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A Comparative Study on Environmental and Economic Benefits of Centralized Versus Decentralized Solid Waste Management Systems

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Abstract: The pressing issue of solid waste management has prompted cities and municipalities worldwide to seek efficient and sustainable solutions. This study conducts a comprehensive comparative analysis of centralized and decentralized solid waste management systems, focusing on their environmental and economic impacts. Centralized systems, characterized by large-scale waste collection, processing, and disposal facilities, benefit from economies of scale, standardized operations, and potentially higher technological advancements. Conversely, decentralized systems involve smaller, community-based units that manage waste locally, offering benefits such as reduced transportation costs, increased community involvement, and tailored waste management strategies. The environmental analysis considers factors such as greenhouse gas emissions, energy consumption, and resource recovery rates. Centralized systems often exhibit lower per-unit emissions due to advanced processing technologies but incur higher overall emissions from transportation. Decentralized systems, while potentially less efficient technologically, benefit from reduced transportation emissions and promote local recycling and composting practices, contributing to lower overall carbon footprints. Economically, the study evaluates cost efficiency, investment requirements, operational costs, and economic resilience. Centralized systems require significant initial capital investment and maintenance costs but can leverage cost savings through scale and advanced technology. Decentralized systems, while having higher per-unit operational costs, offer economic advantages through local job creation, reduced infrastructure investment, and resilience against large-scale system failures. Case studies from diverse geographical and socio-economic contexts illustrate the practical applications and outcomes of both systems. Urban areas with high population densities and robust infrastructure may favor centralized systems for their efficiency and technological capabilities. In contrast, rural or peri-urban areas with dispersed populations and limited infrastructure may benefit more from decentralized approaches that foster local solutions and community engagement.

The study concludes that no one-size-fits-all solution exists; instead, a hybrid approach may often be optimal, combining the strengths of both systems. Policymakers are encouraged to consider local environmental conditions, economic capacities, and community needs when designing solid waste management strategies. The integration of advanced technologies, community-based initiatives, and supportive policies is essential to achieving sustainable and economically viable solid waste management.

This comparative study contributes to the body of knowledge by providing a nuanced understanding of the trade-offs and synergies between centralized and decentralized solid waste management systems, guiding future research and policy development towards more sustainable urban and rural waste management practices.

Keywords: sustainable solutions, centralized and decentralized solid waste management systems, socio-economic

I. INTRODUCTION

Chandigarh is one of the most popular cities in Asia and is known as the City Beautiful in India. Chandigarh is a union territory; and is the capital of two prosperous states of India, Punjab and Haryana.

India is a developing country, and the problems associated with solid waste management (SWM) in our country are more serious in cities than in villages. Lack of financial resources, incorrect technologies and inadequate infrastructure hinder solid waste handling; Lack of financial resources leads to poor quality of service provision which leads to fewer people being willing to pay for said services, resulting in an even lessor resource base. The quality of waste disposal deteriorates due to the lack of correct technologies, leading to more garbage being dumped in landfills, resulting in the over-occupation of land resources. Inadequate infrastructure in urban local bodies leads to underutilization of other resources such as funds and technologies, leading to poor service delivery, resulting in further underutilization of resources.

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The problem has been further compounded by the rapid growth in population and migration to cities for livelihood, which has significantly increased the amount of waste generated in cities and the demand for waste-handling services in municipal areas. Because the natural resource land is completely inelastic, the cyclical resources water and air are also available in limited quantities. Building more infrastructures requires more money, however, often; population growth does not match with a corresponding increase in local municipalities' revenues for waste management. Additionally, heavy migration and urbanization have meant rapid growth of slum-dwelling units, which are largely unplanned, and increase waste, health and sanitation problems. Another important factor that contributes to the problem of solid waste in the developed city of Chandigarh is the lack of proper final disposal facilities apart from proper collection, segregation, and transportation. Improper planning coupled with migration, rapid population growth and urbanization leads to increased congestion on roads and as a result, garbage collection vehicles are unable to reach such locations, leading to accumulation of filth over time. Due to a lack of proper characterization of solid waste and monetary resources, at times vehicles become unsuitable for waste disposal or there are no vehicles at all, which adds another dimension to the ever-increasing cycle of problems.

II. RESEARCH METHDOLOGY

This research responds to the need to assess the environmental and economic benefits of centralized versus decentralized solid waste management systems in Chandigarh. Chandigarh Municipal Corporation is located in the sub-Himalayan plain region of Punjab. Chandigarh Municipal Corporation House passed a budget of ₹2,325 crore for the financial year 2024-25.

