Assessment of Integrated Waste Management System for Sustainable Development: The Case of Goa, India

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Abstract: Significant management challenges have resulted from South Goa's rapid population and tourism boom, with inappropriate disposal raising concerns for the environment and public health. The purpose of this study was to determine whether implementing an Integrated Waste Management (IWM) plan in South Goa, India would be feasible in order to address those issues and produce a variety of sources from trash. In order to ascertain the area's waste management requirements, the study included evaluating the site and gathering information on trash generation, composition, and present management procedures from local authorities and government reports. The findings found out that South Goa generates 197.87 metric tons of waste each day, with 51 % being wet waste and 49% dry waste. A significant portion of this waste comes from residential and commercial sources, exacerbated by tourist inflow. The IWM plan includes techniques for waste reduction, segregation, recycling, composting, and waste-to-energy processes, which could remodel waste into beneficial merchandise like electricity and fertilizers. Implementing IWM in South Goa may want to put off the need for landfills by converting waste into power and compost, contributing to environmental sustainability and local energy needs.
***Keywords*:** integrated waste management, solid waste, South Goa, waste-to-energy, composting.

1. Introduction

The fundamental problem faced by the municipal authorities of most developing countries is the management of solid waste. These delivered services have failed to provide the communities with a satisfactory environment and good quality of life. Most of these services are defective, inefficient, and costly. The concept of integrated solid waste management was adopted as a policy in 1974. Municipal Developed Countries (MDCs) have quality waste management consisting of separate storage of solid waste and inoperative collection and transportation of these wastes with a system that accepts and transports special wastes; treatment and safe disposal of all waste; a system to transport those who produce waste to the waste stream and a system that charges those who produce the waste for the full cost of the various waste management services. Developed countries work with waste of different types, and the waste characteristics affect the system and design (Kamal et al., 2024). In order to reduce these associated pollution problems, facilitate recycling, reduce land disposal, and minimize environmental impact, solid waste management and its different elements must be integrated with each other and with other elements of society.

The rapid increase in population worldwide has led to a corresponding rise in waste generation. In developing countries, managing solid waste is one of the most critical crises, second only to water quality issues. Solid waste includes unwanted substances like garbage, refuse, and sludge from household, industrial, and commercial sources (Dianat et al., 2024). In India, approximately 1,33,760 metric tonnes of municipal solid waste are generated daily, with an estimated 90% being dumped in public spaces (Sharholy et al., 2008). This improper disposal causes environmental degradation, public health issues, and water pollution. Although waste generation cannot be stopped, it can be minimized (Abdel-Shafy and Mansour, 2018). Proper collection and management are crucial before waste is ultimately disposed of in engineered landfills(Siddiqua et al., 2022). Goa, known as the 'Pearl of the East,' is a major tourist destination in India. As the smallest state, with an area of 3,702 square kilometers and a population of 1.5 million, Goa faces significant waste management challenges. The annual influx of 8 million tourists exacerbates these challenges. Goa's rich heritage, extensive coastline of 110 kilometers, and afforestation covering 59.9% of its land make it an attractive destination. According to National Environmental Engineering Research Institute (NEERI), waste generation per person is 0.54 kg/day, resulting in a total of 810,000 kg/day. Additionally, tourists contribute another 7.42 T/d(Goa Waste Management Corporation, 2022). Limited land for waste disposal exacerbates the issue, making it a common urbanization problem in developing countries, Sustainable solid waste management can generate beneficial revenue from waste (Abubakar et al., 2022). It is essential for maintaining a stable and healthy quality of life in urbanizing regions like Goa. Utilizing waste as a resource can mitigate its harmful environmental effects (Goa, 2020). Integrated waste management, which tailors techniques to the region, climate, and social conditions, offers a comprehensive and sustainable approach (Awasthi et al., 2021). This paper aims to suggest integrated waste management strategies for the South district of Goa, addressing the critical problem of persistent, unhealthy waste accumulation due to poor waste management in the region

2. Literature Review

The literature on sustainable waste management highlights diverse techniques and demanding challenges in various areas, emphasizing the significance of context- specific solutions. Joshua(Joshua Oyebode, 2024) discusses the significance of waste reduction, reuse, and recycling, advocating for integrated waste management to attain environmental and public health benefits. Taiwo focuses in composting as a sustainable method in growing developing countries, recognizing its environmental and socio-economic benefits despite situations like poverty and urbanization (Taiwo, 2011). In Goa, efforts to manipulate waste through superior separation techniques are important for handling diverse waste types (Kazi, 2016). In Ebonyi State, Nigeria, Okwesili (Okwesili, Ndukwe and Iroko, 2016) highlights the importance of waste-to-energy technology in addressing solid waste issues including pollution and insufficient infrastructure. The paper recommend for an integrated approach to waste management, combining prevention, recycling, composting, and proper disposal to reduce environmental impacts(Singh, Singh and Singh, 2024). These studies together underscore the need for progressive, region-specific waste management strategies to promote sustainability.

