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Integrating Urban Forests and Parks in Solid Waste Management in the Growing Urban Areas: "A Case of Ward 15 of Dharan"

by

Chudamani Karki

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DECLARATION

I declare that the thesis submitted to the Department of Architecture at Pulchowk Campus, Institute of Engineering, Tribhuvan University, as part of the fulfilment criteria for the Master of Science in Urban Planning (MSURP) degree, is the result of my research conducted between May 2023 and November 2023, under the supervision of Professor Dr. Sangeeta Singh. I affirm that the content of this work is entirely my own and has not been previously submitted for academic credit at any other institution.

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ABSTRACT

With cities rapidly growing worldwide, effective waste management has become a substantial challenge in both developed and developing urban settings. According to projections by the World Bank, global waste generation is expected to increase from 2.01 billion tons in 2016 to 3.40 billion tons in 2050, with low-income countries facing a threefold increase, amplifying challenges related to waste mismanagement. Dharan, a city in eastern Nepal, facing similar challenges, produces about 50.92 tons of municipal waste daily. Due to the absence of an official landfill site, a significant portion of this waste is disposed of in the Bajhagara forest area. Since unsanitary dumping is an unsustainable solution, it poses various adverse effects on the environment. This study seeks to evaluate the current state of solid waste management practices in Dharan, focusing on the prevalent use of forest areas for disposal. The research also reviews existing literature on similar initiatives worldwide, drawing valuable lessons and insights. Additionally, it explores how the community perceives and engages with current waste management and disposal methods, focusing on Ward No. 15, where the municipal dumping site is located. Employing a mixed-methods approach, incorporating literature review, surveys, GIS mapping, and analysis, this research investigates the present Dharan's solid waste management system. It aims to explore the potential for improving waste management to enhance the environment, biodiversity, and community well-being. The findings of this research can provide valuable lessons and insights into sustainable waste management practices, underscoring the significance of urban forests and parks in growing urban areas.

Keywords: *Urban Planning, Urbanization, Solid Waste Management, Urban Forest, Sustainable Development, Environmental Sustainability, Dharan, Nepal.*

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LIST OF ABBREVIATIONS

ADB: Asian Development Bank

BS: Bikram Sambat

BPKIHS: B.P. Koirala Institute of Health Science

CBS: Central Bureau of Statistics

EPA: Environmental Protection Agency

FY: Fiscal Year

GoN: Government of Nepal

HHs: Households

IoT: Internet of Things

IP: Incineration Plant

IUDP: Integrated Urban Development Plan

KVDA: Kathmandu Valley Development Authority

LGOA: Local Government Operations Act

MSW: Municipal Solid Waste

NEA: National Environment Agency

NuDS: National Urban Development Strategy

SDGs: Sustainable Development Goals

SWM: Solid Waste Management

SMC/SMPC: Sub-metropolitan City

SWM: Solid Waste Management

TPD: Tons per Day

UN: United Nations

WTE: Waste to Energy

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CHAPTER 1. INTRODUCTION

1.1 Background

Solid waste refers to domestic waste, industrial waste, chemical waste, health institution-related waste, or harmful waste. It includes materials that are currently unusable, discarded, in a rotten stage, or emitted in solid, liquid, gaseous, thick liquid, smoke, or dust form, causing environmental damage. (SWM Act 2011). Solid waste tends to increase with rapid urbanization, improved living standards and changing consumption patterns. Dealing with the increasing amount of solid waste has become a noteworthy issue in many growing cities (Kaza et al., 2018). Proper management can transform solid waste into a valuable resource, but if handled inadequately, it can lead to considerable adverse effects on both the ecology and communities. Therefore, municipalities play a crucial role in delivering an essential and resource-intensive service through effective solid waste management. As nations and cities undergo urbanization, economic development, and population growth, the World Bank projects a substantial increase in waste generation from 2.01 billion tons in 2016 to 3.40 billion tons in 2050 (Kaza, 2018). The quantity of waste generated in low-income countries is expected to triple by 2050, with approximately 33% of this waste being globally mismanaged through open dumping or burning. This is particularly prevalent in lower-income countries where landfills are not yet established (Kaza, 2018).

In Nepal, urban areas, including cities and towns, are grappling with significant waste management challenges due to rapid and uncontrolled urbanization, lack of public awareness, and inadequate municipal management. Therefore, SWM has become a major concern for the municipalities of Nepal (ADB, 2013). As per the survey conducted by Nepal's Central Bureau of Statistics (CBS), solid waste management is regarded as the most significant environmental problem by a majority of urban residents in Nepal's urban areas (CBS, 2021). The issue of waste management has become a critical concern for sustainable development, as improper waste disposal practices can adversely affect the environment, public health, and the overall urban liveability of Nepal. Dharan City, situated in eastern Nepal, is no exception to this global problem. With its growing population and urbanization, the city is facing escalating pressures on its waste management infrastructure, demanding urgent attention and effective solutions. The current waste management infrastructure in Dharan City is finding it difficult to keep up with the rising amounts of waste produced due to the city's growing population and expanding commercial endeavours. According to reports released by Dharan Sub-metropolis, a significant portion of Dharan's daily waste, nearly 35 tons out of a total of 47, is directed to the dumping site situated at Bajhagara Community Forest and the Seuti River (Dahal, 2020). The practice of depositing waste in the Bajhagara area has roots dating back to 1986, while dumping in the Seuti River ceased following protests from Baklauri residents. However, Dharan's daily waste has now found a new location in the Charkoshe forest in Dharan-15. Additionally, sewage is being discharged into these areas, causing severe environmental pollution that adversely impacts local vegetation. Disturbingly, reports indicate wildlife fatalities resulting from the ingestion of these waste materials (Dahal, 2020).

The consequences of improper waste management and the indiscriminate disposal of waste in open spaces, community forests, and water bodies go beyond environmental degradation, posing significant health risks to the population. Rajan Moktan, the chairman of Bajhagara Community Forest, has voiced concerns about extensive damage to the forest due to the presence of garbage, citing the loss of over 300 plants and numerous mature trees (Dahal, 2020). The once thriving bee population in the forest has declined due to smoke from garbage incineration, leading to the deaths of many birds and butterflies. Furthermore, the consumption of discarded dogs in the garbage by wild boars, deers and foxes has resulted in a decline in their numbers. Dhiren Limbu, a public health and environment microbiologist, emphasized the adverse effects of waste dumping in forested areas, highlighting that gases such as methane, carbon monoxide, and chloro fluoro oxides are generated during prolonged waste disposal, contributing to global warming (Dahal, 2020). Limbu explained that plants convert these gases into oxygen through photosynthesis, but excessive carbon dioxide disrupts this natural process, affecting wildlife, birds, human health, and the overall ecological balance. Efforts have been made to address challenges in Dharan City, including the establishment of an environmentally friendly waste-to-energy plant in Panbari. Inaugurated by Prime Minister Sher Bahadur Deuba, the plant can recycle 50 tons of waste daily, producing biogas and organic fertilizers (Dahal, 2020). Despite these positive steps, the haphazard dumping of municipal waste into Bajhagara Forest persists.

This research aims to investigate the current state of solid waste management in Dharan City, focusing on forest area disposal, studying methods and practices, and understanding public perception and engagement. The goal is to propose sustainable waste management solutions that consider environmental preservation, public health, and economic viability by aligning with successful practices from other contexts.

1.2 Problem Statement

The efficient collection, management and disposal of waste are vital aspects of municipalities' sustainable development. However, the constrained capabilities in waste handling, collection, transport, resource recovery, and safe disposal present substantial challenges for numerous municipalities in Nepal(CBS, 2021). Dharan, a city in eastern Nepal, faces a critical challenge in waste management due to unprecedented urbanization and population growth. The Asian Development Bank (ADB) reports that Dharan sub-metropolis generates 50.92 tons of municipal waste daily, with 35 tons collected(ADB, 2013). Out of the waste collected, about half of the waste ends up in the Bajhagara forest, causing air, water, and soil pollution, wildlife impact, habitat loss, health concerns for residents and adverse effect in neighbouring municipalities. This issue has persisted since 1986 A.D (Dahal, 2020). Despite efforts, including the establishment of a waste-to-energy plant, the persistent problem of haphazard waste dumping remains inadequately addressed. This prolonged and impactful issue of unsanitary waste disposal in the Bajhagara forest has become a critical urban challenge, adversely affecting the environment, wildlife, and public health. Recognizing the gravity of this problem, the central focus of this research lies in indiscriminate disposal of waste in the urban forest, giving rise to essential inquiries about its origins, the most effective strategies for the present circumstances, and gauging community's attitudes toward this issue.

Hence, the major concerning problem for this research is:

- Indiscriminate dumping and disposal of municipal solid waste in Bajhagara forest area.

Which then led to the questions:

- What causes it in the first place?
- What can be done to minimize the impact?
- How does the community perceive this?

Figure 1 Waste Dumping Scenario of Dharan, source: Annapurna Post

1.3 Rationale of Research

The Solid Waste Management Act of 2011 in Nepal came into effect on 15 June 2011. The primary goals of this legislation are to ensure a clean and healthy environment by reducing the negative impacts of solid waste on public health and the surroundings. According to the Chapter 2 in Solid Waste Management Act 2011, the local bodies, such as municipalities, are responsible for the construction, operation, and management of infrastructure for collection, treatment, and final disposal of MSW. Dharan City, like many places around the world, is grappling with a growing problem of solid waste management. As the city has grown rapidly, more and more waste is being generated, and it's not being handled properly. Though, the government has laws in place to manage solid waste, but the situation on the ground is far from ideal. The major problem lies in indiscriminate dumping and disposal of MSW in Bajhagara forest area. Waste is often dumped inappropriately, leading to pollution of the land, water, and air. This not only harms the environment but also puts people at risk of diseases carried by pests attracted to the waste. Effective waste management is not just about cleanliness; it has far-reaching social and economic implications. It's crucial for Dharan City to find a sustainable way to manage its waste. This means reducing waste, recycling, and disposing of it properly to protect the environment and the health of its residents. This research aims to address these urgent issues by studying Dharan City's waste management practices and challenges. It will investigate why waste is being haphazardly dumped into the forest areas, identify practical solutions tailored to the city's unique circumstances and analyze people's perception and engagement for mitigating the impacts due to solid waste. The findings will be valuable for planners, policymakers, and anyone involved in managing waste in similar urban areas. Ultimately, this research seeks to pave the way for a cleaner, healthier, and more sustainable Dharan City.

1.4 Validity of Research

With population growth being inevitable, the pattern of waste generation will always keep on rising. While waste generation rates cannot be controlled, effective strategies and methods can help manage and dispose of waste more efficiently. Globally, waste is predicted to increase by over 70% in the next three decades, with developing countries expected to see a threefold increase (Kaza, 2018). Similarly, Dharan Sub-metropolitan city has also experienced a remarkable surge in population over recent decades. This rapid urbanization has led to increased density and the formation of economic hubs and central business districts (CBDs). Consequently, consumption and waste generation pattern has escalated. The city's geographical constraints, surrounded by hills and forests, limit the availability of open land for landfill operations and environmentally-friendly waste disposal. Due to which, most of the collected waste ends up haphazardly in the dumping zone. Despite the presence of a waste-to-energy (WTE) plant in Dharan, operated by Venture WTE Pvt. Ltd., it has not successfully handled the entire volume of the city's waste. This underscores the need to explore alternative waste management strategies and practices. The research acknowledges the urgency to address waste management in the context of this rapidly growing urban setting. It explores the environmental impact of existing practices and highlights areas for improvement. This research also includes a focus on understanding the perspectives and preferences of the local community. It actively engages the local community, ensuring that findings are rooted in their actual experiences and needs. This participatory approach strengthens the validity of the research by incorporating the perspectives and preferences of those directly or indirectly affected. Similarly the integration of urban forests and parks into solid waste management is an increasingly important topic, given the growing challenges of urbanization and waste generation. The research seeks practical strategies and solutions, making it timely and aligned with contemporary environmental concerns. Hence, the research topic holds a lot of potential and similar research has not been carried out in the context of Dharan. That is why the research seems to be Valid.

1.5 Research Purpose

1.5.1 Research Objective

The main purpose of this research is to:

Assess the current municipal solid waste management practices/strategy and explore the ways to manage the unsanitary disposal of solid waste in urban forests taking the case of Bajhagara forest of ward no 15 of Dharan.

The main objective is further classified into following specific objectives:

- To assess the current patterns of waste management in Dharan, with specific emphasis on ward no. 15, and the prevalent use of forested areas for waste disposal.
- To review methods and strategies for efficiently managing urban-generated waste in forested areas with a focus on reducing negative environmental impacts.
- To gain insight into the perspectives and preferences of the local community regarding the integration of waste disposal activities within the urban forest.

By achieving these research objectives, this study aims to understand sustainable ways of managing solid waste in urban areas and review practical insights for operating ecologically safe waste disposal in urban forest of Dharan City.

1.5.2 Research Hypotheses:

- ✓ The prevalent use of forests for waste disposal has negative environmental consequences.
- ✓ Identifying and implementing best waste management practices will mitigate environmental impacts.
- ✓ Positive community perceptions and active engagement contribute to effective waste management.

1.6 Limitations of the Research

This study primarily focuses on the managerial aspects of municipal solid waste management in Dharan, specifically pertaining to the collection, treatment, and disposal of solid waste. Since the main affected area i.e. Bajhagara forest dumping zone lies in ward no. 15, the main focus of this study will be limited on ward no. 15 of Dharan, with findings drawn from this specific context. Due to data saturation, the household survey included a limited sample of 50 respondents. The research relies extensively on secondary sources such as literature, articles, academic papers, official reports, and relevant case studies from similar contexts. Data analysis is based on existing datasets, municipal profiles, open data platforms, research articles, and municipal documents. While the research provides potential recommendations for effective sustainable waste management strategies, it does not delve into the practical implementation of these recommendations.

CHAPTER 2. CONCEPTUAL FRAMEWORK AND RESEARCH METHODOLOGY

Research is the practice of scientifically exploring relevant information on a particular subject (Kothari, 2004). In the words of Clifford Woody, the research process involves defining and redefining problems, formulating hypotheses or proposed solutions, collecting, organizing, and evaluating data, making deductions, reaching conclusions, and ultimately rigorously testing the conclusions to ascertain their alignment with the formulated hypotheses. In summary, research is the systematic and objective pursuit of knowledge to find solutions to a problem (Kothari, 2004).

The assessment of the present municipal solid waste management strategy and practices with prevalent use of forest in Dharan, employs a variety of methods, including literature review, case study analysis, interviews, surveys, and observation. The study's conceptual framework involves acquiring insights into current SWM practices and the use of forested areas for disposal. It also includes a review of practical and innovative solutions and an exploration of community perceptions regarding the current practices and situation. Throughout this analysis, careful attention is paid to safeguarding the citizens' right to access information and their privacy.

2.1 Research Paradigm:

A research paradigm serves as a theoretical framework that shapes our understanding and perception of the social world. It establishes fundamental beliefs about ontology, epistemology, methodology, and procedures, providing the lens through which we comprehend and study reality (Rehman & Alharthi, 2016). Decision-making regarding techniques, methods, literature, and research design hinges on the chosen paradigm. Common paradigm classifications include Positivism, Post-positivism, Interpretivism, Transformative, and Pragmatics.

Positivism, rooted in the belief that reality exists independently of humans and is governed by unchanging laws, asserts that social processes can be understood through scientific procedures. However, it recognizes limitations in applying objective and scientific methods to social phenomena (Rehman & Alharthi, 2016). Positivism emphasizes objectivity and empirical evidence, guiding the systematic collection and analysis of data to discern causal relationships and patterns, particularly in the context of solid waste management.

In contrast, Interpretivism serves as a response to the dominance of positivism. It rejects the notion of a single, independently existing reality that cannot be verified by human senses.

Interpretive ontology is anti-foundationalist, positing that various realities are socially produced. The aim of interpretive research is to comprehend how individuals perceive the social phenomena they engage with, prioritizing context-specific and value-laden insights over universal knowledge and truth (Rehman & Alharthi, 2016). This paradigm is inclined towards qualitative data and analysis, employing methods such as interviews, questionnaires, and observations in research approaches aligned with Interpretivism.

The research paradigm in this case is a blend of both positivism and Interpretivism. Positivism, linked with quantitative research, addresses solid waste management, while Interpretivism explores the social and human aspects of urban forests and parks integration. The epistemological approach blends positivism and constructivism, utilizing empirical observation and measurable data for waste management assessment. Constructivism recognizes socially constructed knowledge, relevant to understanding perceptions and attitudes.

2.1.1 **Ontology:**

Ontology refers to the prediction of the nature of reality. While this may seem abstract and distant from the intended research project, ontological assumptions play a crucial role in shaping how the research object is perceived and studied (Rehman & Alharthi, 2016). The ontological perspective of this research asserts that the significant waste generated by rapid urbanization results in various problems upon disposal. However, these issues can be successfully mitigated by adopting environmentally friendly waste management methods.

2.1.2 **Epistemology:**

Epistemology concerns assumptions about knowledge, what constitutes acceptable, valid and legitimate knowledge, and how we can communicate knowledge to others (Rehman & Alharthi, 2016). The epistemology claim for this research is that the epistemological claim asserts that insights into integration of forest with SWM can be validly discerned through a comprehensive analysis of relevant literature, case studies, or survey data in real-world scenarios.

2.2 Research Design

2.2.1 Methods

This research employs mixed methodology as a research strategy. Mixed methodology involves the combination of different research methods. A mixed-methods approach integrates both quantitative and qualitative methods. In a mixed methods research design, data is collected, evaluated, and blended from both qualitative and quantitative methods within a single study to enhance the comprehension of a research problem.

2.2.2 Literature Review

Comprehensive review of existing literature on solid waste management will be carried out focusing on urban areas and similar challenges. This review will encompass an analysis of various waste disposal methods, their environmental implications, and the perceptions held by the community.

2.2.3 Observation

A thorough observation should encompass various elements, including the site, surroundings, and waste disposal practices. Additionally, the use of photography and sketches in the study areas can enhance the observational process. This immersive approach to observation aims to analyze actual conditions and identify problems within the study areas.

2.2.4 Sample survey

A random sampling technique will be employed for the survey within the selected households. The chosen respondents will be representative of a diverse range of demographics, including ages, genders, occupations, income levels, building use, and more. The survey's objective is to gather insights into participants' perspectives on current waste management practices and community engagement. Through the utilization of a questionnaire, the research aims to comprehend users' perceptions of waste management and the significance of community participation.

2.2.5 Key Informant Interviews

Key informant interviews involve qualitative, in-depth conversations with individuals who possess a deep understanding of community dynamics. Semi-structured and open-ended questionnaires will be employed for key informants in the designated area. Interviews will also be conducted with users, relevant stakeholders, and responsible agencies/organizations involved in the management. These interviews aim to understand the actual situation and shed insights into challenges in the study areas.

2.2.6 Case Study Analysis

The focus on a specific case (Ward 15 of Dharan) allows for an in-depth exploration of the existing practices, problems, and issues of urban forests and parks in solid waste management within a real-world context. Similarly, relevant national and international cases will also be reviewed.

2.2.7 Spatial Analysis:

Google Maps and GIS mapping will be utilized to identify and visualize critical areas of waste dumping. Examination of geographical patterns will be employed to understand the spatial distribution of waste-related issues.

2.2.8 Data Analysis

A diverse range of methods will be employed to analyse both quantitative and qualitative data, including the use of graphs, bars, charts, surveys, observations, and interviews. To enhance the verification and validity of the research outputs, triangulation will be applied in the findings of this research. The research report would be prepared as a result of these procedures.

2.2.9 Data Collection Techniques

Primary data collection encompasses surveys, questionnaires, interviews, and on-site observations to gather comprehensive insights into the nature of solid waste management. Pictures, checklists, and field notes will be used to record observations. Individual conversations will be utilized to perform semi-structured and open-ended interviews. Surveys with open-ended questions will gather opinions on solid waste.

On the other hand, secondary data collection involves a comprehensive exploration of existing textual resources, images, relevant journal articles, and municipal profiles. The digital domain will be employed to enhance the spatial understanding of waste management activities through the use of Geographic Information System (GIS) data and Google Maps. In addition, a thorough analysis of case studies relating to waste management from both domestic and foreign sources will be conducted.

