. Dumpsites that are unlined and unscientific generate toxic leachate that contaminates both surface water and groundwater resources by creating puddles in the immediate vicinity and seeping into the earth. Methane and other greenhouse gases are released from these landfills. They are more likely to experience dumpsite surface fires, which cause a rapid release of hazardous pollutants into the surrounding environment. Urban development is also constrained by arbitrary dumps.

Generally, fresh municipal solid waste and legacy waste are mixed at Indian disposal sites[3]. Legacy waste differs from new municipal solid waste in terms of composition and characteristics. This distinction has a big impact on the decision made about treatment methods and the usage of recovered materials. The type of residual waste that a landfill contains is significantly influenced by how old it is. The single largest element of legacy waste is typically fines. The only item that makes up the fines in legacy waste is organic waste that has decomposed and been mineralized, which is mixed with silt, sand, and small bits of construction and demolition (C&D) waste. The amount of fines is larger in older landfills because microbial decomposition needs more time to occur. Decomposition contributes to the settlement (decrease in volume and mass) of the landfill. However, this is dependent on several variables, including initial compaction, waste properties, level of decomposition, the impact of air and water on waste consolidation, the height of the finished landfill, availability of moisture, and moisture route inside the landfill. Waste's ability to decompose and degrade effectively is also limited by several reasons such as low moisture content, inadequate shredding of garbage dumped in landfills, excessive bulk density, and a lack of inoculum (microbial population). Depending on income level, the waste composition varies, reflecting various consumption patterns. The geographical location and age of a dumpsite also affect the legacy waste's composition. The global waste composition percentage is shown in Figure 2.

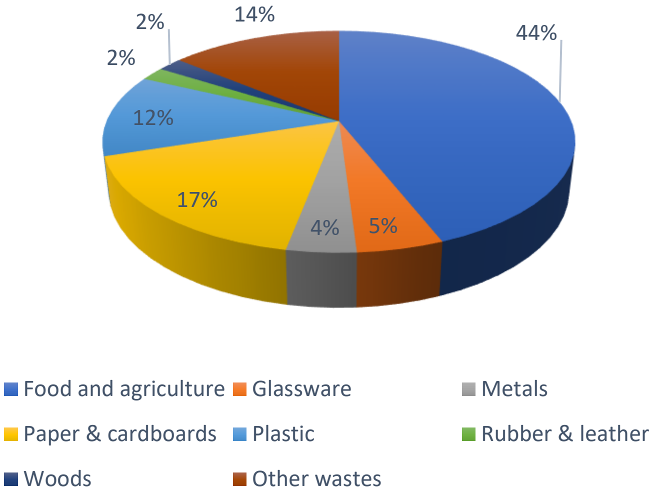

Fig. 2 Global waste composition percentage

Biomining is an advanced waste processing method in which excavating, treating, separating, and profitably utilizing the old municipal solid waste that is dumped in landfills. It is a method that treats waste by using natural components like sunlight and air or microorganisms. The biodegradable part of the waste gradually decomposes naturally over time, while the non-biodegradable parts are then dealt with separately [4]. It recovers valuable metals from mining waste or rock ores[5]. The six basic steps of biomining of dumping site are as follows:

i. Pre-feasibility evaluation, which includes detailed site research studies, surveys, and waste characterization;
ii. systematic excavation of waste
iii. stabilization by bio culture spraying to reduce waste volume and mass
iv. processing of the excavated fraction
v. use of retrieved waste fractions in various profitable applications
vi. clearing and preparing recovered land

The main factors that have contributed to the rising need for bio-mining concepts are,

i. To reduce greenhouse gas emissions.
ii. To avoid surface and groundwater contamination from open dumps because they are unlined.
iii. Land scarcity.
iv. Increased energy demand.
v. For improved reuse and recycling concepts (particularly the variety of metals available that have a market value).
vi. To decrease post-closure operation and maintenance costs.

Thus, in terms of material recycling, power generation, reclaiming land, and pollution prevention, bio-mining is a green technology with enormous both economic and ecological potential [6]. Cost-benefit analysis of biomining at solid waste dumping sites is important as, by analyzing different steps involved in cost as well as benefit, it can be concluded whether or not the biomining process is profitable or not[7]. When making assessments about a biomining project, determining the project's economic viability is a crucial consideration, but very few studies have specifically addressed this issue[8] [9]. The major steps involved in cost and benefit are listed in Table 1[10].