Sustainable waste management in India is a matter of national concern because of the huge quantity of solid waste that adds to health hazards and invariably pollutes the environment (Kamal et al., 2014). The fast pace of urbanization and the need for the development of Indian industry generate the creation of huge quantities of hazardous waste. Material recycling and waste-to-energy conversion can provide a solution for sustainable waste management; however, decisions regarding the costs of waste management and the use of service sector energy in a beneficial way, other than practices that view waste as a disposal problem, require organized professionals capable of envisioning a project with an integrated approach (Kamal, 2010). These needs are best met by waste management professionals who are trained in an interdisciplinary educational program that combines waste management and resource recovery skills to simultaneously solve problems and incorporate environmental protection into all aspects of the waste management system (Kamal and Brar, 2023).

3. Research Methodology

The methodology of this studies focuses on developing an incorporated waste management plan for South Goa, India. It starts with a comprehensive literature evaluation to pick out current sustainable waste management practices and challenges. Following this, information on waste generation, composition, and contemporary management practices in South Goa have been collected from government reports and local authorities. A particular detailed site analysis was carried out to assess the particular waste management needs of the district, thinking about factors like waste types and infrastructure. Based on these findings, an Integrated Waste Management (IWM) plan turned into evolved, incorporating strategies for waste reduction, segregation, transportation, remedy, and disposal. The plan also includes an evaluation of best practices from different regions, tailored to the local context to enhance efficiency and sustainability. The final step involved formulating techniques to optimize waste control in South Goa, with a focal point on improving segregation, recycling, and waste-to-energy tactics.

4. Existing Waste Management in Goa, India

4.1 Site Location

The South Goa District encompasses the southern region of Goa, covering an area of 1,966 square kilometers. The district spans 86 kilometers from north to south and 40 kilometers from east to west (Administration, Aug 10, 2020). Murmugao serves as the district headquarters, and the district is divided into seven talukas: Ponda, Murmugao, Canacona, Dharbandora, Quepem, Salcette, and Sanguem. It includes 205 villages with a total population of 640,537 people.

(a)

(b)

Figure 1. (a) Map of India showing location of Goa; (b) District Map of South Goa

4.2 Solid Waste Management (SWM), 2016 Plan

The Government of Goa, in collaboration with the Department of Science, Technology & Environment, has established the Goa Waste Management Corporation (GWMC) to oversee solid waste management across the state. Under the Solid Waste Management (SWM) Rules of 2016, issued by the Government of India, the Goa State Pollution Control Board holds local bodies, such as municipal councils and village panchayats, accountable for waste management within their respective areas. In the South Goa District, waste management is handled by seven municipal councils and 89 village panchayats. According to the Indian Village Directory, South Goa has 151,845 households, comprising 53,504 rural and 98,341 urban households. Waste collected from these areas is categorized into residential, commercial, institutional, and industrial packaging, as well as office, kitchen, and canteen waste.

Solid Waste Management Proposed Plan for South Goa District Rules

- Door-to-door Collection: Waste collection from all municipal councils and village panchayats is carried out using a door-to-door method, ensuring 100% coverage.
- Segregation of Waste: Collected waste is segregated into four categories: wet waste, dry waste, sanitary waste, and domestic waste.
- Streamwise Segregation: The waste is further separated by streams into wet waste, dry waste, and street sweepings.
- Collection Frequency: Wet waste is collected daily, while dry waste is collected on alternate days, twice a week, or twice a month, depending on the area.
- Collection and Transportation: The district is divided into five clusters, each with designated transfer points and treatment facilities to manage waste efficiently.
- Clusters in South Goa:
- Site 1 Cluster 4 - Cacora: Includes the municipal areas of Dharbandora, Sanguem, Quepem, and Canacona, along with 30 village panchayats.
- Site 2 Cluster 5 - Verna: Comprises the municipal areas of Verna, Mormugao, and Salcete talukas, along with 39 village panchayats.