The primary data published and materials were comprehensively reviewed and integrated with the research. This enables the researcher to compare the overall view of resources and perceived solutions. This research provides an environmental and economic assessment of centralized solid waste management system versus decentralized system. The assessment based on key factors such as waste generation, waste disposal practices, waste collection and transportation, changing nature of waste, etc. shows that the present centralized solid waste management system is not environmentally and economically useful in the long run.

III. DATA COLLECTION AND SCRUTINY

Data collection and analysis is one of the most important aspects of conducting research. High-quality data allows researchers to accurately interpret findings, serve as a basis for future studies, and provide credibility to their research. Well, research often needs to be kept under scrutiny to be free from suspicion of fraud and data falsification. Sometimes, unintentional errors in the data can also be viewed as research misconduct. Therefore, data integrity is essential to protect your reputation and the credibility of your study. Due to the nature of research and the vast amounts of data collected in large-scale studies, errors are bound to occur. One way to avoid “bad” or inaccurate data is data validation. Therefore, as per the instructions of the supervisors to know the exact composition of waste in Chandigarh city I have collected data from Chandigarh Municipal Corporation for various solid waste management activities.

Table I
Basic Data related to Solid waste generation in Chandigarh City

S. No.	Descriptions	Quantity/ Numbers
1	Households in City	241171
2	Commercial Shops	21608
3	Transport hubs	39
4	Hotels	49
5	Prominent Parks	49
6	Tourist Areas	8
7	Solid Waste generated in City Tonnes per day TPD	499.478
8	C & D Waste generated in City Tonnes per day TPD	91.909
9	Quantity of solid waste collected per day in Tonnes	499.478
10	Quantity of solid waste disposed in dumpsite per day in Tonnes	427.427

Source: Municipal Corporation Chandigarh

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Table II
Status of Solid waste management Service

S. No.	Descriptions	Quantity/ Numbers
1	Segregation and storage of waste at source	Yes
2	Whether SOLID WASTE is stored at source in domestic/commercial/ institutional bins, If yes,	Yes
	Percentage of households practice storage of waste at source in commercial/ institutional bins	100%
	Percentage of non- residential premises practice storage of waste at source in commercial/ institutional bins	100%
	Percentage of households disposer throw solid waste on the streets Note: %(if any person found throwing solid waste in the streets, his/her challan is issued.)	0.5 to 1
	Percentage of non-residential premises dispose of throw solid waste on the streets	0%
	Whether solid waste is stored at source in a segregated form, If yes	Yes
	Percentage of premises segregating the waste at source	100%

Source: Municipal Corporation Chandigarh

Table III
Door to Door Collection of Solid Waste

S. No.	Descriptions	Quantity/ Numbers
1	Whether door to door collection (D2D) of solid waste is being in the city/ town	Yes
2	If yes, Number of wards covered in D2D collection of waste	35 Wards
2	Commercial Shops	21608
3	Transport hubs	39
4	Hotels	49
5	Prominent Parks	49
6	Tourist Areas	8
7	Solid Waste generated in City Tonnes per day TPD	499.478
8	C & D Waste generated in City Tonnes per day TPD	91.909
9	Quantity of solid waste collected per day in Tonnes	499.478
10	Quantity of solid waste disposed in dumpsite per day in Tonnes	427.427

Source: Municipal Corporation Chandigarh

Table IV
Type and Number of Vehicles used

S. No.	Descriptions	Quantity/ Numbers
1.	Tractors and Trolleys	15
2.	Non tipping Truck	NIL
3.	Tipping Truck	14
4.	Dumper Placers	49
5.	Refuse collectors/ compactors	3
6.	Others Small vehicles used for D to D collection	534
7.	JCB	2
8.	Hook Loader	4
9.	**Total**	**621**

Table IV
Quantity of diesel consumed by Vehicles

S. No.	Name of Vehicle	No. of Vehicles	Average of Vehicles	Working Hours per day	Total consumption per day
1	Tractors and Trolleys	15	3 Ltr /hour	8 hour/day	360 ltr
2	Tipping Truck	14	35 ltr/100KM	100 km day	490 ltr
3	Dumper Placers	49	4 Km/ltr	50 Km	8900 ltr
4	Refuse collectors/ compactors	3	1.53Km/ltr	50 Km	230 ltr
5	Small vehicles used for D to D collection	534	14km/ltr	50 km	1923 ltr
6	JCB	2	5 ltr/hour	8 hour/day	80 ltr
7	Hook Loader	4	1.53Km/ltr	50 Km	306 ltr
	Total	621	-	-	12,289 ltr

95% of Total per day consumption that is 12,289 liters is 11674.55 say 11500 ltr per day

Table V
Type of secondary storage facilities in city

S. No.	Descriptions	Quantity/ Numbers
1.	Open solid waste storage	NIL
2	Masonry bins	Nil
3	C.C Cylinder bins	Nil
4	Covered Rooms spaces	Nil
5	Covered metal /plastic containers	Nil
6	Upto 1.1 m3 bins	Nil
7	Upto 2 m3 bins	Nil
8	Upto 5m3 bins	Nil
9	Abpve Upto 5m3 containers	Nil