CHAPTER 3. LITERATURE REVIEW

3.1 Urbanization and Solid Waste Management:

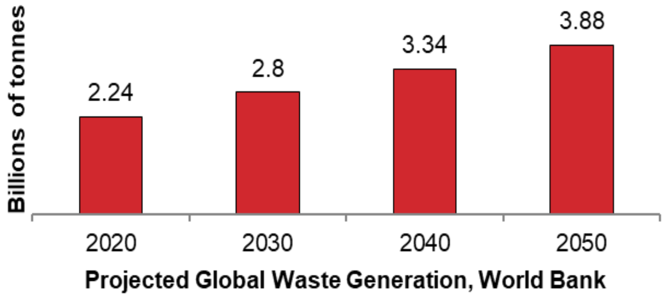

Figure 2 Projected Global Waste Generation, (Kaza, 2018)

	Unit	2020	2030	2040	2050
Projected Waste	*Billions of tons*	2.24	2.8	3.34	3.88

Table 1 Projected Global Waste Generation, (Kaza, 2018)

On a global scale, the rates of waste generation are on the rise. In 2020, the world produced an estimated 2.24 billion tons of solid waste, translating to a daily per capita footprint of 0.79 kilograms (Kaza, 2018). With the swift increase in population and urbanization, the annual waste generation is predicted to rise by 73% from the 2020 levels, reaching 3.88 billion tons by 2050 (Kaza, 2018). The total quantity of waste generated in low-income countries is expected to increase by more than threefold by 2050 (Kaza, 2018).]. In low-income or developing countries, over 90% of waste is often disposed of in unregulated dumps or openly burned (Kaza, 2018). These practices contribute to health hazards, methane emissions, climate change, and urban problems (Kaza, 2018). Efficient waste management is vital for sustainable cities, presenting a major challenge for developing nations like Nepal(CBS, 2021). In high-income countries, about one-third of waste is recycled or composted, but the cost is substantial, consuming 20% to 50% of municipal budgets. It requires well-integrated systems that are efficient, sustainable, and supported by the community. Waste collection rates differ by income levels, with high- and upper-middle-income countries typically offering universal waste collection. In low-income countries, approximately 48% of urban waste is collected, dropping to around 26% outside urban areas. Middle-income countries show varied rural waste collection rates from 33% to 45% (Kaza, 2018). As per the World Bank survey report, global waste disposal methods include 37% in landfills, 33% openly dumped, and 19% recycled or composted, and 11% incinerated. Adequate waste disposal is primarily found in high- and upper-middle-income countries, while lower-income countries often resort to open dumping, with 93% of waste dumped in low-income countries and only 2% in high-income countries (Kaza, 2018).

Table 2 Global waste disposal method, World Bank (Kaza, 2018)

S.N.	Disposal Method	Percent (%)
1	*Composting*	33
2	*Landfill*	25.2
3	*Recycling*	13.5
4	*Incineration*	11.1
5	*Sanitary Landfill*	7.7
6	*Open Dumping*	5.5
7	*Controlled Landfill*	3.7
8	*Others*	0.3

As per the ADB survey report of 2013, out of 58 surveyed municipalities of Nepal, majority of them were dumping their waste haphazardly in open areas and riverside(ADB, 2013).

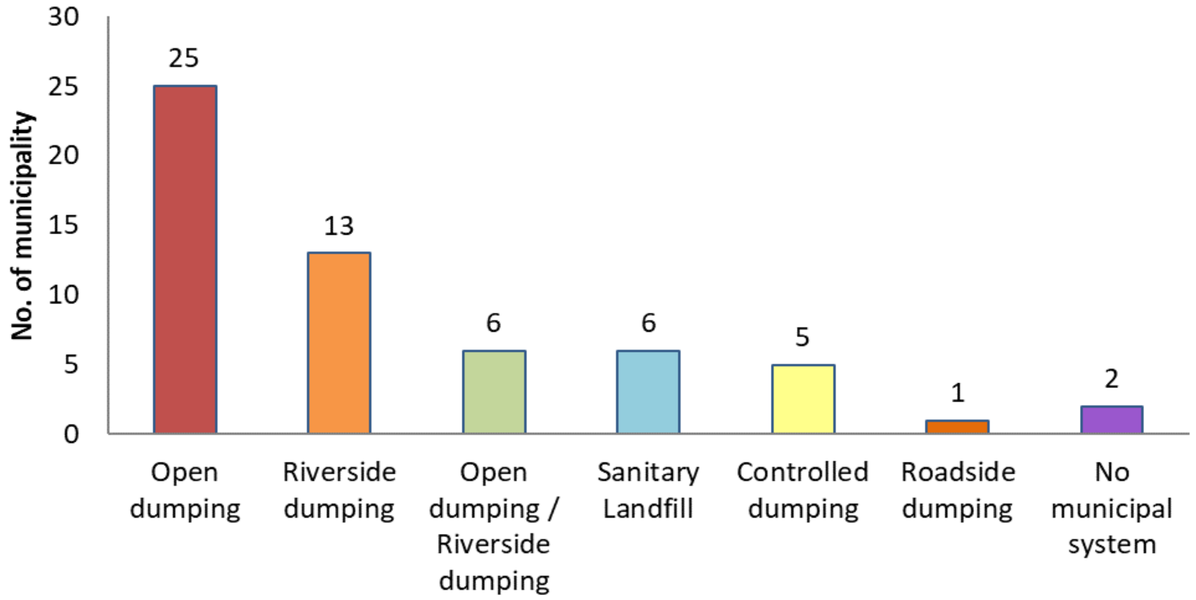

Figure 3 Nepal's disposal method, ADB 2013

Similarly, a 2017 IUDP Dharan survey identified unmanaged waste as a major issue, accompanied by concerns like bad smells, air pollution, parking, and drainage problems(IUDP, 2017).

3.2 Importance of Urban Forests and Parks:

Urban forests, defined by FAO (2016), comprise all woodlands, clusters of trees, and individual trees located in urban and peri-urban areas, contributing significantly to physical and mental well-being. This encompasses forests, street trees, trees in parks and gardens, as well as trees in neglected areas (Salbitano et al., 2016; Tyrväinen et al., 2005). Urban forests have the potential to bring about positive transformations in cities and positively impact their residents. They play a crucial role in enhancing physical and mental health by providing spaces for physical activities and alleviating stress (Tyrväinen et al., 2005). Recognized for enhancing air quality, social well-being, and overall urban life, cities globally are prioritizing the conservation and expansion of green spaces (Salbitano et al., 2016; Tyrväinen et al., 2005). Urban forests serve as a foundation for green infrastructure, connecting rural and urban areas and reducing a city's environmental impact (Salbitano et al., 2016). They play a crucial role in purifying air, influencing urban climates, and supporting local livelihoods (Monteiro et al., 2019; Tyrväinen et al., 2005). Urban forests, from a social perspective, play a vital role in strengthening community bonds, enhancing food security for marginalized communities, connecting urban dwellers with nature, and promoting equity. Transforming small areas into pocket parks with trees and seating creates spaces for social interaction (Tyrväinen et al., 2005). In Nepal, urban forestry has a rich history dating back to the Malla dynasty, with King Jayasthiti Malla initiating planting of trees along streets and wells (Ranjit, 2019). This tradition continued, and in the 1960s and 1970s, significant tree planting initiatives were undertaken in Kathmandu during the Rana regime and the ring road plan (Ranjit, 2019). Presently, the government remains committed to prioritizing urban forestry through diverse programs, such as the 'Nepal Clean Environment Grand Expedition 2075 AD' and the 'Forest Decade Program (2014-2023).' that promotes afforestation with the theme 'one house: one tree, one village: one forest, and one town: several parks' (Ranjit, 2019).

3.3 Existing Solid Waste Management System and Practices

3.3.1 Waste Source

Typically, the primary origins of solid waste include (Hoornweg & Thomas, 1999):

- Residential (domestic or household)
- Commercial
- Institutional
- Construction waste
- Treatment plant Waste

- Solid Industrial Waste
- Solid Agricultural Waste
- Medical wastes
- Mining wastes
- Hazardous wastes

Appropriate solid waste management strategies may vary for institutional, communal and domestic sources, depending on types and volumes of waste.

3.3.2 Waste Characteristics

Understanding the waste characteristics is crucial for effective waste management strategies. The characteristics of MSW collected from any area depend on various factors such as consumer patterns, food habits, the cultural traditions of inhabitants, lifestyles, climate, and economic status. In Nepal, studies have consistently shown that the majority of municipal waste is organic. A comprehensive study across 58 municipalities carried out by the Solid Waste Management & Resource Mobilization Center (SWMRMC) revealed the average composition of MSW as follows: organic waste 56%, plastics 16%, paper and paper products 16%, glass 3%, metals 2%, textiles 2%, rubber and leather 1%, and other materials 4% (ADB, 2013).

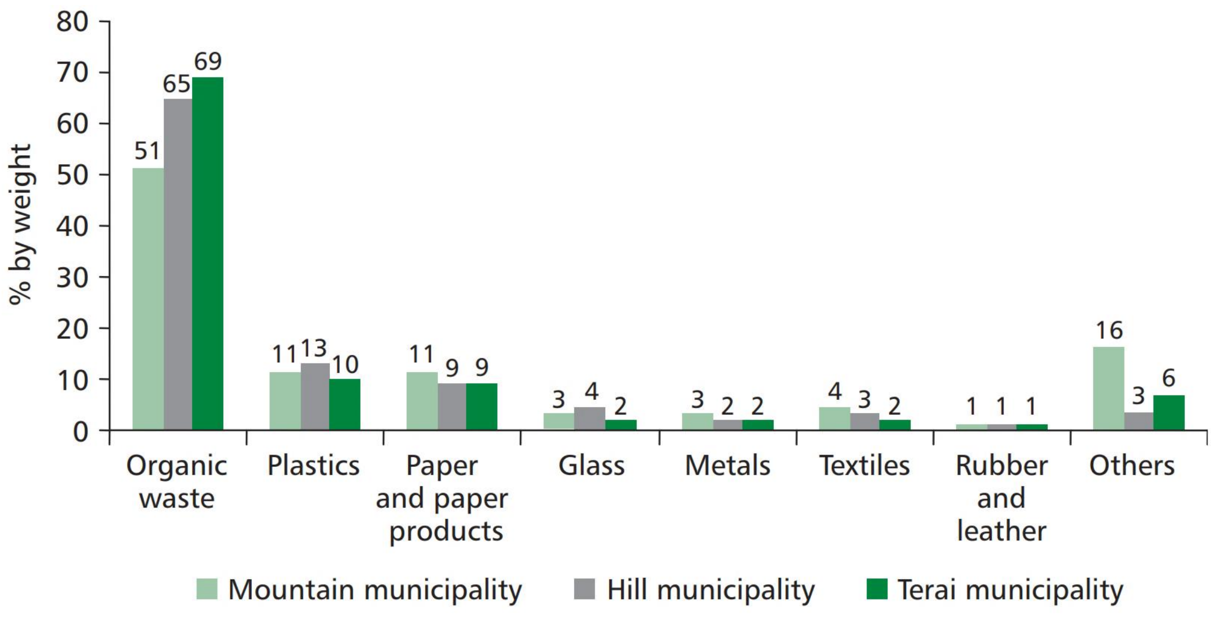

Figure 4 Waste composition according to municipalities (ADB, 2013)

The composition of MSW is changing with increasing use of packaging materials and plastics. Another critical aspect of waste is its density, which plays a vital role in determining the necessary container or vehicle size for collection, storage, and transportation. Waste density can vary considerably based on the type of waste, how it's stored, and the level of compaction. Typically, waste starts with low density when generated but becomes denser during the collection, transportation, and management processes (ADB, 2013).

Table 3 Nepal's municipal solid waste composition, (ADB, 2013)

Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	66	43	22
Plastics	12	22	21
Paper Products	9	23	45
Glass	3	4	1
Metals	2	2	1
Textiles	2	2	2
Rubber/Leather	1	1	1
Others	5	4	8

3.3.3 Waste Generation

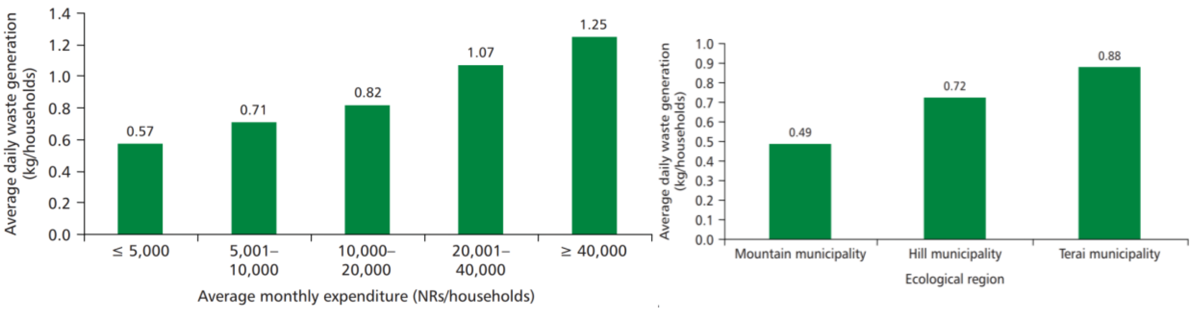

Figure 5 Waste generation according to income and ecological regions (ADB, 2013)

According to (Maharjan & Lohani, 2019) waste generation in municipalities of Nepal is about 3023 tons per day and the average per capita waste generation is 0.223 kg/person/day. The household waste generation rate of Nepal varies according to the economic status, population distributions, ecological regions and consumption patterns. The rates of waste generation can fluctuate based on factors such as the season, month, and day of the week. In households spending $417 or more per month, the average daily waste generation is 1.25 kilograms (kg) per household. This quantity surpasses more than double of the 0.57 kg per household per day produced by households with monthly expenses below $52 (ADB, 2013). Similarly, the average household waste generation was found higher in terai municipalities (0.88kg/household) and lower in mountain municipalities (0.49 kg/household) (ADB, 2013).

3.3.4 Collection and Segregation

According to ADB's survey conducted across 58 municipalities, it was observed that about 70% of households dispose of their waste directly into the main stream for collection and disposal without any prior segregation. The remaining 30% of households, primarily in rural areas, practiced segregation of kitchen waste for their specific needs (ADB, 2013). However, there is a lack of effective and widespread segregation programs implemented by many municipalities (ADB, 2013). It's important to highlight that, in certain instances, segregated waste may reintegrate and mix during the collection and transportation phases, primarily due to the lack of dedicated methods for separate collection and treatment. The average collection efficiency is estimated to be around 62%, although this figure may not be entirely precise due to the absence of a comprehensive and scientific recording system for waste management activities (CBS, 2021).

3.3.5 Transport and Final Disposal

Table 4 Nepal's waste disposal method, (ADB, 2013)

S.N.	Disposal Method	No. of Municipality
1	*Open Dumping*	25
2	*Riverside Dumping*	13
3	*Open Dumping/Riverside Dumping*	6
4	*Sanitary Landfill*	6
5	*Controlled Dumping*	5
6	*Roadside Dumping*	1
7	*No Municipal System*	2

The availability of vehicles and equipment for waste collection and transportation varies significantly among municipalities in Nepal (ADB, 2013). The initial phase of waste collection commonly utilizes rickshaws and carts, with tractors typically handling the secondary collection or transportation. Subsequently, dump trucks are employed to transport the waste to disposal sites (ADB, 2013). Nevertheless, not every municipalities possess all types of waste transport vehicles, potentially impacting the effectiveness of waste transfer processes from the initial collection stage to waste treatment centres or final disposal sites. Unfortunately, many municipalities have yet to identify suitable locations for treatment facilities and sanitary landfill sites (ADB, 2013). As a result, waste is frequently discarded without undergoing treatment in makeshift dumping sites, presenting hazards to public health and contributing to environmental issues. Open dumping practices was observed in 45 out of the 58 municipalities, including Dharan Sub-metropolitan City, involve dumping waste in forest areas, along riversides, and on roadsides (ADB, 2013). Only six municipalities, including KMC, Lalitpur, Pokhara, Ghorahi, Dhankuta, and Tansen, have taken steps to construct sanitary landfill sites (CBS, 2021).

3.4 Methods and Strategies for Efficient Waste Management in Forested Areas:

3.4.1 Source Reduction

Source reduction, also referred to as waste prevention, involves minimizing waste at its origin and is considered the most environmentally preferred strategy. This approach can manifest in various ways, such as reusing or donating items, purchasing in bulk, minimizing packaging, redesigning products, and decreasing toxicity (EPA, 2016). Engaging in source reduction practices provides environmental benefits by lowering energy consumption and pollution, conserving natural resources, and prolonging the lifespan of valuable landfill space. Additionally, it can yield economic advantages by reducing costs related to the transportation, disposal, or recycling of waste (EPA, 2016) .Source reductions can (EPA, 2016):

- Reduce greenhouse gas emissions,
- Save natural resources,
- Conserve energy,
- Reduce pollution,
- Reduce the toxicity of our waste, and
- Save money for consumers and businesses alike.

3.4.2 Reduce, Reuse, Recycle (3R)

In the area of waste management, policy has progressed from solely relying on landfills to adopting the waste hierarchy concept, known as 3R policies (Hezri, 2010). The waste hierarchy—Reduce, Reuse, Recycle—guides waste management based on environmental impact and resource efficiency, promoting sustainability (Hezri, 2010). The first of the 3Rs, Reduction, is a key strategy in maintaining a cleaner environment by addressing waste at its source (Abdul-Rahman & Wright, 2014) . It involves generating less waste initially, and if households collectively adopt this approach, the overall waste problem will be reduced (Abdul-Rahman & Wright, 2014). Reducing contributes in eliminating the need for extracting raw resources, manufacturing goods, designing shipping materials, using additional resources for transportation, and determining disposal methods (Abdul-Rahman & Wright, 2014).

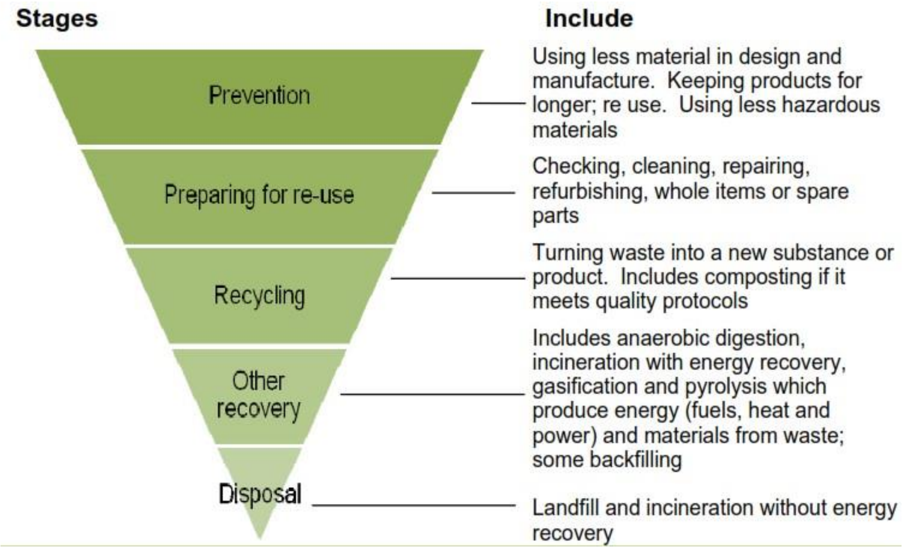

Figure 6 Waste Management Hierarchy, source: https://www.designingbuildings.co.uk/

Reuse, the second aspect of the waste hierarchy, involves repurposing items to prevent unnecessary waste, encouraging creativity, and conserving resources. (Abdul-Rahman & Wright, 2014). Recycling, the third ”R,” entails reclaiming materials from waste, like recycling scrap metal or transforming waste plastic and paper into new products (Sciortino & Ravikumar, 1999). Recycling as a waste minimization strategy offers three advantages: it reduces the demand for new resources, decreases transportation and production energy expenses, and utilizes waste that would otherwise end up in landfills (Tam & Tam, 2006).