Table 1. Waste Generation Analysis of Different Talukas

S. No.	Taluka	Local body	Population	Total waste generated MT/ day
1.	Canacona	Municipal Corporation Village panchayat	14230 32643	7 9.2
2.	Dharbandora	Village Panchayats	49335	5.6
3.	Murmogoa	Municipal Corporation Village panchayat	87650 58734	40.5 22.31
4.	Quepem	Municipal Corporation Village panchayat	14775 35004	4.8 8.61
5.	Salcette	Municipal Corporation Municipal Corporation Village panchayat	16623 87650 147531	5.5 70 2.9
6.	Sanguem	Municipal Corporation Village panchayat	6444 27573	1.7 0.323
7.	Ponda	Municipal Corporation Village panchayat	22664 135302	14.5 4.936

According to the data from the table above, the South Goa District generates approximately 197.87 metric tonnes of waste daily. Of this total, 51% is wet waste, and 49% is dry waste. Waste collection is predominantly from residential areas, accounting for 68%, while commercial activities, including restaurants and hotels, contribute 26%, with additional waste generated by tourist inflow. The average per capita waste generation in the district is approximately 425 grams per day.

5. Analysis of Integrated Waste Management System

Waste produced per day by a single person = 0.54 Kg

The population of South Goa = 640,000

Waste produced per day by residents of South Goa

= (The population of South Goa)×(Waste produced per day by a single person)

= 640,000×0.54 = 345,600 Kg

Waste produced by tourists per day in Goa = 7,420 Kg

Assuming, waste produced by tourists per day in South Goa = (Waste produced by tourists per day in Goa)/2 = 7,420/2 = 3,710 Kg

Total waste produced per day in South Goa

= (Waste produced by the residents of South Goa)+(Waste produced by tourists in South Goa)

= 345,600+3,710=349,310 Kg

The following pie chart shows the percentage distribution of different categories in the total waste produced by the state:

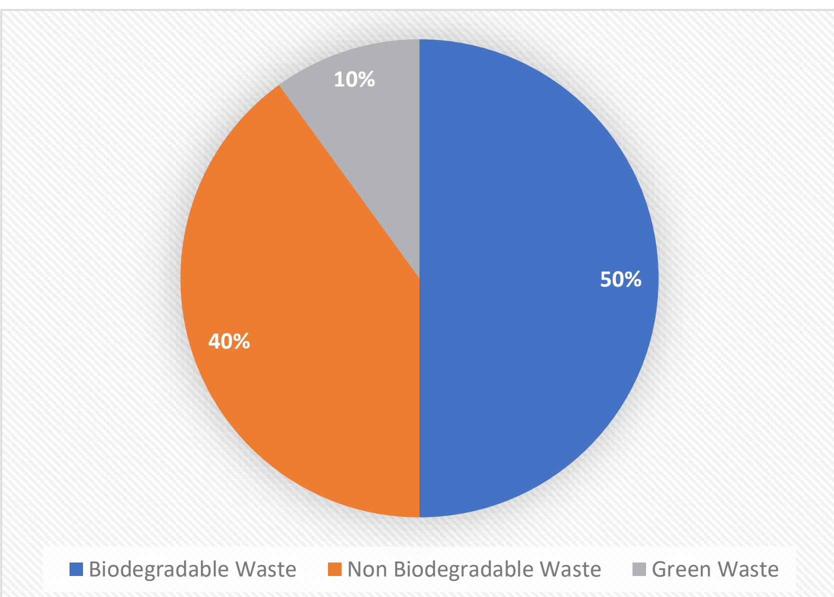

Figure 2. Percentage Contribution of Different Categories of Waste

Table 2. Amount of Different Types of Waste Produced

Type	Weight
Biodegradable Waste	174,655 Kg
Non-Biodegradable Waste	139,724 Kg
Green Waste	34,931 Kg

Step 1: It involves the segregation of waste into three parts i.e. Biodegradable, Non-Biodegradable, and Green waste.

Step 2: Material is recovered which can be recycled from the Non-Biodegradable.

In India, 30% to 70% of the waste is recycled in different states. We are going to assume that 40% of the Non-Biodegradable waste is recycled in South Goa.

Recycled waste = 40% of (Total Non-Biodegradable waste)

= 40/100 ×139,724 = 55,889.6 Kg

Step 3: The green waste is used to make compost by the process of composting.

Step 4: Biodegradable waste is used in the process of "Anaerobic Digestion".

Step 5: The residual waste from the Non-Biodegradable part of the total waste is managed by the process of incineration.

Residual Waste = 60% of (Total Non-Biodegradable Waste)

= 60/100 ×139,724 = 83,834.4 Kg

5.1 Cost Analysis

The cost analysis is strictly based on the setup cost. The setup cost includes the cost of the new equipment required and the cost of new machines to be installed.

5.2 Composting

No major setup cost or operating cost is needed in composting.

Amount of waste to be treated using composting = (Amount of green waste)

= 34,931 kg

Tools required for composting are buckets and shovels.