Table 1. The major steps involved in cost and benefit

Costs involved in biomining	**Benefits involved in biomining**
i.Excavation transportation, window formation, Bioculum slurry, and stabilization cost.	i. The benefit of reclaimed land for urban development
ii.Stabilized garbage transportation to the processing unit and processing costs.	ii. The benefit of recovered airspaces
iii.Solid combustible fuel (SCF/RDF) removal and disposal costs	iii. Recycling soil-type materials to organic fertilizer and substrate
iv.Construction and debris removal costs. v. Process inert to landfill transportation and landfill maintenance cost.	iv. Recycling stones and construction waste to regenerate construction materials.
v.Bio-soil disposal cost.	v. Recycling metals and glasses
Power cost, firefighting, and dust control cost.	vi. Producing residue-derived fuels (RDFs) from waste plastics
viii. Manpower cost	vii. Generating heat or electricity by incinerating waste plastics or other combustibles
ix. Machinery recovery cost.	viii. Avoidance of leachate collection and treatment
x. Miscellaneous and interest costs.	ix. Avoidance of landfill gas emission
xi. Contingency cost, weighbridge, shed, EB work, civil, and electrical work.	

2. MATERIALS AND METHODOLOGY

2.1 Study area

The selected area of study is an active open dumpsite from the eastern part of Tamil Nadu have a total area of 200 acres, where At least 35 lakh cubic meters of waste dumped over 30 years. The study area where the biomining project is already ongoing is shown in Figures 1(a), and 1(b). Waste samples are collected from different points as well as the different heights of solid waste dumped at the biomining project site. To identify the quality of waste for further processing and thermo-chemical processes, it is important to find out the preliminary characteristics of solid waste (Kieckhäfer et al., 2017) [12]. Samples are given for testing after separation by the quartering technique.

Fig. 1(a), 1(b) ongoing biomining process at site

2.2 Preliminary characteristics

Different characterization tests done for solid waste collected from open dumpsite are,

i.Calorific value
ii.C/N ratio
iii.Density
iv.Moisture content
v.Total organic carbon.

Calorific value is the amount of energy in a fuel or food that can be measured by measuring the amount of heat that is created once a specific amount of it is completely burned. It is often represented in joules per kg. The content of the garbage affects the Calorific Value of waste. Waste that contains more PVC does have a greater calorific value than waste that contains more paper and less PVC. The C/N Ratio refers to the mass proportion of C to N in organic remnants. Bacteria need a proper mix of C and N to be active. Thus, it is important to measure the C/N ratio of the solid waste sample collected. According to the composition of waste, the density of MSW will change. The planning of a landfill depends on density just as much as it does on the storage, collecting, and transportation of trash. After the waste is dumped, it must be compacted to the ideal density for the landfills to operate effectively. Solid wastes' moisture content is often represented as moisture content weight/ kg of wet material. As moisture content will directly affect the density as well as the treatment processes, it is important to find out the MC of MSW. A significant component of the MSW is made up of organic component, which includes garbage, food remnants, papers, and gardening debris. High organic content MSW that is landfilled harms the ecosystem.

2.3 Cost-benefit analysis

There are different types of cost analysis techniques existing for analyzing the economic efficiency of Biomining of MSW like NPV (Net Present Value), BCR (Benefit-cost ratio), and IRR (Internal rate of return)[13][14][15].

2.3.1 Benefit-cost ratio

An indicator used in a cost-benefit analysis called the benefit-cost ratio (BCR) aims to sum up the total value for the money of such a proposal. A project's or proposal's BCR is the ratio of its benefits, expressed in financial terms, to its expenses, similarly represented in monetary terms. The formula for finding the Benefit-cost ratio is given in equation (1)

$$\text{Benefit-cost ratio} = \frac{PV\ of\ benefit\ expected\ from\ the\ project}{PV\ of\ cost\ of\ project} \quad \text{……….. (1)}$$

Where PV is the present value.

3. RESULTS AND DISCUSSIONS

There are different processes that are carried out throughout the biomining process. According to the waste composition, it may vary[16]. Major components of waste collected from dumpsites were soil, stones, plastic, wood, textile, glass, paper, metals, and other wastes. The composition of waste by percentage is depicted in Figure 1.