3.4.3 Bioremediation

The contamination of soil by leachate is a significant global issue. Leachate, a harmful liquid that permeates through waste in landfills and other disposal sites, has the potential to contaminate nearby soil and groundwater (Mendoza-Burguete et al., 2023) .The extent of this contamination varies across countries and regions, presenting significant environmental and human health risks. To mitigate this, it is essential to implement measures that reduce and control soil and groundwater contamination caused by landfill leachate (Mendoza-Burguete et al., 2023). Bioremediation, an eco-friendly, cost-effective, and efficient technology, is suitable for treating industrial wastewater and leachates (Coelho et al., 2020). It involves the utilization of microorganisms to diminish the toxicity of harmful wastes, heavy metals, hydrocarbons, polymers, and organic pollutants in both soil and water. Industries and power plants typically emit hazardous waste, which has a significant impact on human health. To combat this type of problems, bioremediation is often used (Ali et al.). Bioremediation falls into two primary types: in-situ bioremediation, treating contaminated sites without excavation, and ex-situ bioremediation, involving excavation and transportation of contaminated soil for additional treatment. This in-situ and ex-situ bioremediation is further sub divided into following category (Coelho et al., 2020):

- Bioventing
- Biosparging
- Bioaugmentation
- Biopiling
- Landforming
- Bio-composting

3.4.4 Composting

Composting is a controlled biological process converting the organic fraction of waste into stable, humus substances, ideal for soil amendments (Adani et al., 1995; Cooperband, 2002). With landfills reaching capacity and restricting organic waste, composting emerges as a more viable method for managing organic waste (Cooperband, 2002). Microbes reduce organic waste volume by up to 50%, resulting in compost or humus, resembling potting soil, suitable as a soil conditioner or mulch. This contributes to improved soil quality, essential for ecological balance and increased food production (Srivastava et al., 2016). Studies show that composting inherently reduces metal availability compared to alternative methods. This intricate process depends on microbial machinery and enzymes, varying with compost composition, physico-chemical conditions, and microbial community dynamics (Srivastava et al., 2016). The use of bio-solid compost and sugar beet lime improves vegetative cover and biomass production in contaminated soil by decreasing metal concentrations in plants (Srivastava et al., 2016).

3.4.5 Bio-mining

As per the guidelines provided by the Central Pollution Control Board (CPCB), “Bio-mining is the scientific process of excavation, treatment, segregation and gainful utilization of aged municipal solid waste lying in dumpsites typically referred to as legacy waste”(Mendoza-Burguete et al., 2023). This process encompasses four key steps: the excavation of legacy waste, the application of bioremediation to stabilize the waste, segregation of the excavated waste, and finally, the sustainable management and safe disposal of the treated waste. Bio-mining involves the use of bio-organisms or natural elements such as air and sunlight for the treatment of garbage or waste (Tam & Tam, 2006). Over time, the natural decomposition process targets the biodegradable fraction of waste, leaving the non-biodegradable materials to be handled separately (Tam & Tam, 2006). Bio-mining offers several advantages, including the absence of emissions and minimal residues, contributing to the reduction of soil pollution, soil contamination, and groundwater pollution (Mendoza-Burguete et al., 2023). This method also diminishes greenhouse gas emissions and requires no additional energy for its execution. Moreover, the reclaimed land resulting from bio-mining can be repurposed for other development activities. Landfills are among the major sources of disease and clearing them can help in decreasing vector-borne diseases. US Public Health lists 22 diseases that develop due to improper handling of solid waste (Coelho et al., 2020). Bio-mining stands out as an environmentally friendly approach that facilitates resource recycling by extracting valuable components like metals and compost for use in fertilizers (Mendoza-Burguete et al., 2023).

3.4.6 Sanitary Landfill:

The sanitary landfill method involves the disposal of solid waste on land without causing disturbances or hazards to public health or safety. This technique utilizes engineering principles to confine the solid waste to a practical area, reduce its volume, and cover it with a layer of earth, either daily or at more frequent intervals as needed (Bell, 1973). The important considerations in obtaining and operating a sanitary landfill requires (Bell, 1973):

Site selection

Depends on site evaluation and community acceptance. Preferred locations include waste land, ravines, and low-lying areas, with submarginal land being ideal. Longer waste transport distances may be cost-effective than shorter journeys to expensive facilities, and larger cities may require multiple sites for efficiency.

Topographic map

Efficient operation relies on clear plans and topographic maps guiding layout and operations. Detailed information such as fill areas, access roads, drainage grades, and utilities should be included.

Geology

Geological studies are crucial, assessing site characteristics, excavation ease, water pollution, and gas movement. Understanding soil quality helps select suitable cover material to prevent odours, water infiltration, and material scattering.

Site capacity

Effective planning is crucial for maximizing capacity, often expressed per contributory population per year. Actual capacity depends on usable disposal volume, considering both depth and surface area, with sites chosen to provide 20 to 25 years of future capacity.

Water resources

Water pollution risk is significant in landfill development. Landfills should be situated away from water sources, implementing preventive measures like maintaining a safe distance from streams, avoiding fractured limestone, and using impervious earth covers.

Land Reclamation

Deciding the landfill's purpose before operation is crucial. While land reclamation is advantageous, the primary goal is efficient waste disposal. Completed landfills can be transformed into parks, playgrounds, or agricultural areas.

Landfill operation:

Efficient landfill operation and optimal site use require detailed engineering planning and control. There are two primary landfill methods: area and trench.

Area Landfill: Solid waste is spread, compacted, and covered with earth. Suited for flat or gently sloping land, quarries, ravines, or depressions. Cover material is hauled in or obtained nearby.

Trench Landfill: Trench method suits flat lands with a deep water table, reducing hauling but may necessitate multiple equipment pieces.

3.4.7 Estimation of Landfill Space requirements:

The method for calculation and estimation of Landfill space requirements was acquired from (MOHUA, 2023). Following entails the overall process with designated formula for calculation.

a) Proposed life of landfill (in years) = n (years)

b) Waste generation after n years = $W (1 + x/100)^{n}$ (tons per year)

c) Total waste generation in n years (T) in tons

$$T = 1/2 [W + W (1 + x/100)^{n]} n \text{ (tons)}$$

d) Total volume of waste in n years (V_w) (on the assumption of 0.85 t/cu.m density of waste)

$$V_w = T/0.85 \text{ (cu.m.)}$$

e) Total volume of daily cover in n years (V_{dc}) (on the basis of 15 cm soil cover on top and sides for lift height of 1.5 to 2 m)

$$V_{dc} = 0.1\ V_w\ (\text{cu.m.})$$

f) Total volume required for components of liner system and of cover system (on the assumption of 1.5m thick liner system (including leachate collection layer) and 1.0 m thick cover system (including gas collection layer)

$$V_c = k\ V_w\ (\text{cu.m.})$$

(k = 0.25 for 10 m high landfill, 0.125 for 20 m high landfill and 0.08 for 30 m high landfill. This is valid for landfills where width of landfill is significantly larger than the height)

g) Volume likely to become available within 10 years due to settlement / biodegradation of waste

$$V_s = m\ V_w$$

(m = 0.10 for biodegradable waste; m will for less than 0.05 for incinerated/inert waste)

h) First estimate of landfill capacity

$$(Ci) = V_w + V_{dc} + V_c - V_s\ (\text{cu.m.})$$

3.4.8 Fukuoka Method (Semi-aerobic)

The Fukuoka method landfill, developed through a collaborative effort between Fukuoka University and Fukuoka City in Japan, stands out as the optimal choice for replacing open dumpsites (Amiri et al., 2016). Applicable in both temperate and tropical climates, this method has been implemented in Japan and various tropical countries, including Malaysia, Indonesia, China, Sri Lanka, and Iran, since the 1980s. Distinguishing itself from traditional anaerobic landfills, the Fukuoka method promotes air circulation through drainage pipes, facilitating the penetration of air to the bottom layer. Natural convection currents, driven by microbial fermentation-generated heat, allow fresh air to reach all parts of the landfill. The dense network of pipes within the landfill accelerates waste decomposition and reduces contaminant concentrations in leachate (Amiri et al., 2016). Importantly, the Fukuoka Method is adaptable to various materials, allowing the use of locally available resources such as construction and demolition waste or bricks, making it particularly beneficial in developing countries with limited access to natural stones (Amiri et al., 2016).

3.4.9 Waste-to-Energy (WtE) Technologies:

Waste-to-Energy (WtE) technologies encompass diverse waste treatment processes that capture energy, such as electricity, heat, or transport fuels, from different waste sources. These technologies are applicable to different types of waste, including semi-solid waste, liquid waste, and gaseous waste (e.g., refinery gases). Nevertheless, the predominant use is in treating Municipal Solid Waste (MSW) (Lorel et al., 2013). According to Mitsubishi Heavy Industries Environmental and Chemical Engineering incineration emits carbon dioxide and land-filling generates methane gas, which is 25 times as potent as a greenhouse gas. Shifting to incineration reduces the amount of landfill waste and the effect on the environment. WtE technologies can convert the energy content of different waste types into valuable forms of energy, generating power for local and national grid systems. The produced heat can serve district heating purposes or specific thermodynamic processes, and bio-fuels can be derived from the organic components of waste, refined, and introduced to the market (Lorel et al., 2013).

3.4.10 Sensor-Based Monitoring Systems (IoT):

In recent years, Internet of Things (IoT) has become a pivotal technology in the twenty-first century (Vishnu et al., 2021). Comprising a network of smart devices with embedded electronic components like sensors, CPUs, and communication hardware, IoT enables the collection, transmission, and processing of data from the surroundings, reducing the need for human intervention (Vishnu et al., 2021). Its applications range from wearables, healthcare, and smart cities to agriculture and industrial automation. In smart cities, IoT revolutionizes solid waste management. IoT-enabled waste management systems offer several key benefits (Vishnu et al., 2022):

- No Missed Pickups: Smart bins detect fill levels and automatically notify authorities, ensuring timely pickups and preventing overflowing bins.
- Waste Production Analysis: Connected devices monitor bin fill rates, enabling data analysis for optimized bin distribution, proper disposal, and landfill waste reduction.
- Route Optimization: Real-time data from smart bins helps determine optimal garbage collection routes, prioritizing high-demand areas.

IoT technology not only enhances efficiency but also reduces costs, promoting sustainable waste management practices.

3.4.11 Community-Led Clean-up Initiatives:

In the context of solid waste management, community participation is vital because it's an ongoing maintenance system (ADB, 2013). Promoting this involvement requires information, education, and communication campaigns to raise awareness of sustainable principles like Reduce, Reuse, and Recycle (3R) and effective waste management. Clean Up Australia, founded in 1989, is a nationwide community-led initiative focusing on environmental conservation and cleanliness. Originating in Sydney, it has become a national event, mobilizing millions of volunteers to remove tons of waste from natural environments. This initiative emphasizes community engagement, active citizenship, overall cleanliness, health, biodiversity preservation, and ensuring accessibility. Nepal's 'Sithi Nakha' is also a remarkable annual community clean-up initiative in the Newar community, fostering unity and traditions by cleaning water sources, spouts, taps, and surroundings (Murugan et al.). In Dharan, Mayor Harka R. Sampang highlights community-led initiatives contributing to plantation, afforestation, and water supply improvement. Active community participation successfully imported water from a source more than 40 km away, showcasing collective achievements in solid waste management.

3.5 Community participation in Solid Waste Management

Waste (1996) defines a community as a group of individuals residing together within a certain framework of social organization and cohesion (Anschütz, 1996). Community participation, as described by (Gotame, 2012), is the process by which individuals and families assume responsibility for both their personal well-being and that of their community, actively contributing to development. (Anschütz, 1996) underscores the crucial role of community participation in solid waste management. The Brundtland Commission highlights its importance in achieving sustainable development, especially in solid waste management compared to other urban services (ADB, 2013; Kaza et al., 2018). Relying solely on local authorities is inadequate to address the challenge of maintaining clean and liveable towns. Therefore, it is important to promote community participation through campaigns focusing on the principles of reduce, reuse, recycle (3R), and enhanced solid waste management (ADB, 2013). When establishing new waste disposal sites, it's vital to engage nearby communities by considering their opinions and concerns in the planning process, ensuring proper site management, and incorporating social programs that benefit the local residents. Similarly, effective waste segregation and collection techniques should involve close community involvement and participation to tailor solutions to their particular needs (ADB, 2013).

CHAPTER 4. CASE STUDY

4.1 National context

In Nepal, managing solid waste in urban areas poses challenges. Among 753 local governments, 293 are urban, housing around 16.5 million people (Bank, 2020). The daily waste generation rate of Nepal is 3023 tons/day, with 63% from the Terai region. Only half of this waste is collected. A survey on solid waste management (SWM) in 58 municipalities revealed six with proper landfill facilities; others use haphazard disposal (CBS, 2020; Maharjan & Lohani, 2019). A (ADB, 2013) study found 170 grams per capita waste, with 66% being organic. CBS's 2020 study covering 271 municipalities showed 54% organic waste, 48.6% to landfills, 32.1% incinerated, and 27.4% informally dumped. CRISIL's report highlighted the need for 35 hectares of land annually for landfilling. Organic waste has the potential to produce 188,203 cubic meters of biogas and 12,796 kWh of electricity per day. Efforts are underway for 200 TPD bio-methanation plants, covering 7% of the 2,700 TPD of organic waste (CBS, 2020).

4.2 National case study

4.2.1 Pokhara

Pokhara, the largest metropolitan area in Gandaki Province, spanned an area of 464.24 km2 and was home to a population of 414,141 people in 2011. Due to construction and development, the population surged to an estimated 500,000 by 2019 after the merger of Pokhara Sub-Metropolitan City and Lekhnath Municipality. Known as PMC, this merged entity comprises 33 administrative wards. PMC's current population is approximately 476,000, driven by the merger and an influx of tourists, necessitating enhanced infrastructure and services (Khadka;, 2020). PMC boasts economic potential in sectors like tourism, agriculture, forestry, and hydropower. The city generates 182.50 tons of waste on a daily basis, and notably, 85% of this waste is recyclable. However, 85 tons of the total waste is directed to the landfill located in

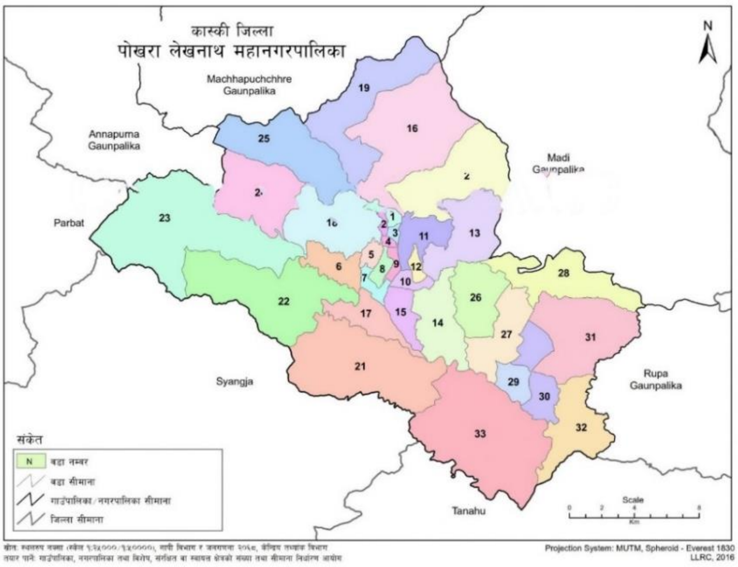

Figure 7 Administrative map, Pokhara SMC

Bachhebuduwa, ward no. 18. In addition to solid waste, the city also deals with 50,000 liters of fecal sludge, which are collected and subjected to treatment processes. PMC's Environment and Disaster Management division oversees waste management, divided into four sub-branches. The Sanitation branch (66 members) handles solid waste operations, the Environment branch (3 members) focuses on tree planting, conservation, training, and awareness programs. The Landfill branch (18 members) is responsible for landfill-related tasks, and the Vehicle branch (3 members) manages waste management vehicles (Khadka;, 2020). PMC lacks material recovery facilities, transfer stations, or treatment plants. Certain residents in Pokhara actively participate in waste management practices by segregating organic waste for composting, while recyclable waste is sold to kabadiwalas. A private contractor oversees additional sorting at the landfill, selling recyclables to larger entities, enhancing waste management efficiency and promoting recycling.

Waste generation and Handling

According to the case study survey report by CRISIL-2019, following is the waste generation pattern of Pokhara SMPC (Khadka;, 2020).

Table 5 Solid Waste Generation and Collection Efficiency (CRISIL-2019)

S.N.	Item	Quantity (Tons/Day)
A	*Primary Waste Measurement results:*	
1	*Household Waste*	145.55
2	*Bulk Waste generators*	4.50
3	*Commercial Waste*	25.53
4	*Institutional Waste*	7.12
B	*Total Waste Generation*	182.50
C	*Current Population (2021)*	513,504
D	*Calculated waste generation (g/capita/day)*	354
E	*Average amount at the disposal site*	85

Waste characterization

According to the study made by (ADB, 2013) the municipal waste composition in Pokhara SMPC from different sectors are as follows:

Table 6 Municipal Waste Composition in Pokhara SMPC

Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	62.65	47.23	26.19
Plastics	8.80	12.60	8.14
Paper Products	11.61	24.68	65.35
Glass	4.54	6.14	0.00
Metals	5.74	1.44	0.00
Textiles	2.221	6.95	0.00
Rubber/Leather	2.82	0.13	0.00
Others	1.63	0.84	0.32

Waste collection and transportation

Pokhara's waste collection is contracted with seven commercial companies, covering 25 wards and approximately 88,000 households (84% coverage based on Census 2011). PMC oversees waste collection in six wards, encompassing about 15,000 households (14%). Two rural wards (3% of households, totaling 3,140 units) lack waste collection services. Pokhara employs curb-side waste collection, with vehicles stopping on main roads, prompting waste generators to dispose of their waste (Khadka;, 2020). In urban and economic regions, collection frequency varies from daily to every two weeks in rural areas. Waste collection vehicles operate without a fixed schedule, as revealed in stakeholder consultations. The fleet consists of four PMC vehicles and 22 from private contractors, with 170 personnel from contractors and 17 from PMC involved. Despite the SWM Act's mandate for waste segregation, PMC gathers mixed waste and transports it to the dumpsite. Households in outer and remote areas frequently separate garbage into wet and dry portions due to irregular collection; wet waste is then used in agriculture or as cattle fodder (Khadka;, 2020).

Waste disposal

Figure 8: Pig farms located along the Seti River bank (left) and the PMC landfill (right)

PMC operates a 4-hectare sanitary landfill site since 2004, primarily functioning as a dumpsite where all city waste is deposited without segregation or processing. Despite having been installed, the septage management plant is not currently in operation at the location. A private company hired by PMC to sort recyclables (paper, plastic, glass, etc.) from the daily garbage that ends up in the dump has agreed to pay a royalty to PMC in exchange for selling the recyclables to big scrap dealers (Khadka;, 2020). In addition to the around 1000 small-scale individual recyclers and the roughly 70 major recyclers, Pokhara is home to a private enterprise called M/s Three Star Pipe Udyog, that acquires recyclable plastic from small-scale recyclers and turns it into plastic pipes. The unit processes 600-700 kg of plastic waste daily, producing 400 kg of pipes. Overall, the city also produces approximately 182 MT of waste per day, of which 47 MT are wet waste and 21 MT are dry waste that are separated and retrieved at the source. Wet waste is repurposed by using it as compost or cattle feed, and dry waste is sold to individual or retail recyclers for materials like plastic, glass, and paper. As a result, disposable waste totals 114 MT. The primary survey indicates that 85 MT of waste per day end up in the landfill, with 29 MT remaining uncollected because of the frequency of collection. This uncollected waste is usually stored, and since organic waste is used for household composting, the stored waste mainly consists of dry recyclables (Khadka;, 2020). PMC faces a significant challenge in shutting down current landfill activities in a way that respects the environment and locating and constructing a replacement landfill site as soon as possible. The city collaborates with a private agency to separate recyclable materials from the waste reaching the current landfill, with the agency paying a royalty to PMC.

Informal Sector Participation

There are between 450 and 500 rag-pickers in the PMC area. They are mostly women, street kids, and elderly individuals. They gather valuable recyclables from public areas and sell them to nearby kabadiwalas. Un-official boundaries delineate the areas designated for recyclable collection among various groups of rag-pickers. Collection activities predominantly occur during the day, as local police restrictions prohibit night-time collection of recyclables for security reasons (Khadka;, 2020).

Policy and Institutional framework for solid waste management

The Solid Waste Management Act of 2068 (2011 AD) and Solid Waste Management Rules of 2070 (2013 AD) are the primary regulations governing the solid waste management (SWM) sector in Nepal. In alignment with these national regulations, PMC has established 'Local SWM Rules' in 2074 (2017 AD). The principal clauses of the national SWM Act consist of:

- Local administrations are entrusted with the responsibility for the environmentally sustainable collection, transportation, and disposal of waste.
- The formation of an SWM Council within the city to formulate regional regulations and establish SWM fees.
- Waste separation and minimization are the duties of producers of garbage, while the Local Authority is responsible for collection and transportation, following a designated schedule.
- Proper waste processing and safe disposal in sanitary landfill sites are mandated.
- Public-Private Partnerships (PPPs) are encouraged for the development of SWM infrastructure.