Bucket used: Nutristar Stainless Steel Bucket

Cost of one bucket = ₹1,699

The capacity of bucket = 20 Litres

Assuming, the number of times each bucket is loaded = 25

The approximate number of buckets required is:

= (Amount of waste to be treated using composting)/((No.of times each bucket is loaded)×(Capacity of each bucket))

= 34,931/(25×20) = 69.862 or 70 buckets

Cost of 70 buckets = (The cost of one bucket)×(Number of buckets) = 1,699 ×70=₹ 1,18,930

Number of shovels required = (No.of buckets) = 70

A shovel used: TATA Agrico Square Shovel with Steel Handle

Cost of one shovel = ₹696

Cost of 70 shovels = (The cost of one shovel)×(No.of shovels required) = 696×70= ₹48,720

Total equipment cost = (Cost of buckets)+(cost of shovels) = 1,18,930+48,720= ₹ 1,67,650

Digester Used for Anaerobic Digestion: Automatic Containerized Biogas Plant

Company: Green Brick Eco Solutions Private Limited

Cost of Anaerobic Digester = ₹ 22,00,000

The capacity of waste intake per day by one digester = 5 Tons or 5000 Kg

Amount of waste to be treated using AD per day = (Amount of Biodegradable waste) = 174,655 Kg

No. of Anaerobic Digesters required = Totalwastetobetreated/Wasteintakecapacityofonedigester = 174,655/5000 = 35

Therefore, setup cost = (No.of digesters required) ×(Cost of one digester) = 35 ×22,00,000 =₹7,70,00,000 or ₹ 77 Million Rupees

Biogas received by 1 Kg of waste = 300 L (Ali Mohammad Rahmani,2019)

Biogas received by 174,655 Kg of waste

= (Biogas received for 1 kg of waste)×(Weight of waste)

= 300 ×174,655=5,23,96,500 L or 52,396.5 cubic metre

The electrical power produced by 1 cubic meter of Biogas = 2 KWh

Therefore, 52,396.5 cubic meters will yield

= (Electrical power produced from 1 cubic meter of biogas)×(Amount of Biogas)

= 2 ×52,396.5 = 1,04,793 KWh or 104.793 MWh or 3,77,254.8 MJ

5.3 The Incineration Process

Incinerator Used: Supervac Stainless Steel Solid Waste Incinerator

Company: Supervac Engineering

Cost of Incinerator = ₹24,00,000

The capacity of waste intake per burn by one incinerator = 22 Tons or 22,000 Kg

Amount of waste to be treated using incineration = (Amount of Residual Waste) = 83,834.4 Kg or 83.8344 Tons

Average burnout time = 8 hrs

No. of shifts per day = 2

No. of incinerators required = Amountofwastetobeincinerated/((No.ofshifts)×(Wasteintakebyoneincinerator)) = 83834.4/(2 ×22000) = 2

Setup cost = (No.of incinerators required)×(Cost of one incinerator)

= 2 ×24,00,000 = ₹48,00,000 or ₹ 4.8 Million

The energy produced by burning 1 ton or 1,000 kg of waste = 500 KWh

The energy produced by incinerating 83.8344 tons of waste = (Amount of waste incinerated)×(Energy produced by incinerating 1 ton of waste)

= 83.8344 ×500 =41,917.2 KWh or 41.9172 MWh or 150,901.92 MJ

5.4 Total Setup Cost

The total set up cost will be calculated as the sum of costs of all the processes involved in the ISWM and it is given as:

Total Cost = (Total Equipment Cost in Composting)+(Total Set-Up Cost in Anaerobic Digestion)+(Total Set Up Cost in Incineration)

= (1,67,650)+(7,70,00,000)+(48,00,000)

= ₹ 8,19,67,650 or ₹82 Million Approximately

6. Conclusions

A little or no integrated approach is utilized in scientific research of Integrated Waste Management in India, allowing for applicable science to flow from basic science research to field implementation within the public sector service community. This paper aimed to address the waste management challenges in South Goa with the aid of an Integrated Waste Management (IWM) plan. Through an intensive evaluation of current waste management practices and information on waste in the vicinity, the study has demonstrated that IWM gives a greater powerful solution as compared to contemporary strategies. The research confirmed that IWM, which includes techniques like waste segregation, recycling, composting, and waste-to-energy methods, is a sustainable approach that not only reduces the environmental and health impacts of waste but additionally affords economic advantages through useful resource recovery. By remodeling waste into other by-products like energy and manure, the IWM plan for South Goa eliminates the need for widespread landfill use, addressing the crucial issue of limited land for waste disposal. The observe additionally highlights the significance of waste management practices, ensuring that the system is both effective and sustainable.

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