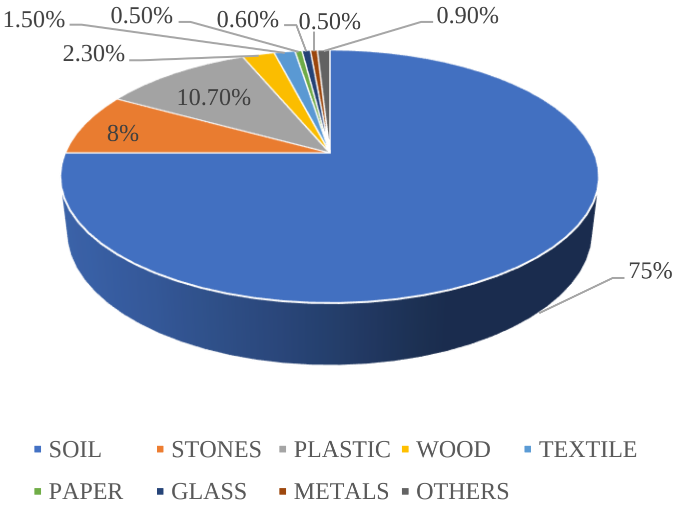

Fig. 1 Percentage by the composition of waste collected

The preliminary characteristics of the waste sample collected are listed in Table 2. According to Solid waste management rules 2016, it is not recommended to send non-recyclable solid waste with a calorific value of 1500 Kcal/kg or more, but it can be used for waste-to-energy processes.

However, the calorific value of collected samples is less than that and thus safe. For optimum digestion, the C/N ratio should be between 30 and 50. As the moisture content is high, it is difficult to process waste immediately, thus we have to adopt techniques for drying like sun drying[17].

Table 2. Preliminary characteristics of the sample collected

Sl. No.	Parameters	Unit	Result
1	Calorific value	Kcal/ Kg	713
2	C/N ratio	-	24.1
3	Density	Kg/m^3	686.3
4	Moisture content	%	43.8
5	Total Organic Carbon	%	20.5

The biomining project is planned for a period of one and a half years, which was started in October 2022. The entire project is divided into six packages by two private organizations. Almost 57 percent of the work has been completed so far, of which 19.66 lakh cubic meters of solid waste have been bio-mined.

3.1Cost analysis

As the biomining project of the total study area is divided into 6 different packages, the total budget of 300 Crores is also divided between these 6 packages. Data regarding the total area, total waste, biomining fee, and project cost under each package as well as interim landfill system cost and environmental and social compliance cost is listed in Table 3. It is identified that the total cost for the biomining project in the study area is Rs. 350.64 Cr.

Table 3. Cost analysis of biomining in the study area

Package	Total area (acres)	Total waste (metric tonnes)	Biomining fee Rs/cum	The project cost is Rs. (lakhs)
1	29.88	541472.91	1070.77	5797.93
2	48.95	574315.16	1070.77	6149.59
3	35.37	474132.78	1070.77	5076.87
4	22.38	470321.24	1070.77	5036.06
5	35.49	470130.21	1070.77	5034.01
6	53.09	532750.39	1070.77	5704.53
Interim landfill system cost (ILF)				1968.78
Environmental and social compliance cost				296.81
Total cost				**35064.59**

3.2Benefit analysis

Different sources of benefit as well as the benefit in rupees is listed in Table 4. The study area has a minimum guideline value of Rs. 750 per sqft to a maximum of Rs. 4500 per sqft. But as it is a marshland as well as due to government guidelines, rather than selling the land reclamation of land as well as airspace is taken into account more seriously. Recycled soil from the biomining site has more nutritional value and the average selling price of it is around Rs. 800 per ton[18]. Due to a shortage of time for completion of the biomining project, it is identified that the authority is selling it for free to reclaim the area easily. Recycled debris and construction waste value are approximately Rs. 1000 per ton. The recycled value of metals is approximately Rs.40500 per ton whereas it is Rs. 6000 per ton for glass. Plastic material collected from dumpsites is sold to industries that have an approximate market value of Rs. 1000 per ton. The total practical benefits of biomining in the study area are identified as Rs.139.96 Cr.