4.2.2 Waling Syangja

The "Waling Nagarpalika Solid Waste Management Centre" was established in 2012 AD on the premises of Purnamrit H. Secondary School, covering approximately 33 Ropanies of land next to the River Andhikhola. Solid waste is produced at the household level, and the municipality encourages waste to be separated into three types: Dry Recyclables, Wet Compostable, and Glass. It is advised that households manage bins, which can take the form of sacks, plastic drums, or dustbins, to promote reuse. The municipality actively engages community groups and societies in solid waste management (SWM) initiatives and has outsourced SWM responsibilities to "Didi Bahini Tatha Samaj Utthan Sanstha," a women's organization that has been engaged in SWM since the end of 2074 (Khadka;, 2020).

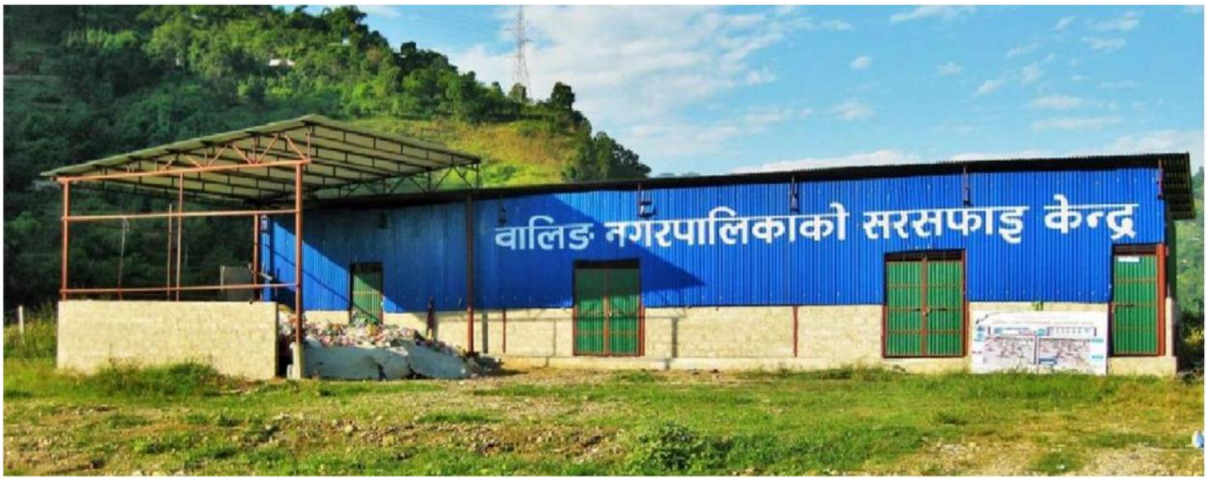

Figure 9 Waling Nagarpalika Solid Waste Management Center

Waste generation and handling

The rate of waste generation and its composition are influenced by factors such as the degree of both urbanization and industrialization, ate of population increase, financial condition of the population, seasonal shifts, and enforcement of the rules and regulations. In the case of WM, there are approximately 13,424 households and a population of about 50,488 (CBS, 2021). According to the ADB 2013 study report, the waste generation and collection rates of Municipal SW are as follows:

Table 7 Solid Waste Generation and Collection Efficiency, Waling (ADB, 2013)

Municipality	Waling
Average Household Waste (Kg/Day)	0.68
Average Household Size (Members)	4.62
Average Per Capita HH Waste (Gm/Capita/Day)	147.92
Daily HH Waste (Tons/Day)	3.58
Daily Commercial Waste (Tons/Day)	1.64
Daily Institutional Waste (Tons/Day)	0.25
Avg. Per Capita MSW (G/Capita/Day)	227.57
Daily MSW Generation (Tons/Day)	5.51
Estimated Waste Collection (Tons/Day)	1.00
Efficiency of Collection (%)	18.2

Households segregate waste at the source, collecting organic, inorganic, and glass bottles separately in different bins. Every household treats these categories separately. Approximately 40 Tole Development Committees actively contribute to solid waste management in respective areas. Yearly, the 5 best TDCs are recognized and rewarded. The municipality has established charges based on the type of waste generated and the quantity generated by various fields. The following are the recorded fees that the municipality administration has set (Khadka;, 2020).

Table 8 Waste collection charge, Waling municipality

S.N.	Description	Charge (NPR/Month)
1	*Typical residences*	50.00
2	*Compact restaurant/hotel*	150.00
3	*Hotel and inn*	500.00
4	*Grocery store/workshop*	75.00
5	*Clothingl store/stationery*	100.00
6	*Medical clinics*	200.00
7	*Butcher shop*	150.00
8	*Craftsmanship workshop*	150.00
9	*Furniture store*	150.00
10	*Hair salon*	150.00
11	*Vegetable/fruit market*	150.00
12	*Hardware store*	150.00

Waste characterization

According to the study made by (ADB, 2013) the municipal waste composition in Waling municipality from different sectors are as follows:

Table 9 Municipal Waste Composition in Waling Municipality

Waste Type	Household Sector	Commercial Sector	Institutional Sector
Organic Waste	47.24	51.04	41.57
Plastics	11.28	12.00	10.99
Paper Products	10.53	15.59	17.08
Glass	5.14	9.64	2.12
Metals	2.61	1.39	1.91
Textiles	4.33	1.95	0.92
Rubber/Leather	0.00	0.00	0.36
Others	18.87	8.40	25.06

Waste collection, transfer and transportation

Figure 10: Waste collection system in Waling Municipality (Khadka;, 2020)

Daily municipal solid waste collection in the city involves two trippers deployed simultaneously, each dedicated to specific waste types—organic and inorganic. Trippers bear slogans corresponding to the waste they collect. Metals and glass are collected monthly. Female waste collectors accompany the vehicles, visiting households daily. Four women, two in each tripper, collect waste from a communal location near households. Approximately 70-75% of total waste generated is collected, with rural areas' houses remaining unattended. After that, the waste gathered is transferred to the Waling Municipality's Cleanliness Centre (Khadka;, 2020).

Waste processing and treatment

The collected waste undergoes segregation by four trained women at the 'Waling Nagarapalikako Sarsafai Kendra.' During office hours, these women diligently segregate the daily-collected waste. Apart from segregation, they actively engage in waste minimization, recycling, and composting practices (Khadka;, 2020).

Figure 11: Waste processing and treatment in Waling Municipality (Khadka;, 2020)

Bio-degradable waste is composted, and old and used clothes are repurposed into items like bedsheets, with some sold to those in need. Bottles, although currently not compacted due to a non-functional machine, were sold previously in Butwal. Presently, stored at the Waling Municipality's Cleanliness Centre for potential use in constructing plastic roads within the city. Waling Municipality has invested in a plastic PET shredding machine for blending with bitumen to construct roads. Additionally, the municipality has established its aerobic composting plant, nearing operational readiness.

Waste disposal

Due to the absence of a suitable location for a sanitary landfill site, Waling Municipality took the initiative to promote waste management at the source. This involved segregating waste, conducting separate daily waste collections, and encouraging households to manage their organic waste on-site, producing compost for their agricultural land. Recyclables were collected during the municipality's regular waste collection campaign, then separated and sent for recycling and reduction techniques. Approximately 3-4 tons of discarded items were gathered at the site of the 'Waling Nagarpalikako Sarsafai Kendra'.

Figure 12: Unmanaged waste dumping at the side of Waling Nagarapalikako Sarsafai Kendra (Khadka;, 2020)

Informal Sector Engagement

“Didi Bahini Tatha Samaj Utthan Sanstha” recorded the municipal solid waste generation quantity. The record of 2074/2075 from the organization is tabulated below.

Table 10: Waste Generation Rate

Description of Waste	Yearly waste generation (Tons)	Percentage
Bio-Degradable		
Agricultural	2550	38.25
Paper products	500	7.5
Clothes	100	1.5
Wood products	100	1.5
Others	1000	15

Total	**4250**	**63.76**
Non Bio-Degradable Waste		
Plastics	500	7.5
Rubber/Leather	100	1.5
Glass	300	4.5
Other	1000	15
Total	**1900**	**28.5**
Hazardous	5	0.07
Chemical Waste	10	0.15
Hospital Related	500	7.5
Grand-Total	**6665**	**100**

Source: “Didi Bahini Tatha Samaj Utthan Sanstha, 2074/2075” (Khadka;, 2020)

Institutional framework and policy for managing solid waste

Waling Municipality established "Local SWM Rules," enacted in 2074 (2017 AD), in accordance with the Solid Waste Management (SWM) Act and Rules. The key sections of the national SWM Act include:

- Local authorities are accountable for collecting,transporting, and disposing of solid waste in an ecologically responsible way.
- Formation of a SWM Council in the city to formulate local rules, impose SWM fees, etc.
- Waste minimization and separation are the responsibilities of waste producers, while the municipality is tasked with collection and transportation, necessitating the preparation and compliance with a schedule for collection.
- Emphasis on processing waste to maximize its resourceful potential before safe disposal in a sanitary landfill site, following the polluter's pay principle.

- Education initiatives aimed at informing the public about source separation, segregated collection, revenue generation, and efficient solid waste operation.

4.2.3 Dhankuta

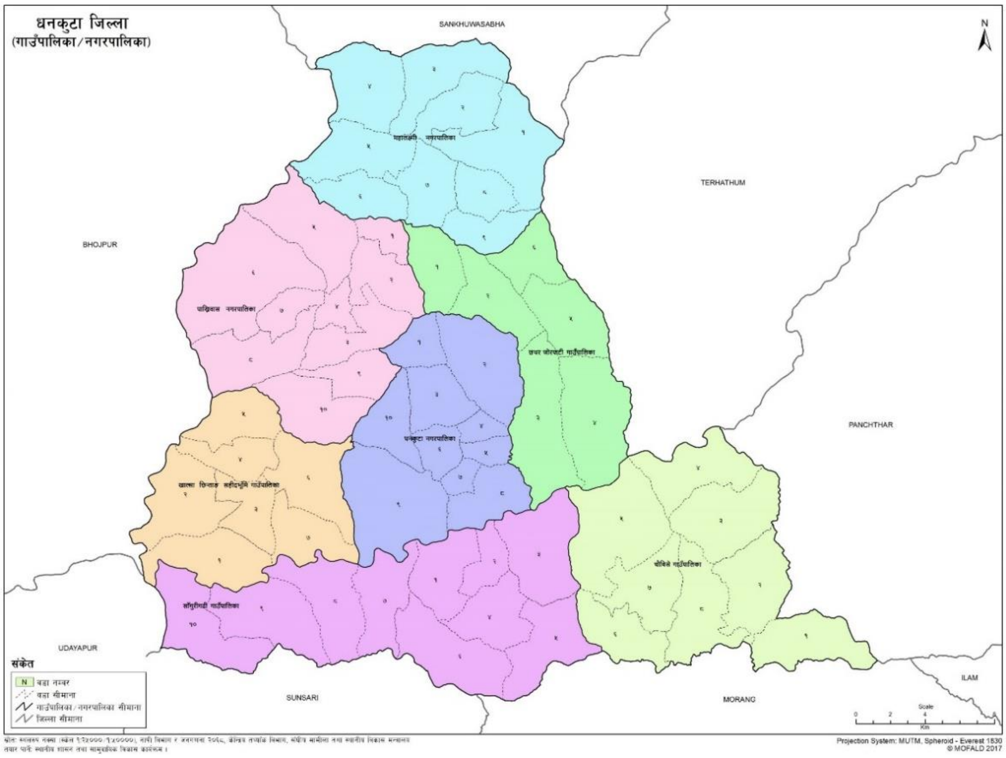

Figure 13 Administrative map, Dhankuta municipality

Dhankuta, situated in the hills of eastern Nepal, is one of the 14 districts in province 1. Encompassing an area of 891 km2, it has a population of 150,599 (CBS, 2021). The district's headquarters is Dhankuta municipality, the most populous urban settlement with 35,983 residents residing in 9,637 households (CBS 2021), established in the year 2035 BS (1987 A.D.). Bordered by Bhirgaon VDC to the east, Belhara VDC to the west, Hattikharka VDC to the north, and Tamor River to the south, the municipality consists of nine wards. Wards 1, 5, 6, and 7 are situated in relatively urban settings, while the rest are in rural areas. Hile, a major market center in the region, is located in ward 1. The municipality enjoys good access to roads, communication, and transportation throughout, serving as an administrative and commercial hub with tourism potential. Despite its small size, a significant portion of the land is dedicated to agriculture.

Waste generation and handling:

In Nepal, where many municipalities struggles with waste issues, Dhankuta shines as a clean city. It was named the cleanest city in the country by the Government of Nepal in 2017, winning a 10 million Nepalese rupees prize. This marked Dhankuta Municipality's second top-ranking achievement (Suraj, 2020). Before achieving this status, the municipality faced similar waste management issues as others. According to municipal data, Dhankuta produces 10 tons of waste daily, with over 50% being organic or biodegradable. With proper training from a project, residents have learned to utilize organic waste for animal fodder and kitchen garden compost, with surplus sold in the market. The non-biodegradable part sent to dump site is managed and recycled by local entrepreneurs. This model yields 50,000 Nepalese rupees in royalty for the municipal office and employs nine people. Workers daily collect recyclable materials from the landfill, selling them to enterprises in Dharan, Itahari, Biratnagar, and even Jogbani, India. Additionally, the municipal office generates revenue from the dumping site by charging government officials 5,000 Nepalese rupees when visiting the small park built atop the waste.

Table 11 Solid Waste Generation and Collection Efficiency (ADB, 2013)

Municipality	**Dhankuta**
Average Household Waste (Kg/Day)	0.69
Average Household Size (Members)	4.78
Average Per Capita HH Waste (Gm/Capita/Day)	143.40
Daily Household Waste (Tons/Day)	4.07
Daily Commercial Waste (Tons/Day)	2.91
Daily Institutional Waste (Tons/Day)	0.42
Avg. Per Capita MSW (G/Capita/Day)	260.73
Daily MSW Generation (Tons/Day)	7.40
Estimated Waste Collection (Tons/Day)	6.0
Efficiency of Collection (%)	81.1

Waste Characteristics:

In Dhankuta, the municipal solid waste composition is similar to that of other municipalities, with organic waste making up the majority. On the plus side, a considerable portion of the organic waste is separated and composted or used as animal feed, meaning that only recyclable waste ends up in the landfill, and even those portion is recycled.

According to a study conducted by (ADB, 2013), the municipal waste composition from various sectors is as follows:

Table 12 Municipal Waste Composition, Dhankuta

Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	59.61	37.93	16.90
Plastics	17.86	17.42	20.80
Paper Products	11.90	21.07	40.25
Glass	0.00	0.00	0.00
Metals	1.28	4.16	0.46
Textiles	3.05	8.15	0.00
Rubber/Leather	0.25	0.00	0.46
Others	6.04	11.28	21.12

Waste collection frequency

Table 13 Waste collection frequency (Suraj, 2020)

Area	Roadside	Open Piles	Door To Door
Densely Populated	Daily	Daily	Almost daily
Outside The Market Area	Daily	Daily	2 to 3 times a week
Semi-Rural Parts	2 times a week	3 times a week	Weekly

Waste collection in Dhankuta is carried out based on available resources and manpower. The collection frequency is influenced by factors such as the size of the municipality, quantity, and nature of waste. In this small-sized municipality, waste collection is a daily practice in the market area, while it becomes less frequent outside the populated zones. The table below illustrates the frequency of waste collection in Dhankuta Municipality.

Waste Disposal

Dhankuta Municipality currently disposes of its waste in an informal dumping site situated in a forest area, approximately 1 km from the city. This site, covering an area of 33 ropani, has been in use for the past seven years. Previously, waste was also deposited at Ghumaune Chautara. The disposal process involves placing waste in temporary open piles and containers. After being loaded, the waste is set for disposal on a tractor trailer. The municipality lacks a door-to-door waste collection system, leading to a significant portion of the waste being left on the roadside for municipal sweepers to pick up. The current disposal site is estimated to be usable for another 20 years. Although the Municipality has plans to construct a landfill site near Karmitar, Salleri Jungle, and Kalchure Dada, financial and technical assistance is needed for this project. The proposed site, located 2.5 km from the city, covers an area of about 3 ropani, and the Municipality believes it could be utilized for approximately 30 years. However, political interference is currently impeding progress in this matter (Suraj, 2020).

Figure 14 Dhankuta's Waste Disposal Site, (Source: Birat Anupam, 2018.)

4.3 International Case studies

4.3.1 Singapore

The National Environment Agency (NEA) is responsible for the planning, development, and supervision of Singapore's solid and hazardous waste management systems. This involves regulatory activities and licensing to ensure the proper collection, treatment, and disposal of waste. The regulations monitoring the management of solid and hazardous wastes in Singapore include the Environmental Public Health Act, Environmental Public Health (General Waste Collection) Regulations, Environmental Public Health (General Waste Disposal Facilities) Regulations, and Environmental Public Health (Toxic Industrial Waste) Regulations (NEA, 2018).

Solid waste management in Singapore

Figure 15 Sustainable waste management strategy (NEA, 2018)

Solid waste generation in Singapore has risen significantly due to its expanding population and thriving economy. From 1,260 TPD in 1970 to a peak of 8,741 TPD in 2021—a sevenfold increase—solid waste generation has increased significantly in Singapore (NEA, 2018). As waste quantities are anticipated to rise further alongside increasing population and changing lifestyle, the primary issue in Singapore's SWM lies in allocating land for disposal, given the limited land resources. Singapore has adopted a set of strategies to develop a more sustainable solid waste management system. Sustainable solid waste management involves the people, private, and public sectors. Working hand in hand with these key stakeholders, NEA has developed a range of initiatives and programmes to slow down waste growth.

	Unit	2019	2020	2021
Total Waste Generated	Mil tonnes/yr	7.23	5.88	6.94
Recycled	Mil tonnes/yr %	4.25 59%	3.04 52%	3.83 55%
Total Waste Incinerated	Mil tonnes/yr %	2.74 38%	2.62 44%	2.88 42%
Total Waste Landfilled	Mil tonnes/yr %	0.24 3%	0.22 4%	0.23 3%
Energy Produced From Incineration	*MWh*	1,173,202	1,060,607	1,177,668

Table 14: Key-Environmental-Statistic-Singapore-2022

Recyclables are sorted and recovered at the source of waste generation to promote resource conservation. The remaining waste is then sent to waste-to-energy plants for incineration, leading to a significant volume reduction of up to 90%, thereby conserving landfill space. Additionally, the heat generated during incineration is utilized to produce steam, driving turbine-generators and contributing approximately 3% to the island's electricity needs. The resulting incineration ash and other non-incinerable wastes are transported to the Tuas Marine Transfer Station (TMTS) and subsequently barged to Semakau Landfill for final disposal. (NEA, 2018).

Waste Minimization and Recycling

The integrated solid waste management system in Singapore centers on two primary objectives – waste minimization and recycling, encapsulated by the 3Rs (Reduce, Reuse, and Recycle). Given Singapore's limited land availability, waste-to-energy (WTE) incineration plants serve as an optimal technical solution, efficiently reducing waste volume to preserve precious landfill space. The 3Rs are instrumental in curbing waste generation at its source, providing a range of associated benefits.