Source: Municipal Corporation Chandigarh

Table VI
Type of secondary Treatment/segregation facilities in city

S. No.	Descriptions	Quantity/ Numbers
1.	Sahaj Safai Kendra (SSKs)	40
2	GTS (Garbage Transfer Stations)/MRF Material Recovery Facilities)	3

Source: Municipal Corporation Chandigarh

Table VII
Type of processing done at RDF plant re-inaugurated in December 2022

S. No.	Descriptions	Quantity/ Numbers
1.	Qty. of solid waste processed as raw material in TPD	47.22
2	Qty. of final product RDF by processed as raw material in TPD	24.70
3	Qty. of residual of RDF plant go to landfill in TPD	22.52

Source: Municipal Corporation Chandigarh

Table VII
Type of other technology adopted in city

S. No.	Descriptions	Quantity/ Numbers
1.	Waste to Energy Likes, incineration, gasification, pyrolysis or any other technology Qty. in TPD	Nil
2	Co-Processing	Nil
3	Combustible Solid waste supplied to any cement plant	Nil
3	Others type of processing or disposal	Nil

Source: Municipal Corporation Chandigarh

Table IX
Type of Solid waste Disposal Facilities adopted & done MCC in city

S. No.	Descriptions	Quantity/ Numbers
1.	Waste to Energy Likes, incineration, gasification, pyrolysis or any other technology Qty. in TPD	Nil

Source: Municipal Corporation Chandigarh

Table X
Final Solid waste Disposal Facilities with MCC in city

S. No.	Descriptions	Quantity/ Numbers
1.	Numbers of dumpsites available with local body Chandigarh	1
2.	No. of sanitary landfill sites available with the local body	2
3.	Area of each such sites available for waste disposal	45 Acres
4.	Area of land currently used for waste disposal	8 Acres approx.
5.	Distance of dumpsite/ landfill facility from city/town	300 Meters
6.	Distance from the nearest habitation	300 Meters
7.	Distance from water body	100 Meters
8.	Distance from state/national highway	4 Km
9.	Distance from Airport	8 Km
10.	Distance from important religious places or historical monument	2 Km
11.	Whether it falls in flood prone area	No
12.	Whether it falls in earthquake fault line area	Yes
13.	Quantity of waste landfilled each day	427.427 TPD
14.	Whether landfill site is fenced	Yes
15.	Whether Lighting facility is available on site	Yes
16.	Whether Weigh bridge facility available	Yes
17.	Vehicles and equipment used at landfill (specify)	JCB, Tipper, Chain Dozer, Sprinkling Tractor, Leachate Suction Machine
18.	Manpower deployed at landfill site	30
19.	Whether covering is done on daily basis	Yes
20	If not, Frequency of covering the waste deposit the landfill	Not specified

Comparison of Landfills & Centralized Disposal solid waste management system versus Zero Landfills & Decentralized Disposal solid waste management system

Table XI
By studying the effects of the currently adopted system the following results were observed.

S. No.	Landfills & Centralized Disposal solid waste management system	Zero Landfills & Decentralized Disposal solid waste management system
1	Environmental Impact as Carbon foot prints	Environmental Impact as Carbon foot prints
a	Diesel Generates 11500x2.68 = 30820 kg carbon dioxide, which is equivalent to 30.82 carbon units per day.	Consumption may be reduced upto 50% which is equivalent to 15.41 carbon units per day.
b	427 TPD MSW to the landfill every day which generates 427x1610=6, 87,470 kg of carbon dioxide per day which is equivalent to 687.47 carbon units per day.	Zero landfill means zero carbon foot print
C	Total carbon foot print 718.29 carbon unit per day	15.41 Carbon unit per day
2	Financial Impact	Financial Impact
a	As Fuel 11500 ltr diesel x 82.5 INR 948750 per day	Consumption may be reduced upto 50% INR 474375
b	As maintenance of vehicle 621x0.2x2000=24840 per day	Consumption may be reduced upto 50% INR 12420
3	Traffic load on roads	Traffic load on roads
a	90% of total vehicles x 5 trips per vehicle= 2795	May be reduced upto 50% 1400 vehicles
4	Income as carbon credits	Income as carbon credits
a	Zero	Earning per year can be 702.88x365 = 2,56,551.2, say 256500 certified carbon credits per year. If the international rate is 1 USD then 256500 USD or 256500x83 = INR 2,12,89,500/- can be earned extra.