Table 4. Detailed benefit analysis

Sl. No.	Source of Benefits	Benefit in Rs.
1	The benefit of reclaimed land	-
2	The benefit of recovered air-spaces	-
3	Recycling soil-type materials to organic fertilizer and substrate	-
4	Recycled debris and construction waste to regenerate construction materials	26.3 Cr.
5	Recycled metals and glasses	78.46 Cr.
6	Selling waste plastics for industries	35.2 Cr.
7	Avoidance of leachate collection and treatment	-
8	Avoidance of landfill gas emission	-
	Total Benefit	**139.96 Cr.**

3.3Benefit-Cost ratio

A benefit-cost ratio greater than 1 implies the biomining project is beneficial, if the ratio is equal to 1 implies the project is neither loss nor beneficial, whereas less than 1 implies the biomining project is not cost-benefit effective. The benefit-cost ratio of the biomining project of the study area is given in equation (2).

$$\frac{Total\ Benefit}{Total\ Cost} = \frac{139.96\ Cr.}{350.64\ Cr} = 0.399 \qquad \ldots\ldots\ldots\ldots(2)$$

The benefit-to-cost ratio of the biomining project is 0.399 which is less than 1, indicating that the project is not cost-benefit effective.

4. DISCUSSION

Our entire world is dealing with waste disposal due to the rise in living standards and technological advancement. Municipalities or local entities collect the garbage produced by various resources, which is then either disposed of in landfills or disposed of in dumping grounds. However, as the years went by, these landfills began to resemble enormous mountains or waste piles. Biomining aims for a scientific technology through which waste can be processed and managed properly, however only by analyzing different steps involved in cost as well as benefit, it can be concluded whether or not the biomining process is profitable or not. In the study area of the eastern side of Tamil Nadu, it is identified that the benefit-by-cost ratio is less than one, which implies the ongoing biomining project is not cost-benefit efficient. Even though the reasons such as type of land area, and shortage of time contribute to this result, with the help of material recovery, energy recovery as well as land reclamation, this biomining project would have been profitable.

5. RECOMMENDATIONS

The main metrics used to assess the benefits of the Sustainable Solid Waste Management (SSWM) System are the reduction of pollution, energy savings, and social benefits. Currently, the production of different building materials in India accounts for around 28% of all energy resources. India produces 960 MT of solid waste as a by-product of various industrial, mining, agricultural, and domestic operations each year, which poses significant environmental and ecological issues in addition to taking up a lot of space for storage and disposal. There is a big potential for setting up secondary enterprises for recycling and utilizing such waste materials in construction when taking into account the enormous number of wastes as resources. Although various lab procedures, products, and technologies based on agro-industrial wastes have been produced, it is necessary to eliminate them. But still, alternative materials made from solid waste that are eco-friendly, economical, and energy-efficient will have a strong market potential to meet the demands of people in both urban and rural locations. Biomining can be made more cost-benefit effective by implementing thermochemical processes which will promote waste-to-energy and thereby increase revenue. And it is recommended to improve the waste management system from collection to disposal which will reduce the further biomining processes easier.

6. CONCLUSION

Exhumation made possible by biomining will allow for the reclamation of landfill space as well as the opportunity to address public health and environmental quality issues related to closed or active open dump sites that wouldn't otherwise be addressed unless serious surface water, ground water, or air contamination occurs. Considering the market potential and economic viability is crucial when deciding whether to move forward with bio-mining initiatives. The most expensive aspect of landfill mining, out of all the costs and benefits, was the cost of excavation and hauling equipment followed by the cost of transportation of materials, as well as waste processing cost. While the benefit from land reclamation as well as soil recovery could have contributed more to the total benefit of the biomining project, due to shortage of time and other independent reasons, benefits for this biomining project are from material recovery only, thus landfill mining is not cost-benefit effective considering the external and internal cost and benefits.