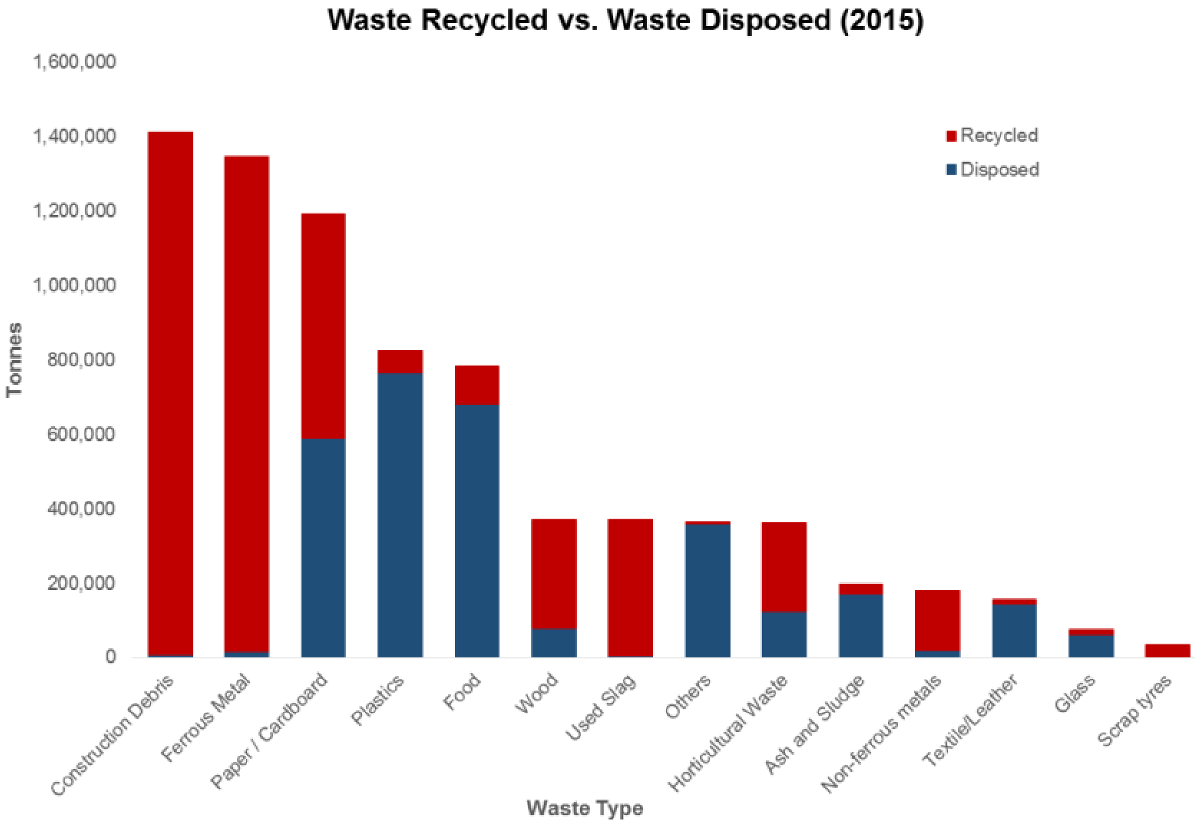

Figure 16: Waste Recycled and Disposed in 2015 (NEA, 2018)

According to 2015 statistics, paper/cardboard, plastic, and food waste collectively accounted for approximately 67% of the total waste disposal. To meet the national recycling target of 70% by 2030, innovative recycling and upcycling methods for these major waste categories, facilitated by technological advancements, could be explored. Among these, paper stands out as one of the most recycled streams, with around 51% of the 1.19 million tons generated being recycled. Paper is typically sorted, baled, and exported for overseas recycling. In contrast, only 7% of the 0.82 million tons of plastic waste generated is recycled, primarily through mechanical processes for secondary raw material production. Technological advancements offer potential for upcycling plastics into higher-value products, such as depolymerisation or conversion into fuel. Food waste, comprising 0.79 million tons, sees a recycling rate of 13%. Challenges arise from the high costs associated with separate collection for food waste recycling. While some food waste is transformed into animal feed, limited demand for compost production exists due to agricultural land scarcity. Effective source segregation of organics from inorganic waste is crucial to incentivize food waste recycling.

Waste Collection Systems

Public waste collectors (PWCs) in Singapore are selected by the National Environment Agency (NEA) through open tenders, covering both domestic and trade premises across geographical sectors. Companies meeting pre-qualification criteria participate in the tenders, and successful bidders secure licenses to offer refuse and recyclables collection services in specific sectors for a duration of seven to eight years. Presently, three PWCs operate in Singapore, serving the six sectors delineated on the map.

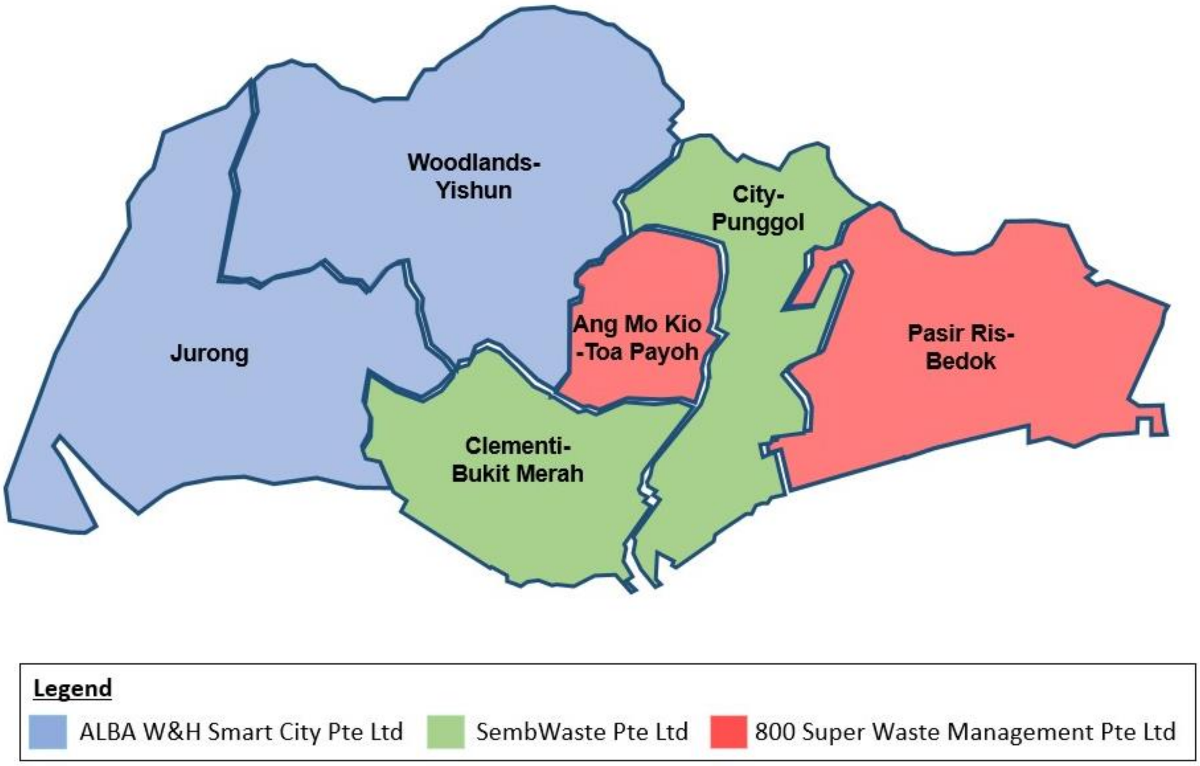

Figure 17 Waste collection coverage (NEA, 2018)

In Singapore, general waste collection is managed either by Public Waste Collectors (PWCs) or individual General Waste Collectors (GWCs) licensed by the National Environment Agency (NEA), depending on the geographical areas and type of premises. High-rise buildings, including public housing estates, private condominiums, and commercial complexes, typically utilize a refuse chute system. Waste is collected directly from centralized refuse chutes via a fixed dust-screw system operated by trucks. However, the current collection and transportation methods may lead to sanitary, odor, and pest issues, as spillage can occur during the transfer process, necessitating regular cleaning of waste receptacle areas to maintain cleanliness in the estates.

Waste Treatment

Singapore employs waste incineration as its primary treatment method for municipal solid waste (MSW), primarily due to land scarcity. Incineration results in a 90% reduction in waste volume.

The mass burn Waste-to-Energy (WTE) technology is the predominant approach for MSW treatment, allowing for energy recovery.

Figure 18: Current WTE IPs in Singapore (NEA, 2018)

	Keppel Seghers Tuas WtE Plant	**Senoko WtE Plant**	**TuasOne WtE Plant**	**Tuas South IP**
Plant Capacity Per Day (TPD)	800	2100	3600	3000
Energy Generation (Mw)	22	36	120	80

Currently, Singapore has four Waste-To-Energy or Incineration Plants: TuasOne Waste-To-Energy Plant (TWTE), Keppel Seghers Tuas Waste-To-Energy Plant (KSTP), Tuas South Incineration Plant (TSIP), and Senoko Waste-To-Energy Plant (SWTE). KSTP, commissioned in 2009, operates under a Design, Build, Own, and Operate (DBOO) model, replacing Singapore's first WTE plant at Ulu Pandan. Senoko Incineration Plant was divested to the private sector in 2009 and is now known as Senoko Waste-to-Energy Plant (SWTE). TWTE, commissioned in 2021, also operates under a DBOO model, replacing Singapore's second WTE plant (Tuas Incineration Plant), which closed in February 2022 after 36 years of operation (NEA).

Waste Disposal

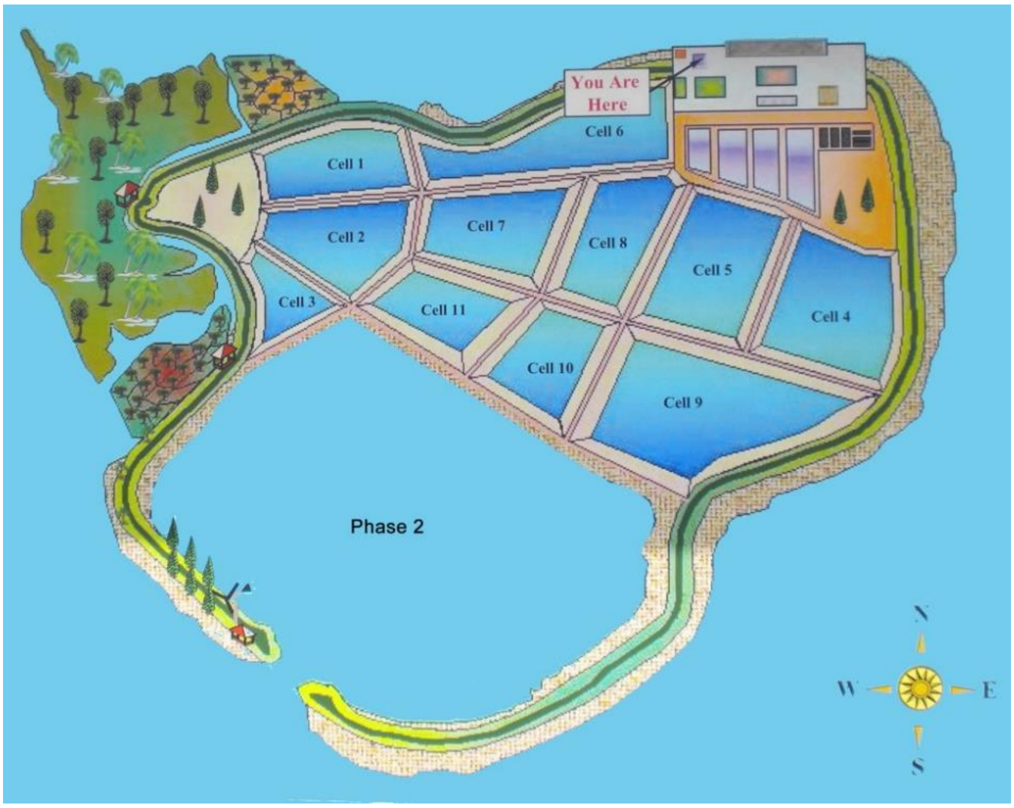

Figure 19: Pulau Semakau landfill site, Singapore

Semakau Landfill, commissioned in April 1999, serves as Singapore's sole landfill for waste disposal. It accommodates ash from incineration plants and non-incinerable waste like construction and renovation debris. Phase 1 construction began in 1995, costing $610 million and completing in four years alongside the construction of Tuas Marine Transfer Station. Phase II, costing $36 million, started in January 2014 and concluded in July 2015. The landfill spans 350 hectares with a capacity of 28 million m3, enclosed by a 7-km perimeter rock bund. The bund, lined with impermeable membrane and marine clay, prevents water accumulation and directs it to a wastewater treatment plant. Ancillary facilities on the island ensure self-sustainability. In 2015, 0.19 million tons of waste (2% of total) were landfilled, and in 2021, the landfill received an average of 2,098 tons of incineration ash and non-incinerable waste daily. Semakau Landfill is projected to fulfill Singapore's landfill needs beyond 2035 (NEA, 2018).

Vision

The vision aims to position Singapore as a global leader in employing cutting-edge technologies for solid waste management. This involves addressing inherent challenges and achieving several key objectives (NEA, 2018):

- Ensuring a high level of public health;
- Minimizing land footprint and environmental impacts;
- Maximizing manpower productivity;
- Enhancing energy recovery by improving existing and alternative Waste-to-Energy (WTE) technology options;
- Optimizing resource recovery to meet the 70% overall recycling target; and
- Maintaining an affordable cost of waste disposal.

4.3.2 Indore City, India

Indore, a rapidly growing city in India, has become a role model for sustainable waste management practices. Despite its population of over 3.2 million, generating approximately 1,100 metric tons of waste daily, Indore struggled with waste management challenges until 2016. The implementation of the Swachh Bharat (Clean India) campaign prompted the Indore Municipal Corporation (IMC) to undergo a significant transformation of its waste management system. This comprehensive effort included revamping infrastructure, revising policies, and engaging the community to establish an efficient and environmentally conscious waste management system (Singh, 2021). On October 2, 2014, the Indian government launched the 'Swachh Bharat Mission' (SBM) on the birthday of Mahatma Gandhi. The mission focused on achieving Open Defecation Free (ODF) status in urban and rural areas. In the urban sector, the emphasis was on creating ODF towns, developing toilets, and managing solid waste. Indore, as part of this initiative, now collects over 1,115 MT of waste daily through efficient door-to-door collection, which started as a pilot project in January 2016 and achieved 100% coverage within a year. The city, with strong community engagement, has achieved 100% waste segregation at the source in both households and businesses. Improved lifestyles and active participation of residents played a crucial role in transforming Indore's cleanliness scenario, turning it into a success story of community involvement (Singh, 2021).

Table 15 Indore Waste Generation (Paul & Paul, 2021)

Year	Population (Millions)	Per Capita Waste (G/Capita/Day)	Total Waste (Tons)
2001	1.62	0.321	522.04
2011	2.10	0.321	675.6
2021	2.68	0.321	860.87

Segregation at the source:

The Indore Municipal Corporation (IMC) introduced a compulsory waste segregation policy, mandating households to categorize waste into wet (biodegradable) and dry (recyclable) segments. This initiative resulted in a more streamlined waste collection and processing system, contributing to higher recycling rates. Currently, over 90% of households in Indore actively participate in waste segregation, leading to increased efficiency in waste management processes and a notable reduction in the pressure on landfills (Singh, 2021).

Waste Collection and Transportation

Indore, divided into 19 zones and 85 wards, ensures 100% ward coverage through a door-to-door waste collection system. Specially equipped vehicles, monitored by GPS, collect waste from households and businesses, with separate bins for wet, dry, and hazardous waste. Any deviations from routes result in penalties. Waste is then transported to transfer stations and disposal sites using designated vehicles. Semi-bulk generators' wet waste is managed through a Bulk Collection System, employing vehicles with dumpers and compactors on a set schedule, transporting waste to a centralized processing plant (Singh, 2021).

Waste processing and final disposal

The Devguradia trenching ground in Indore received significant upgrades to address environmental concerns and enhance waste management. Formerly a basic dumping site with odor issues, the improvements included upgrading the processing plant, constructing new facilities, implementing security measures like CCTV cameras, and creating two engineered landfills. Strategic waste sector division, bioremediation efforts, and additional infrastructure improvements were part of the initiative, aiming to boost efficiency, security, and reduce the environmental impact of the disposal site (Singh, 2021).

CHAPTER 5. STUDY AREA

The study area for this research encompasses Dharan Sub-Metropolitan City, with a primary focus on Ward 15. Dharan is experiencing rapid urbanization and population growth, making it a pertinent case study for understanding the challenges and opportunities associated with urban development and environmental conservation.

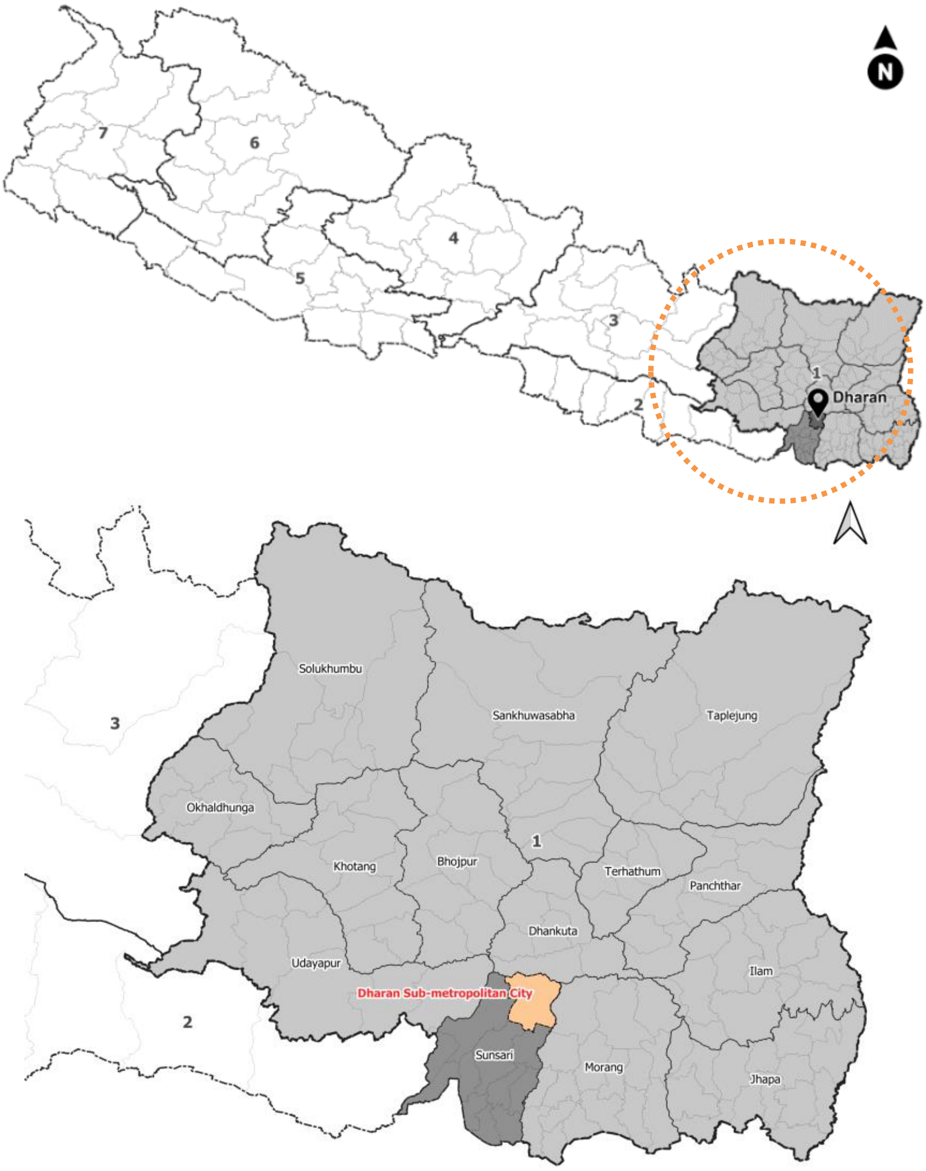

Figure 20: Location Map of Dharan Sub-metropolitan city

Dharan is a sub-metropolitan city located in Sunsari District of Koshi Province, Nepal, which was established as a fourth municipality in the Kingdom in 1958. It is the third most populous city in Eastern Nepal after Biratnagar and Itahari. The Nepali word "Dharan" means a saw pit. According to the (IUDP, 2017), forests cover more than 70% of the total land area of Dharan (192.98 sq.km). Forest plays major role in balancing the eco-system and maintaining the climatic and livable conditions of Dharan. However, since it has been used as a dumping ground for municipal waste disposal since 1986 A.D., adverse effects on its environment and biodiversity can be observed. This situation has directly impacted the adjacent river body and the health of people in surrounding municipalities. According to the survey conducted by IUDP Dharan in 2017, unmanaged waste is the major communal and environmental problems experienced by the inhabitants; followed by bad smell, air pollution, parking, drainage etc. (IUDP, 2017). As Dharan is experiencing rapid urbanization and along with the population growth, the waste generation pattern is also arising. This makes it a pertinent case study for gaining insights into the challenges and opportunities associated with urban development and environmental conservation.