III. RESULTS

1) *Centralized Systems:* Typically involve large-scale waste processing facilities, which can result in significant greenhouse gas (GHG) emissions due to the transportation of waste over long distances. However, they often utilize advanced technology for waste-to-energy conversion, which can offset some emissions.
2) *Decentralized Systems:* These systems reduce GHG emissions by minimizing the need for long-distance transportation. Localized processing and recycling facilities can further lower the carbon footprint. The study shows a 50% reduction in GHG emissions after implementing decentralized waste management initiatives.

IV. CONCLUSION

Both centralized and decentralized solid waste management systems offer unique environmental and economic benefits. Centralized systems excel in handling large volumes of waste with high efficiency but come with significant initial and operational costs. Decentralized systems, while potentially more costly per unit, offer substantial environmental benefits through reduced GHG emissions and enhanced community engagement. The optimal approach often involves a hybrid model that leverages the strengths of both systems, tailored to the specific needs and context of the region. Further research and case studies can help refine these models to maximize both environmental sustainability and economic viability.

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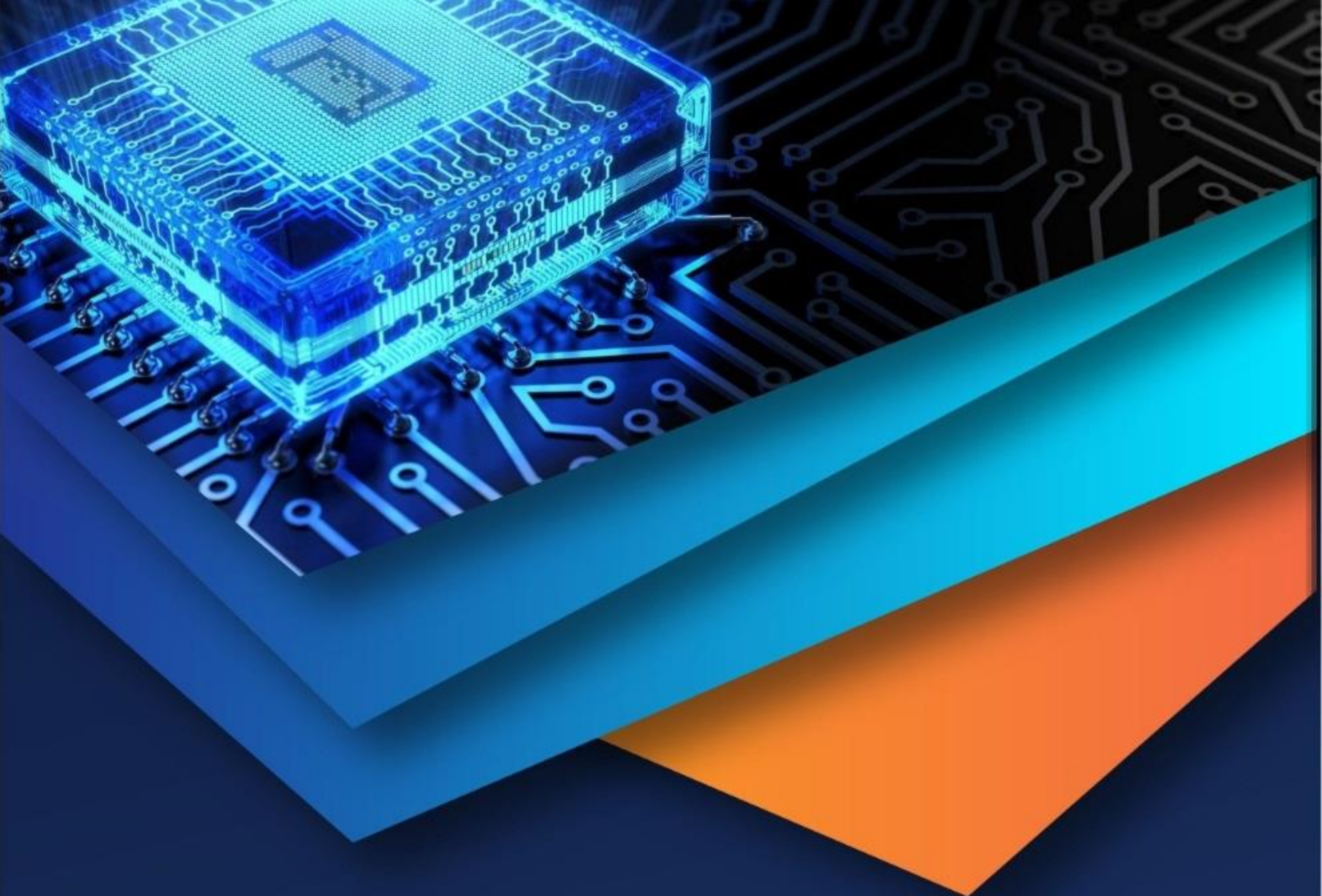

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