REFERENCES

1. Taşkın and N. Demir, “Life cycle environmental and energy impact assessment of sustainable urban municipal solid waste collection and transportation strategies,” *Sustain Cities Soc*, vol. 61, Oct. 2020, doi: 10.1016/j.scs.2020.102339.
2. “MSW_AnnualReport_2020-21”.
3. Singh and M. K. Chandel, “Effect of ageing on waste characteristics excavated from an Indian dumpsite and its potential valorisation,” *Process Safety and Environmental Protection*, vol. 134, pp. 24–35, Feb. 2020, doi: 10.1016/j.psep.2019.11.025.
4. S. Mohan and C. P. Joseph, “Biomining: An innovative and practical solution for reclamation of open dumpsite,” in *Lecture Notes in Civil Engineering*, Springer, 2020, pp. 167–178. doi: 10.1007/978-981-15-0990-2_12.
5. D. B. Johnson, “Biomining-biotechnologies for extracting and recovering metals from ores and waste materials,” *Current Opinion in Biotechnology*, vol. 30. Elsevier Ltd, pp. 24–31, 2014. doi: 10.1016/j.copbio.2014.04.008.
6. Engineering, “Life Cycle Assessment and Cost-Benefit Analysis of Landfill Mining at the City of Denton,” 2017.
7. Laner *et al.*, “Systematic assessment of critical factors for the economic performance of landfill mining in Europe: What drives the economy of

landfill mining?," *Waste Management*, vol. 95, pp. 674–686, Jul. 2019, doi: 10.1016/ j.wasman.2019.07.007.

8. T. Wolfsberger, M. Pinkel, S. Polansek, R. Sarc, R. Hermann, and R. Pomberger, "Landfill mining: Development of a cost simulation model," *Waste Management and Research*, vol. 34, no. 4, pp. 356–367, Apr. 2016, doi: 10. 1177/0734242X16628980.
9. L. Chand Malav *et al.*, "A review on municipal solid waste as a renewable source for waste-to-energy project in India: Current practices, challenges, and future opportunities," *J Clean Prod*, vol. 277, Dec. 2020, doi: 10.1016/j.jclepro.2020.123227.
10. Zhou, Z. Gong, J. Hu, A. Cao, and H. Liang, "A cost-benefit analysis of landfill mining and material recycling in China," *Waste Management*, vol. 35, pp. 191–198, Jan. 2015, doi: 10.1016/j.wasman.2014.09.029.
11. K. Kieckhäfer, A. Breitenstein, and T. S. Spengler, "Material flow-based economic assessment of landfill mining processes," *Waste Management*, vol. 60, pp. 748–764, Feb. 2017, doi: 10.1016/j.wasman.2016.06.012.
12. M. S. Senthil and E. S. M. Suresh, "Energy Recovery Analysis of Perungudi landfill Waste of Chennai, Tamilnadu," *IOP Conf Ser Earth Environ Sci*, vol. 982, no. 1, p. 012038, Mar. 2022, doi: 10.1088/1755-1315/982/1/012038.
13. M. Danthurebandara, S. Van Passel, I. Vanderreydt, and K. Van Acker, "Assessment of environmental and economic feasibility of Enhanced Landfill Mining," *Waste Management*, vol. 45, pp. 434–447, Oct. 2014, doi: 10.1016/j.wasman.2015.01.041.
14. S. Van Passel *et al.*, "The economics of enhanced landfill mining: Private and societal performance drivers," *J Clean Prod*, vol. 55, pp. 92–102, Sep. 2013, doi: 10.1016/j.jclepro.2012.03.024.
15. O. Ayalon, N. Becker, and E. Shani, "Economic aspects of the rehabilitation of the Hiriya landfill," *Waste Management*, vol. 26, no. 11, pp. 1313–1323, 2006, doi: 10.1016/ j.wasman.2005.09.023.
16. T. Mönkäre, M. R. T. Palmroth, K. Sormunen, and J. Rintala, "Scaling up the treatment of the fine fraction from landfill mining: Mass balance and cost structure," *Waste Management*, vol. 87, pp. 464–471, Mar. 2019, doi: 10.1016 /j.wasman.2019.02.032.
17. Pappu, M. Saxena, and S. R. Asolekar, "Solid wastes generation in India and their recycling potential in building materials," *Build Environ*, vol. 42, no. 6, pp. 2311–2320, Jun. 2007, doi: 10.1016/j.buildenv.2006.04.015.
18. T. Huang, S. Kou, D. Liu, D. Li, and F. Xing, "Evaluation of the Techno-Economic Feasibility for Excavated Soil Recycling in Shenzhen, China," *Sustainability (Switzerland)*, vol. 14, no. 5, Mar. 2022, doi: 10.3390/ su14053028.