5.1 Physical Profile

Dharan is located on the foothills of the Mahabharata Range, with its southernmost point touching the edge of the Terai region at an elevation of 1148 ft. (349m).

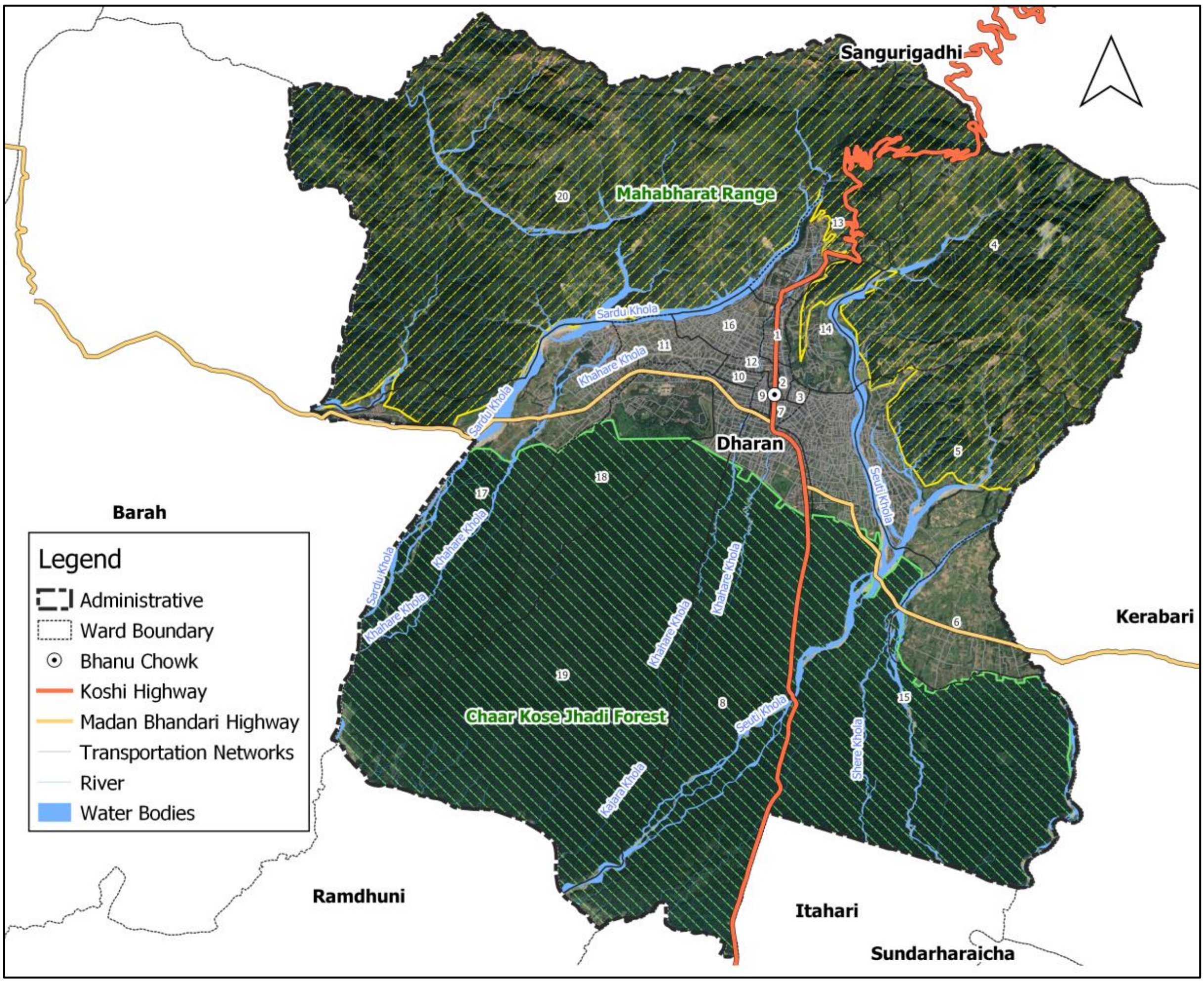

Figure 21: Physical setting of Dharan

The Koshi highway runs through the heart of the city, linking it to the provincial capital of Biratnagar and the Itahari junction of the east–west Mahendra highway, situated 41 km and 17 km to the south, respectively. Additionally, the Nepal-China border of Kimathanka lies 115 km to the north. The road from Biratnagar, originally constructed for the British Gurkhas' Gopher Camp, and the road from Dharan to Dhankuta, funded by the UK and largely completed by 1982, contribute to the city's connectivity. Several rivers, including Seuti, Andheri, Shere, and Masane, flow in the east, while Sardu River and Khahare Khola flow in the west. The southern part of Dharan is enveloped by the Chaar Kose Jhadi forest areas, playing a significant role in supporting the city's wildlife. To the north, the city is surrounded by the Mahabharata Range, marking the starting point for the upper hilly region. Administrative boundaries of Dharan Sub-metropolitan city are delineated by municipalities like Kerabari, Sangurigadhi, Itahari, Ramdhuni, Baraha, Belaka, Sundarhaicha, etc.

5.2 Municipality Profile

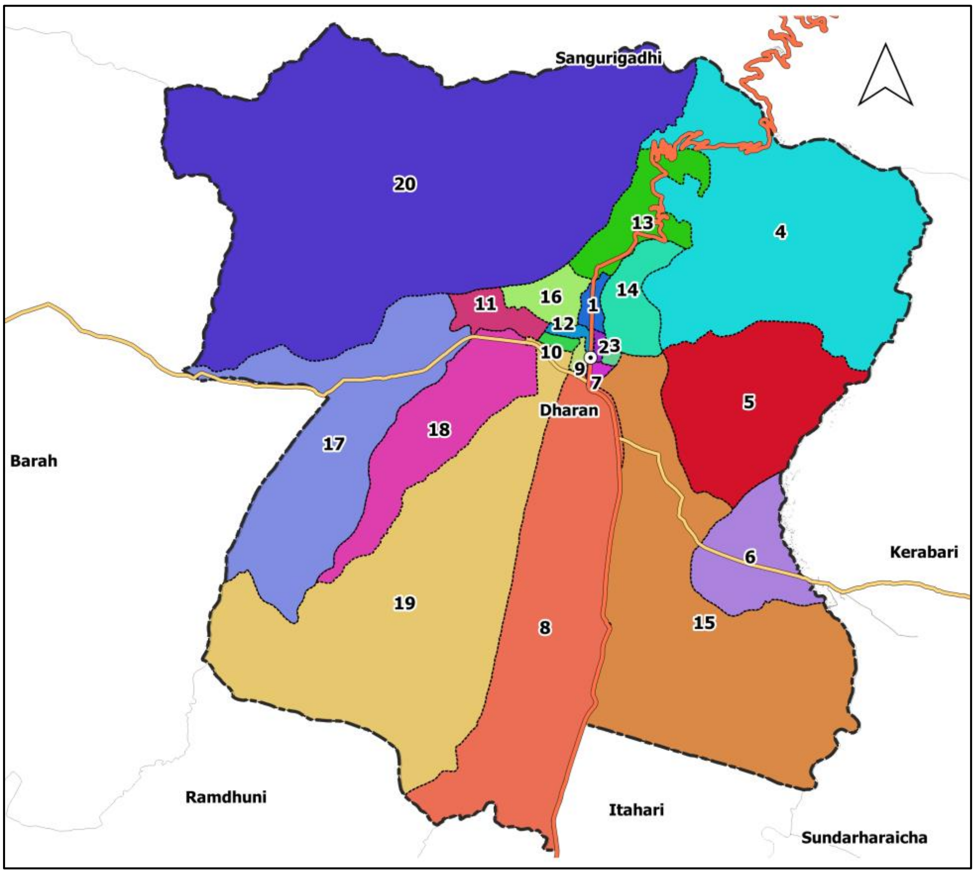

Figure 22: Municipal Ward Division Map

After adding two VDCs, Panchkanya and Bishnupaduka, to its initial 21.12 sq. km size, the Dharan municipality was expanded and designated as a sub-metropolitan city in 2016. This expansion increased the total area of DSMC to 192.61 sq. km. Following a recent ward readjustment, DSMC now comprises a total of 20 wards. Among these, ward 20 has the largest land coverage, while ward 3 has the smallest. Additionally, ward no. 15 has the highest population, while ward no. 2 has the least.

5.3 Climatic Profile:

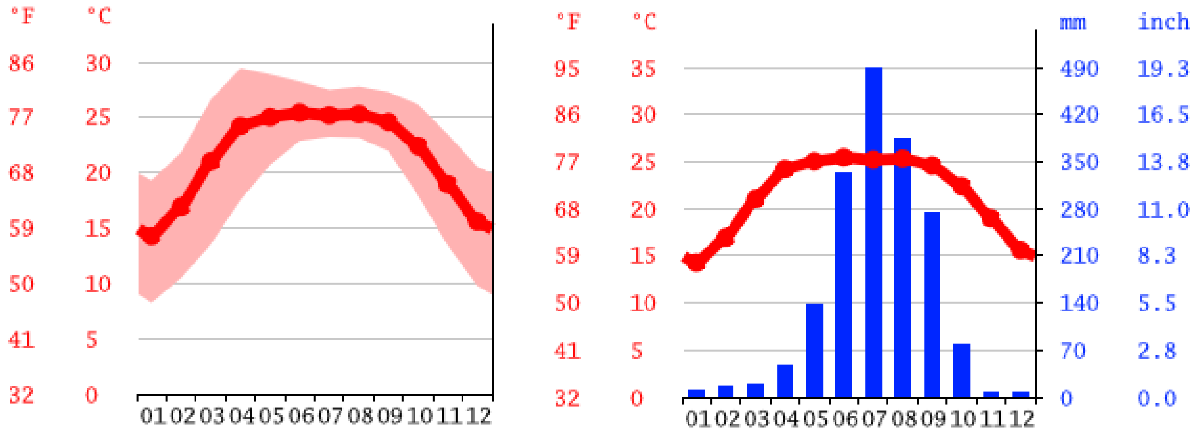

Figure 23: Temperature pattern and rainfall pattern of Dharan, Source: Climatedata.org

Dharan experiences a mild and moderate climate, characterized by less rainfall in winter compared to summer. According to the Köppen-Geiger climate classification, the climate is categorized as Cwa. The mean temperature in Dharan is recorded at 21.6 °C | 70.8 °F, and the annual precipitation is approximately 1796 mm | 70.7 inch. December marks the lowest precipitation with only 6 mm | 0.2 inch, while July sees the highest with an average of 490 mm | 19.3 inch.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	14.2 °C (57.6) °F	16.9 °C (62.5) °F	21 °C (69.8) °F	24.2 °C (75.6) °F	25 °C (77) °F	25.4 °C (77.8) °F	25.2 °C (77.3) °F	25.3 °C (77.5) °F	24.6 °C (76.2) °F	22.4 °C (72.3) °F	18.9 °C (66.1) °F	15.6 °C (60.1) °F
Min. Temperature °C (°F)	8.2 °C (46.8) °F	10.5 °C (50.9) °F	13.5 °C (56.3) °F	17.5 °C (63.5) °F	20.7 °C (69.2) °F	22.9 °C (73.2) °F	23.2 °C (73.8) °F	23.1 °C (73.7) °F	21.9 °C (71.5) °F	17.9 °C (64.3) °F	13.4 °C (56.2) °F	9.8 °C (49.6) °F
Max. Temperature °C (°F)	19.3 °C (66.8) °F	21.8 °C (71.3) °F	26.6 °C (79.9) °F	29.4 °C (85) °F	28.9 °C (84) °F	28.3 °C (82.9) °F	27.5 °C (81.5) °F	27.8 °C (82) °F	27.3 °C (81.1) °F	26.2 °C (79.1) °F	23.5 °C (74.2) °F	20.5 °C (69) °F
Precipitation / Rainfall mm (in)	10 (0)	15 (0)	17 (0)	46 (1)	136 (5)	334 (13)	490 (19)	383 (15)	273 (10)	78 (3)	8 (0)	6 (0)
Humidity(%)	71%	64%	51%	53%	71%	83%	87%	86%	85%	79%	71%	71%
Rainy days (d)	1	2	3	7	14	20	21	21	18	7	1	1
avg. Sun hours (hours)	7.7	8.3	9.8	9.6	9.0	7.8	7.3	7.8	7.9	8.8	8.6	7.9

Data: 1991 - 2021 Min. Temperature °C (°F), Max. Temperature °C (°F), Precipitation / Rainfall mm (in), Humidity, Rainy days. Data: 1999

Figure 24: Annual Climate data of Dharan, Climatedata.org

Dharan, situated in the northern hemisphere, has summer months from June to September. The recommended months for visiting are March, April, May, June, August, September, and October.

5.4 Demographic profile:

The Dharan Sub-Metropolitan City encompasses with 866 population densities (Census 2021) per km2. Based on census 2021 (CBS), a total of 166,531 people (47.1% male and 52.9% female) are living in 42,396 households within the city.

Table 16: Demographic Profile, Source: CBS 2021

Ward no.	Household (2017)	Population	Male	Female	Area (Sq.Km)	Density
1	1,199	4962	2413	2549	0.494	10044
2	540	2275	1124	1151	0.172	13226
3	1,034	4662	2304	2358	0.131	35587
4	713	3783	1822	1961	23.012	164
5	1,779	13651	6380	7271	10.632	1283
6	1,371	8455	3983	4472	4.589	1842
7	777	2967	1480	1487	0.194	15293
8	2,818	12126	5829	6297	19.616	618
9	1,022	3564	1727	1837	0.211	16891
10	1,384	4612	2144	2468	0.222	20774
11	2,708	17168	7904	9264	1.352	12698
12	796	3029	1468	1561	0.276	10974
13	2,034	9138	4167	4971	3.397	2690
14	851	4803	2286	2517	2.468	1946
15	4,726	27441	12845	14596	25.544	1074
16	2,763	14665	6835	7830	1.429	10262
17	2,610	15912	7509	8403	14.578	1091
18	1,620	4579	2072	2507	7.21	635
19	1,154	5313	2415	2898	28.297	187
20	784	3426	1703	1723	49.156	69
Total	32,683	166531	78410	88121	192.98	866

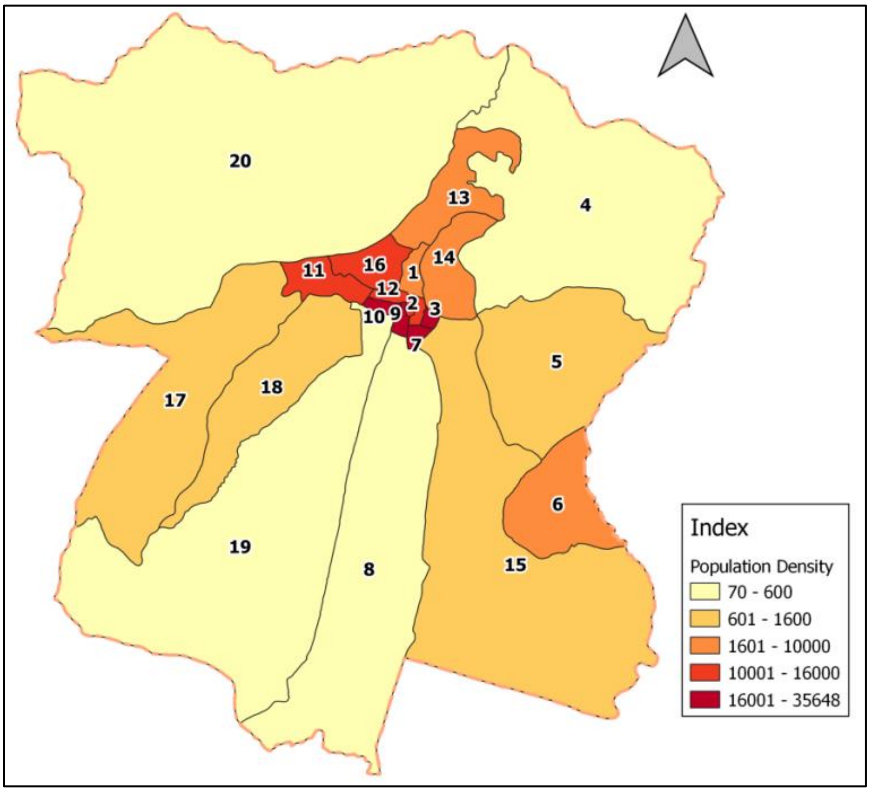

Figure 25: Ward-wise Population Density map

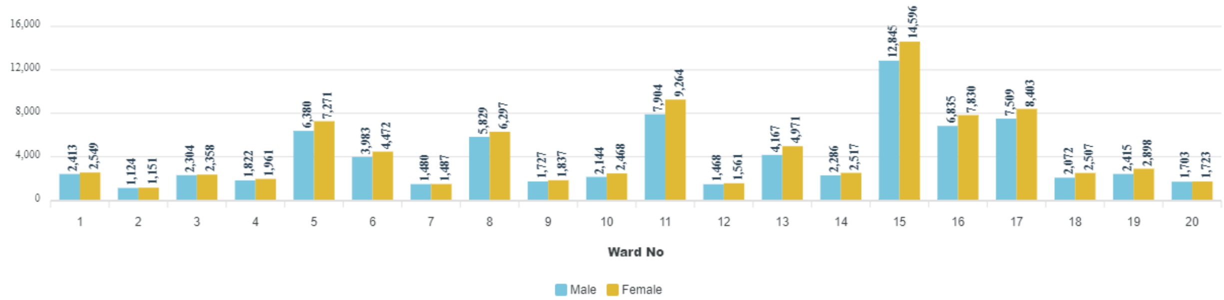

Figure 26: Ward-wise population, CBS 2021

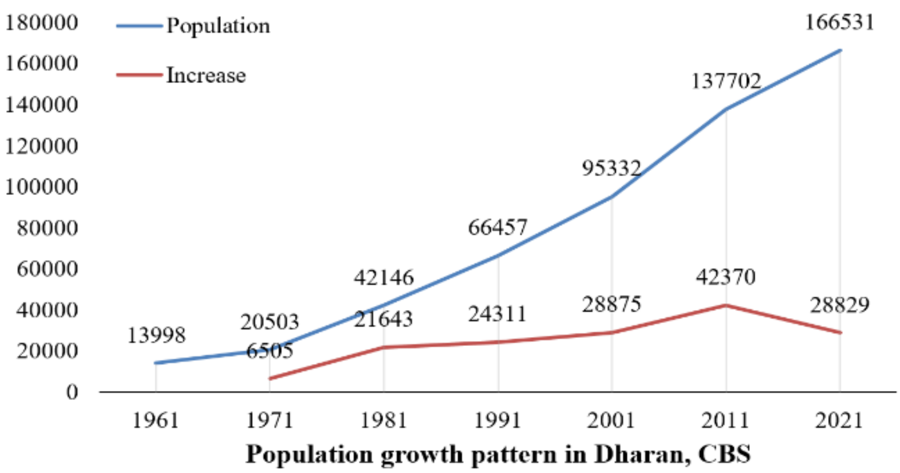

Figure 27: Population growth chart of Dharan SMC

5.5 Land Use Pattern

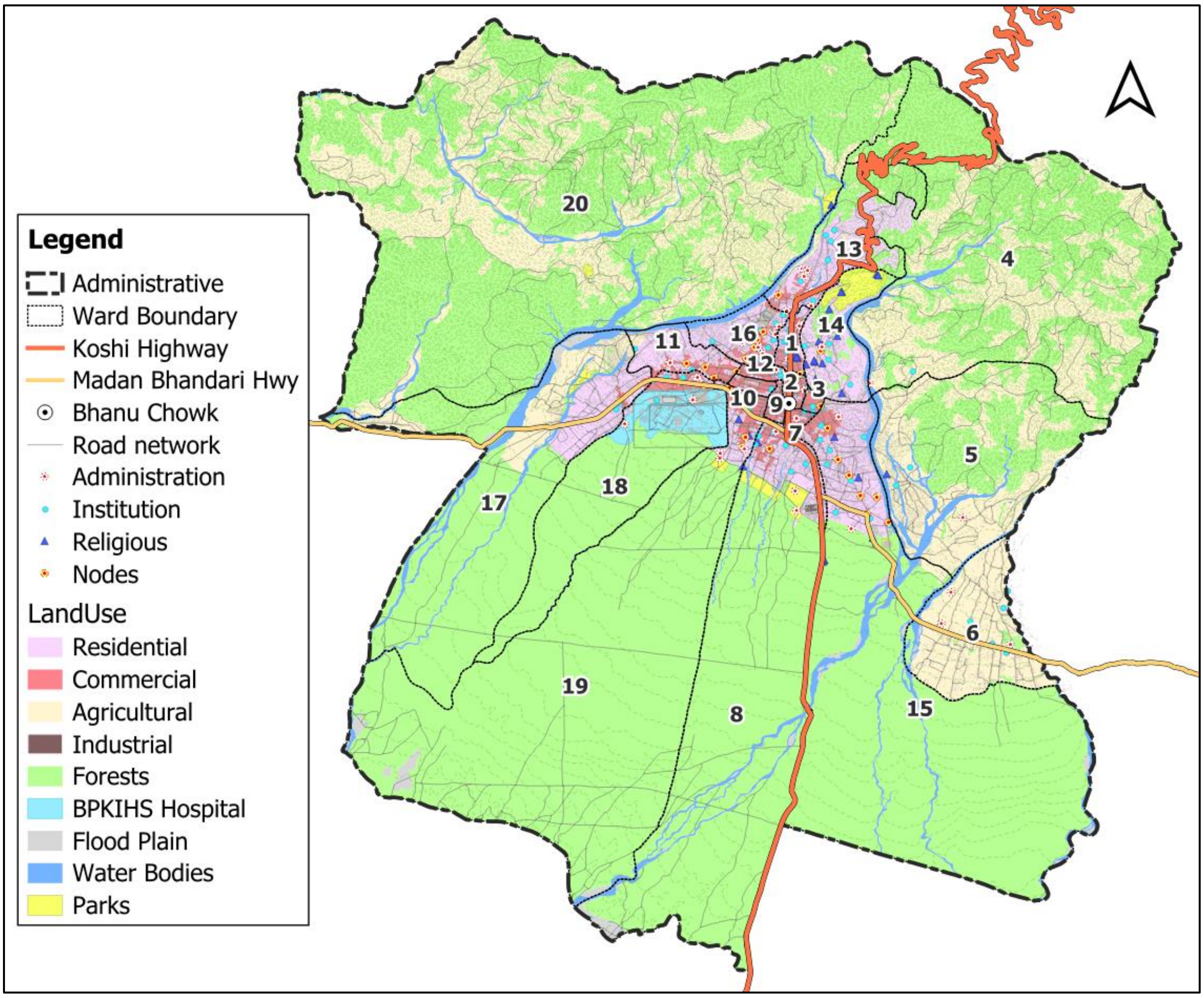

Figure 28: Land Use Map, Dharan

Dharan's land use is diverse and includes the main core urban area, residential zones, agricultural regions, waterbodies and rivers, forests, highways and transit areas, parks and open space, as well as industrial and academic sectors. The table clearly shows the current land usage:

Table 17: Land Use Category (IUDP, 2017)

Categories	Area (sq.km.)	Percentage (%)
Built-up area	3.45	1.78
Vegetation	135.74	70.33
Waterbodies	0.01	0.67
Cultivable land	45.98	23.82
River bed	7.09	3.67
Cutting cliff	0.87	0.45

The plain areas in the south are primarily designated for agriculture, while the hilly sections are predominantly covered by forests. Notably, around 50% of Dharan's total area is covered by the preserved Char Koshe Forest. The core settlement is concentrated in the central part of the municipality, extending westward. Forests account for a significant 70.33% of the total land area, while approximately 23.82% is dedicated to agriculture and cultivation. These sloping, low-angle fields are good for cultivating cereals, wheat, millet, and maize. The built-up area comprises only 1.78%, and water bodies cover 0.67% of the total area.

5.6 Economic Profile:

Dharan, once the gateway town to the hills, is experiencing a shift towards Itahari, with many warehouses, health facilities, and educational activities growing along the Mahendra highway. Despite this shift, Dharan still serves the hills by collecting agricultural products and offering services for finished goods and human resources. It plays a vital role in the Dharan-Biratnagar industrial corridor. The economy of Dharan, as per the (IUDP, 2017), is based on various sectors, including:

- Transport sector / Auto services
- Hotels and restaurants
- Banking and finance
- Industries and Business
- Agro-business
- Health sectors
- Education sectors

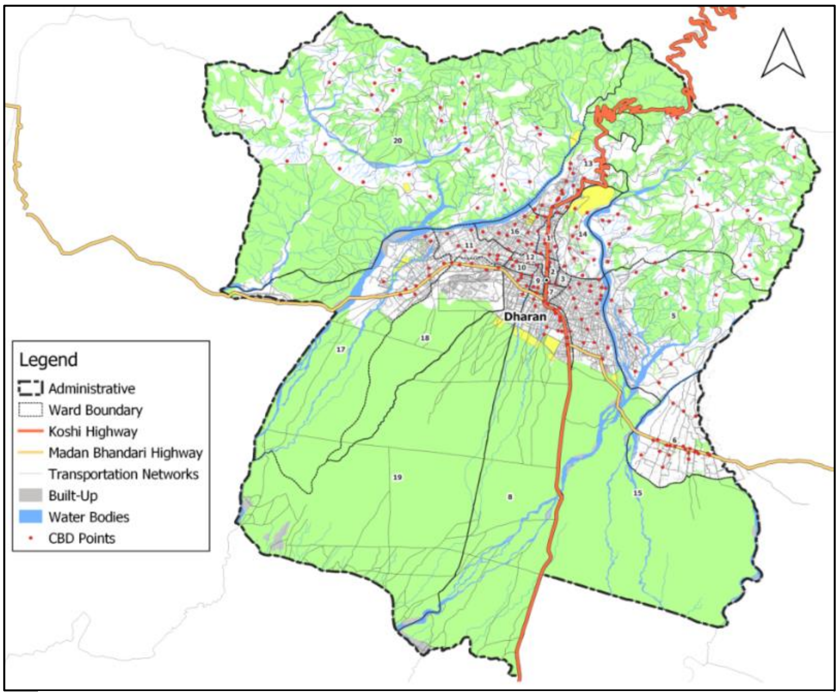

Figure 29 Map showing CBD points in Dharan

The primary occupation of the residents in this municipality is in the service sector (45.83%), working in various private and government organizations. In addition to the service sector, a significant portion is involved in business (32.3%), followed by agriculture (2.08%), and 19.79% engage in other economic activities. Dharan serves as a trade and industrial centre in the region, strategically positioned between the Terai and the mountains of Nepal. It also functions as an economic hub connecting

Dhankuta, Bhedetar, Biratnagar, Inaruwa, and Itahari. According to the municipal website, the city is home to numerous industries, hotels, and shops.

Table 18: Trade and Industries in Dharan, IUDP 2017

Trade and Industries	No.
Medium Scale Industry	*24*
Small Scale Industry	*104*
Hotel/Lodge/Guest House	*78*
Restaurants	*45*
Shops	*1950*
Other business	*40*

5.7 Environmental problems:

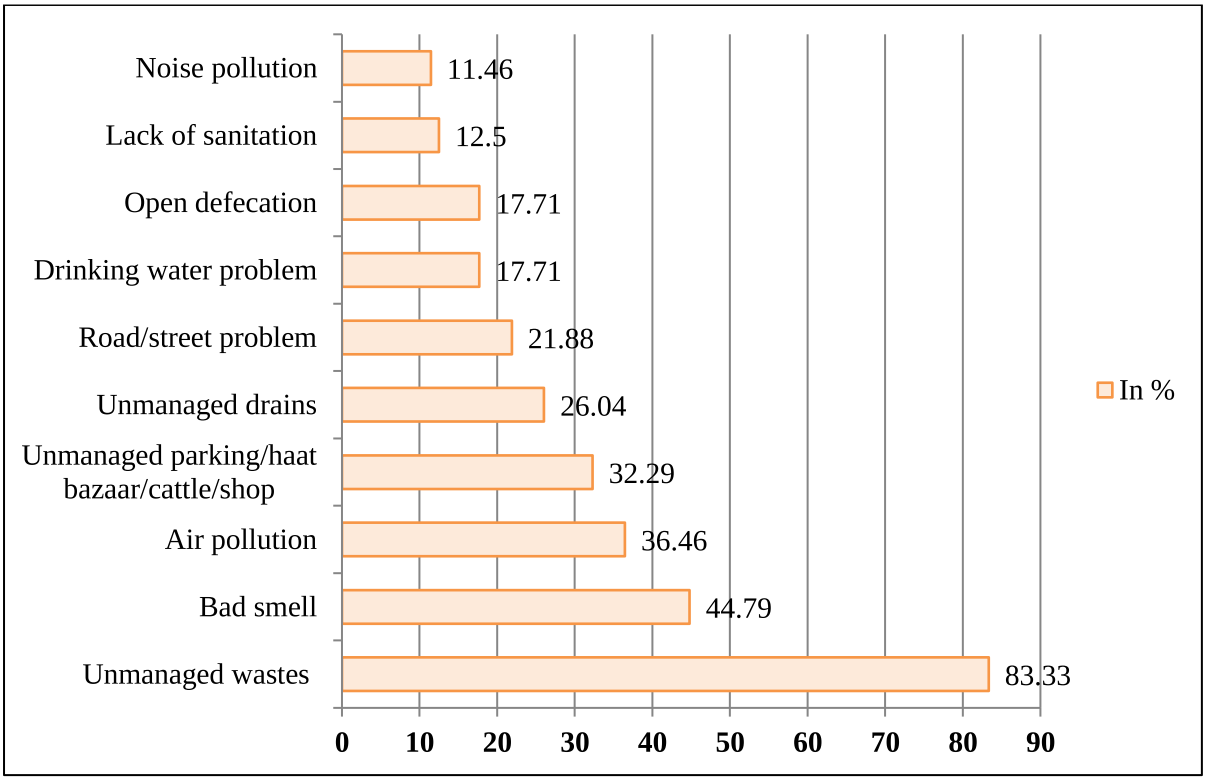

Figure 30: Community level problems (Source: IUDP 2017)

The expanding urban population has led to environmental pollution in Dharan, with solid waste and sewerage being the primary contributors to river pollution, land pollution, and air pollution. Emissions of odours and dust, particularly from rice mills, jute mills, and furniture industries, contribute to air and noise pollution. Additionally, haphazard construction, unregulated displays and advertisements, and metal workshops along the roads contribute to visual and auditory pollution in the city. According to the survey conducted by IUDP Dharan in 2017, unmanaged waste is the major communal and environmental problems experienced by the inhabitants; followed by bad smell, air pollution, parking, drainage etc. The primary sources of environmental pollution in Dharan municipality are vehicular emissions, increased traffic, urban development activities such as road extensions and building construction, and open burning of solid waste by households, agriculture, and other sources.

5.8 Selected Case Area: Ward no. 15

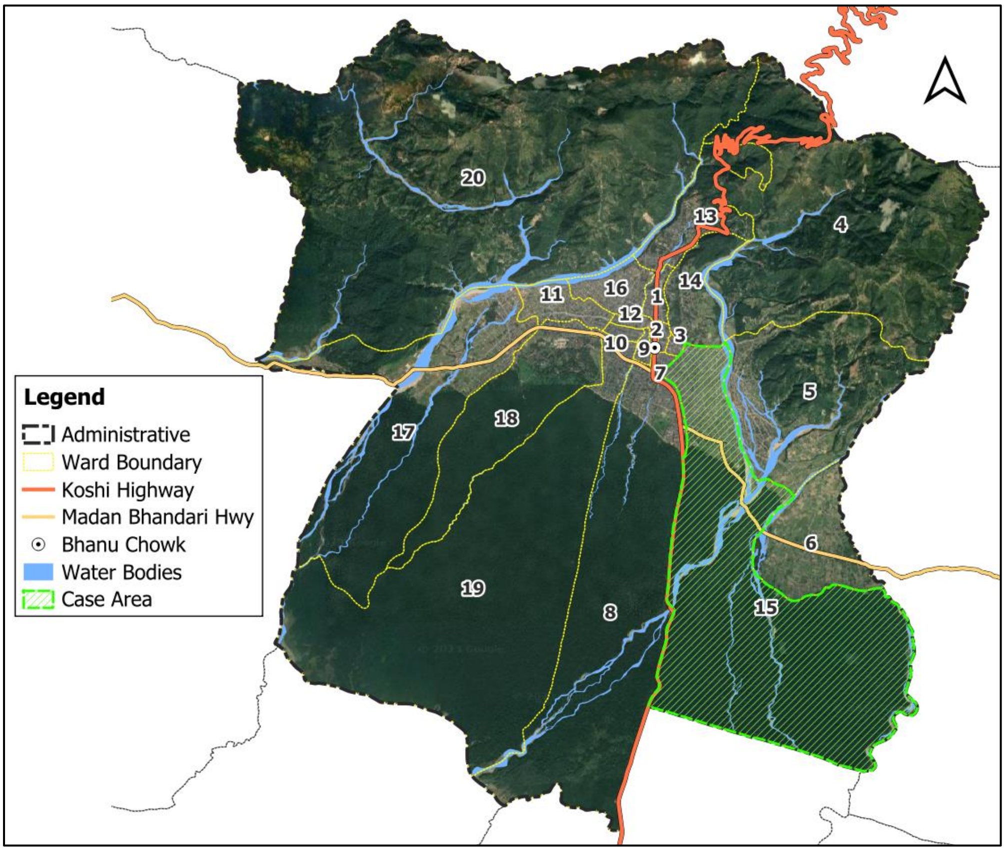

Figure 31 Map of designated case area

The selected study site is Ward 15 within the Dharan Sub-metropolitan city, comprising a total population of 27,411 individuals, with 12,845 being males and 14,596 females (CBS 2021). This ward spans across an area of 25.54 square kilometres and encompasses 4,726 households. Ward 15 has become a focal point of concern due to its proximity to the municipal dumping site, which has adverse effects on nearby forests and rivers. Additionally, this ward is experiencing rapid growth and the emergence of new developments.

Ward No.	Household (2017)	Population	Male	Female	Area (Sq.Km)	Density
15	4,726	27441	12845	14596	25.544	1074
Total	32,683	166531	78410	88121	192.98	866

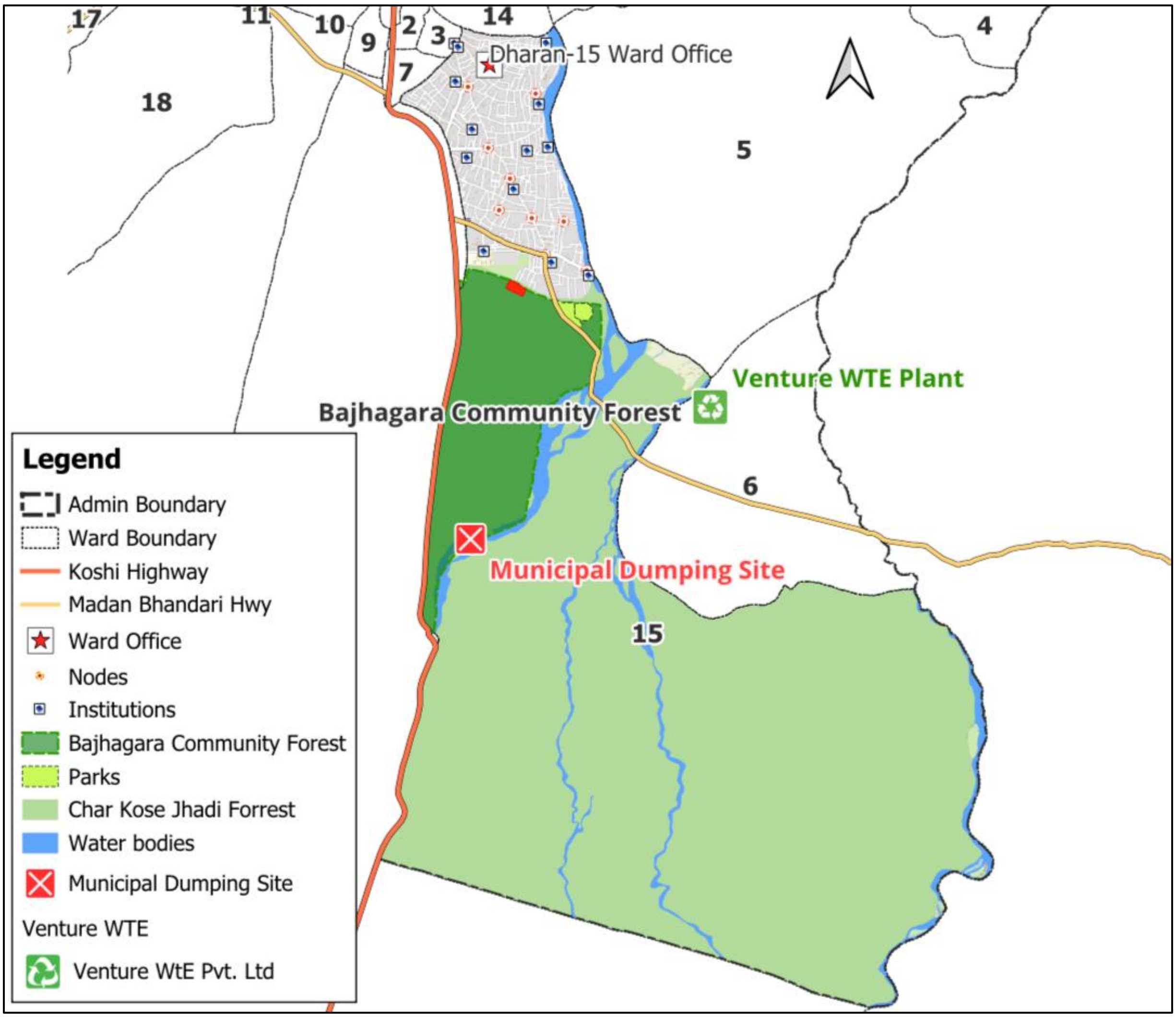

Figure 32 Ward 15, case area

Site Features (Ward no. 15):

- Location of municipal dumping site
- Location of Bajhagara community forest (affected area)
- Location of Seuti River (affected area)
- Ward wise highest number of population

Dharan has been rapidly urbanizing. Along with the population growth, the waste generation pattern is also arising.

Waste management cannot be accomplished sustainably with the current available conventional waste management approach of collection, transport, and disposal. Since the collection and disposal of waste only move problems from one location to another, waste management is more than crisis management related to these activities. Therefore, it is necessary to assess the current waste generation and management system.

CHAPTER 6. ANALYSIS AND FINDINGS

6.1 Data collection framework

For the data collection, the main objective was classified into further sub-objectives or specific objectives. And from the primary and specific objectives, variables or research or research questions were derived. After establishing the variables, data were gathered from diverse sources, including Key Informant Interviews (KII), household surveys (HH's survey), observations, literature reviews, case studies, and more.

Table 19 Framework for data collection

Main objective	Specific objective	Variables or Research questions	Sources
To assess the current municipal solid waste management pattern and explore the ways to manage the unsanitary disposal of solid waste in urban forests taking the case of Bajhagara forest, ward no 15 of Dharan	Assessment of current waste management pattern of Dharan with prevalent use of forest for disposal	Nature of waste and composition	Literature study
		Current state of Municipal Solid Waste Management and Disposal	Literature study KII FGDs Observation
		Case study of Bajhagara forest Dumping area	KII Survey Observation
	Study of relevant waste management methods and Practices	Relevant methods/practices	Literature Journals, Articles
		Case Studies	National Case Studies International Case Studies
	Perception and insight of the public regarding SWM	Analysis and findings from case area survey	Field Observation Household Survey Questionnaire Data Analysis

6.2 Waste Generation Pattern:

The waste generation rate of municipal waste is 424.62gm/capita/day and household waste is 212.31gm/capita/day in Dharan city which results in a total waste generation to be 50.92 tons/day (ADB, 2013). Around 7.53 tons/day of solid waste is generated from the commercial areas and 25.46 tons/day from households (ADB, 2013). According to the Dharan SWM team, approximately 10-15% of readily bio-degradable waste is composted individually and 20-30% non-bio degradable waste is either collected by or sold to recyclers and kabadiwalas. The rest of the waste is collected by the SWM team on a daily, weekly or 15 days interval depending upon the location and frequency of waste generation. The municipal waste of Dharan is composed of the waste from residential, commercial, mixed-use, school, cottage industry, etc. Households waste, followed by commercial waste and institutional waste is the disintegrated source of waste in the municipality.

Table 20: Municipal Waste Generation Rate, ADB 2013

Municipality	Dharan
Average Household Waste (Kg/Day)	1.17
Average Household Size (Members)	5.53
Average Per Capita HH Waste (Gm/Capita/Day)	212.31
Daily Household Waste (Tons/Day)	25.46
Daily Commercial Waste (Tons/Day)	7.53
Daily Institutional Waste (Tons/Day)	0.44
Avg. Per Capita MSW (G/Capita/Day)	424.62
Daily MSW Generation (Tons/Day)	50.92
Estimated Waste Collection (Tons/Day)	35.0
Efficiency Of Collection (%)	68.7

6.3 Waste Characteristics

The quality and composition of waste in Dharan differs accordingly to the people activities. Following are the waste composition in different purpose like household, commercial, and institutional. According to the ADB 2013 survey report, the municipal solid waste composition was found out to be as follows:

Table 21: Municipal Solid Waste Composition of Dharan, ADB 2013

Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	58.34	25.57	22.39
Plastics	15.49	18.27	21.29
Paper Products	11.30	17.09	37.81
Glass	2.43	7.99	3.70
Metals	6.24	6.76	3.89
Textiles	2.96	4.23	2.26
Rubber/Leather	0.75	0	1.18
Others	2.48	20.09	7.47

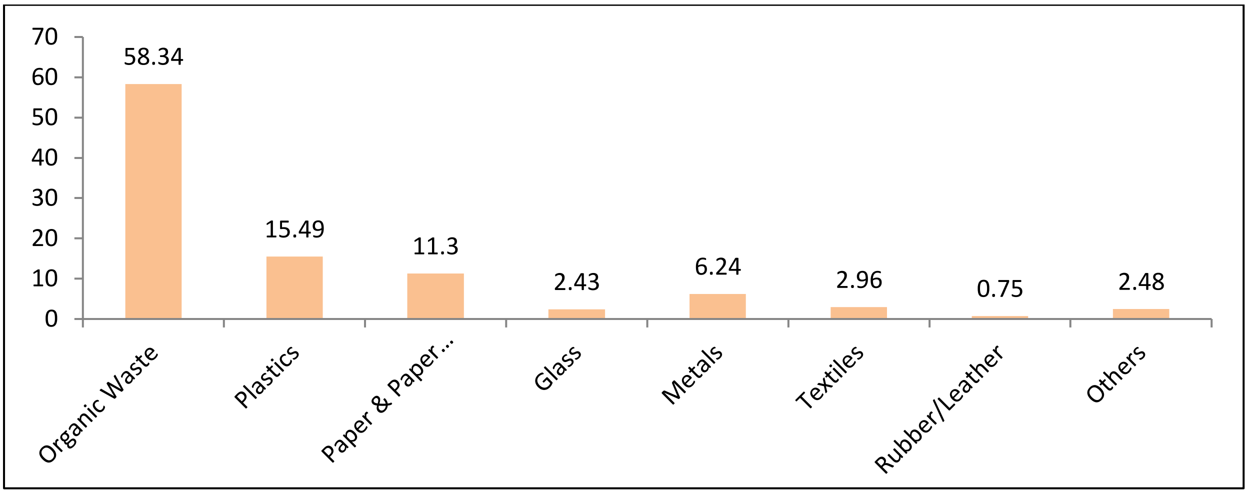

Figure 33: Household Waste Composition (%)

Institutional Waste Composition of Dharan

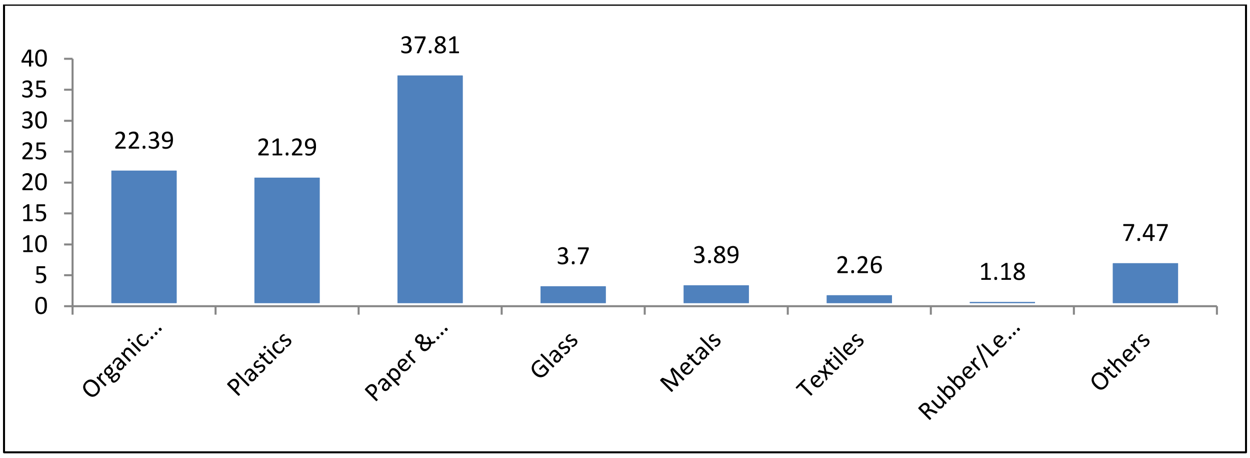

Figure 34: Institutional Waste Composition (%)

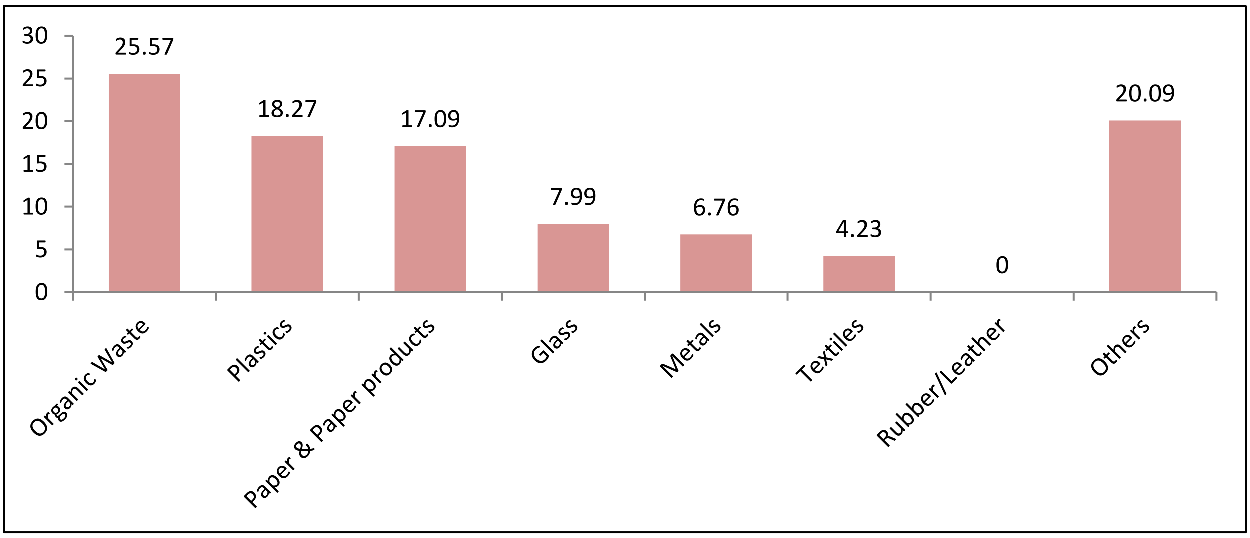

Figure 35: Commercial Waste Composition (%)

6.4 Existing Solid waste management strategy in Dharan

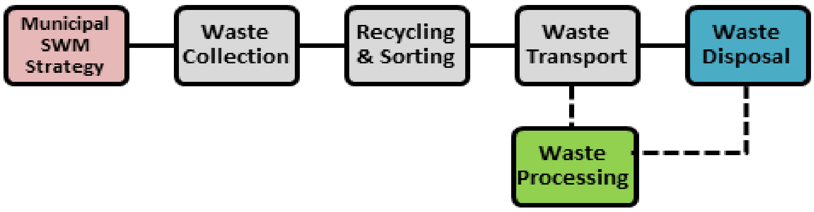

Figure 36: Municipal Solid Waste Management Strategy

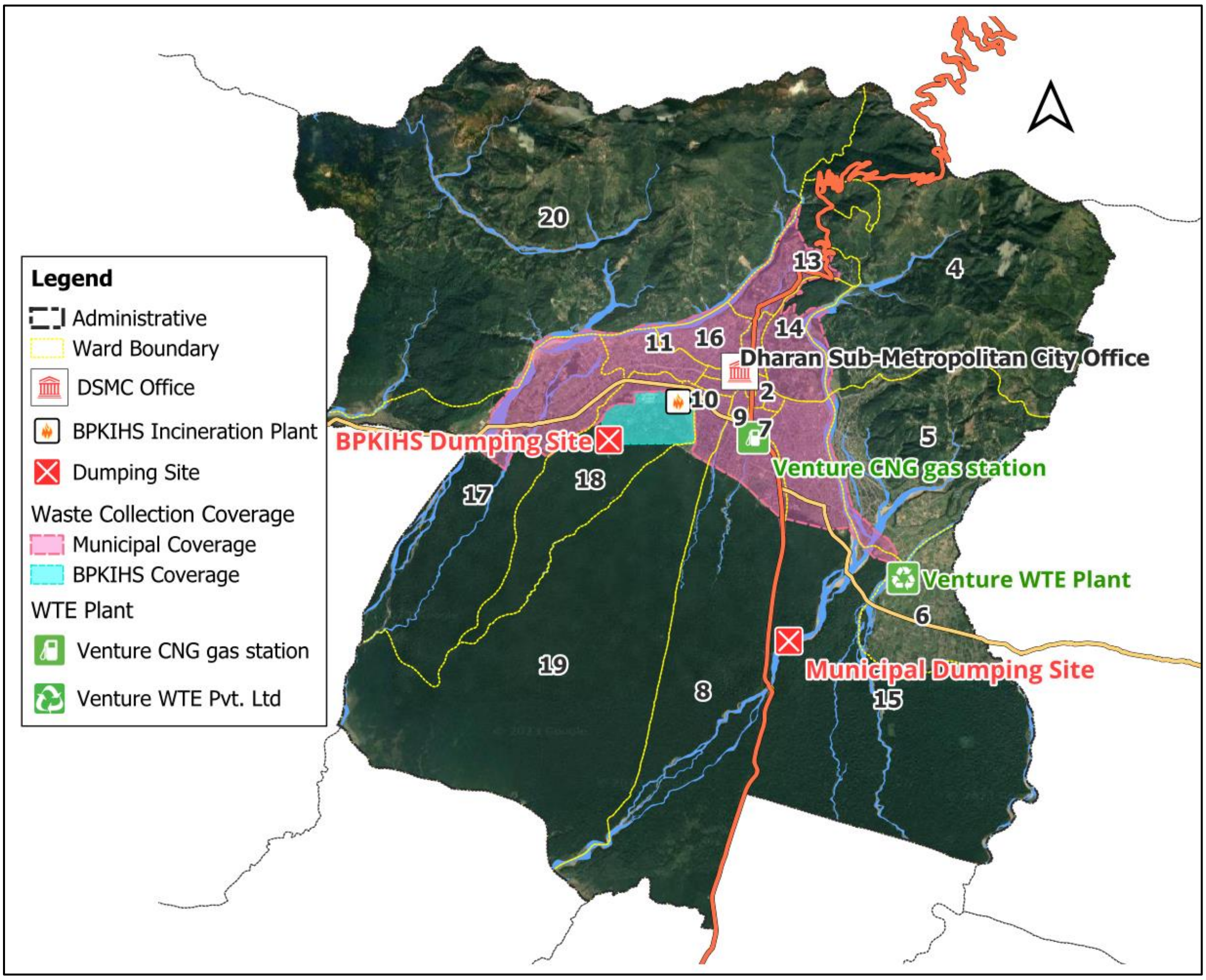

Figure 37: Solid Waste Management System, Dharan

The sub-metropolitan city has department of forest, environment and risk management to analyze and control all the relevant forest and environmental issues and hence is responsible for regulating the policies and managing all the activities that is concerned with solid waste management of the overall city. The sub-metropolitan city has registered service providers for solid waste management. The registered solid waste management team works under the supervision of environment officer and respective authorities. The overall team is led by an assigned in-charge of the SWM team. The SWM team is equipped with 9 Waste collection vehicles (3 tripper and 6 tractors) and 75 members. Out of which, 63 actively works in fields and remaining 12 handles the office and paper works. The SWM team looks after the solid waste of only municipal designated areas. This area includes all the wards of Dharan except for ward no. 5, 6 & 20. The SWM team also excludes the BPKIHS area from waste management because BPKIHS have their own autonomous waste management strategy and all the hospital wastes are collected and disposed of internally. Among the 42,396 households in the city, 32,891 households have access to services provided by solid waste management organizations. This implies that a majority, consisting of 9,517 households, are responsible for disposing of or managing their waste independently. According to Bhes Raj Ghimire, Chief of the Department of Environment, Dharan generates approximately 22 tons of organic waste and 15-20 tons of inorganic waste daily. To address waste processing in Dharan, the Venture Waste to Energy Private Limited (Venture WTE Pvt. Ltd) plant was established in the Panbari area, ward no.6 of Dharan. Its establishment resulted from a tripartite agreement involving Dharan Sub-metropolis, the Alternate Energy Promotion Centre, and Venture Waste to Energy Pvt. Ltd. This agreement was formalized on June 8, 2017. The facility has the capacity to process 50 tons of waste daily, with recyclable materials being sold to recycling companies. Plant Engineer Agarwal's analysis indicates that out of the total waste generated, 60-65% can be converted into manure, 17-20% is reusable and recyclable, and the remaining 20% can be managed through sanitary landfill. The plant was officially inaugurated on January 4, 2022, with the ceremony presided over by the Prime Minister Sher Bahadur Deuba. At present, only Venture WTE Pvt. Ltd segregates organic waste from non-organic waste. Most of the municipal household waste collected in the area is sent to the Venture WTE plant in Panbari for processing before final disposal. Mangal Pariyar, the Waste Management In-charge, reports that approximately 50 tons of waste is produced daily, and the Solid Waste Management (SWM) team manages to collect 25-35 tons per day. About 10-13 tons of waste is directed to the Venture WTE plant, while the rest is directly deposited in a dumping site located in a riverside forest area. The waste sent to the processing plant is treated based on its type. According to the plant manager Hari Upreti, approximately 50% Biodegradable organic waste is processed to produce CNG gas costing upto Rs. 130/kg, and solid particles from organic waste are transformed into organic fertilizer, which is priced at Rs. 65/kg. Non-biodegradable recyclable waste (30%) is separated and recycled to the greatest extent possible, with the remaining (15-20%) of non-recyclable waste being sent to the dumping site for final disposal. Unfortunately, due to recent policy complications and coordination issues among stakeholders, the Venture WTE plant has not been able to utilize its full capacity, resulting in inefficiencies in Dharan's solid waste management.

6.4.1 Collection and transportation

There is a provision of door to door waste collection in Dharan city. The door to door collection is available in every ward except ward no. 5,6,20 and BPKIHS area. Waste collection is done daily, weekly, and in 15 days interval. The frequency of collection depends upon the location and the amount of waste generated. There is a fleet of 9 vehicles (3 tripper and 6 tractors) for the waste collection. The crew members operate the waste collection from very early in the morning up to late evening according to the necessity and demand. About 25-35 tons of waste is collected daily depending upon the situation and circumstances. Out of collected trips, 10-13 trip of waste is sent to Venture WTE plant for further processing and the rest is sent to the dumping zone located in Bajhagara forest area, ward-15.

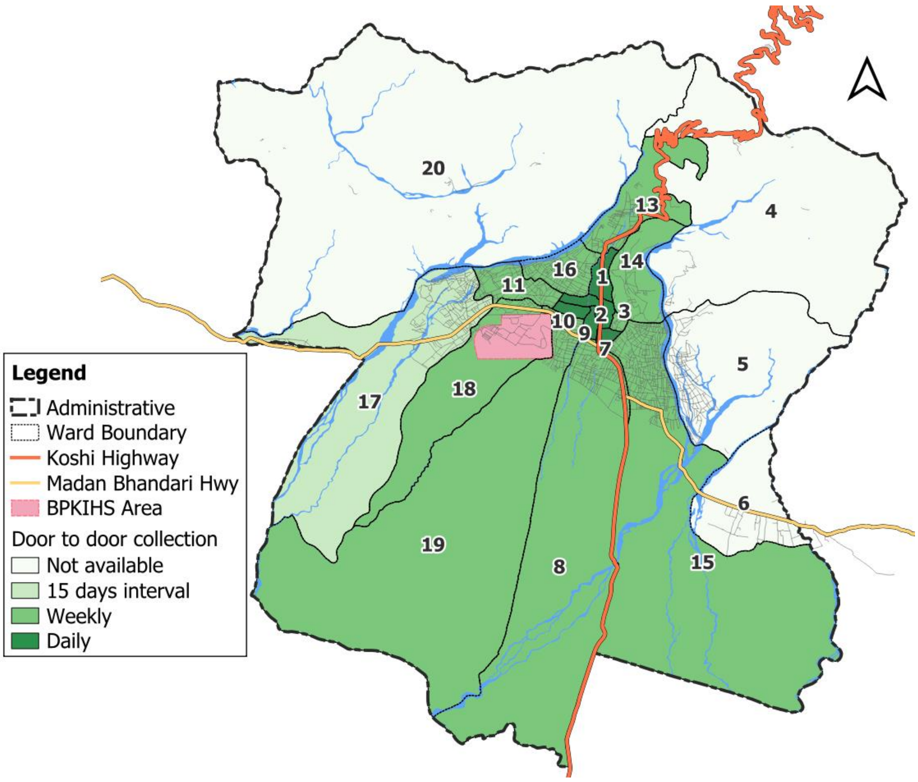

Figure 38: Door to door collection ward-wise

Table 22 Waste collection frequency

Area	Roadside	Community	Door To Door
Densely Populated	*Daily*	*Daily*	*Almost daily*
Outside The Market Area	*Daily*	*Weekly*	*Weekly*
Semi-Rural Parts	*Weekly*	*15 Days interval*	*Not Available*

6.4.2 Waste Processing and Treatment

Figure 39: Venture WTE Plant, Dharan-6

After the collection of municipal household waste, most of the collected wastes are sent to waste processing plant before final disposal. For the waste processing, there is a WTE plant named Venture WTE Pvt. Ltd constructed in Panbari area after a tripartite agreement between Dharan Sub-metropolis, Alternate Energy Promotion Centre and Venture Waste to Energy Pvt. Ltd. on June 8, 2017. The plant has the capacity to refine 50 tons of waste daily while the recyclable waste would be sold to the recyclers. It was inaugurated by then prime minister Sher Bahadur Deuba in Jan 04, 2022. Chief of Department of Environment Bhes Raj Ghimire said that 22 tons of organic waste and 15-20 tons of inorganic waste is produced in Dharan on a daily basis. According to Er. Agarwal, out of the total waste 60-65 per cent of waste can be turned into manure, 17-20 per cent waste is reusable and recyclable and 20 per cent can be managed into sanitary landfill. According to the Waste management in-charge Mangal Pariyar, 50 tons of waste are generated daily, out of which SWM team has been only able to collect 25-35 tons per day. About 10-13 tons of waste is sent to Venture WTE plant and remaining is directly dumped in dumping site located in riverside forest area. The waste that is sent to processing plant will be processed according to its typology. The biodegradable waste is processed to produce CNG gas and the solid particles from organic waste are converted to an organic fertilizer costing up to Rs. 65/kg. Similarly, the non-biodegradable waste is segregated and recycled to most extent and the remaining 30% non-recyclable wastes are sent to the dumping site for disposal. But lately due to some policy implications and coordination among stakeholders, the Venture WTE plant has not been able to utilize its capabilities to full extent. This has led to ineffectiveness and inefficiency in managing the solid waste of Dharan. After the waste treatment and processing, 15-20% non-recyclable waste from WTE plant is then departed towards the dumping site located in Bajhagara forest area near Seuti River for final disposal. The rest of the collected waste those are untreated are also transported towards the dumping site. As per the waste management official, no kind of treatment or technique for final disposal of waste is employed and the waste is directly dumped in an open area in unhygienic way.

Figure 40: Waste segregation and processing, Venture WTE Pvt. Ltd.

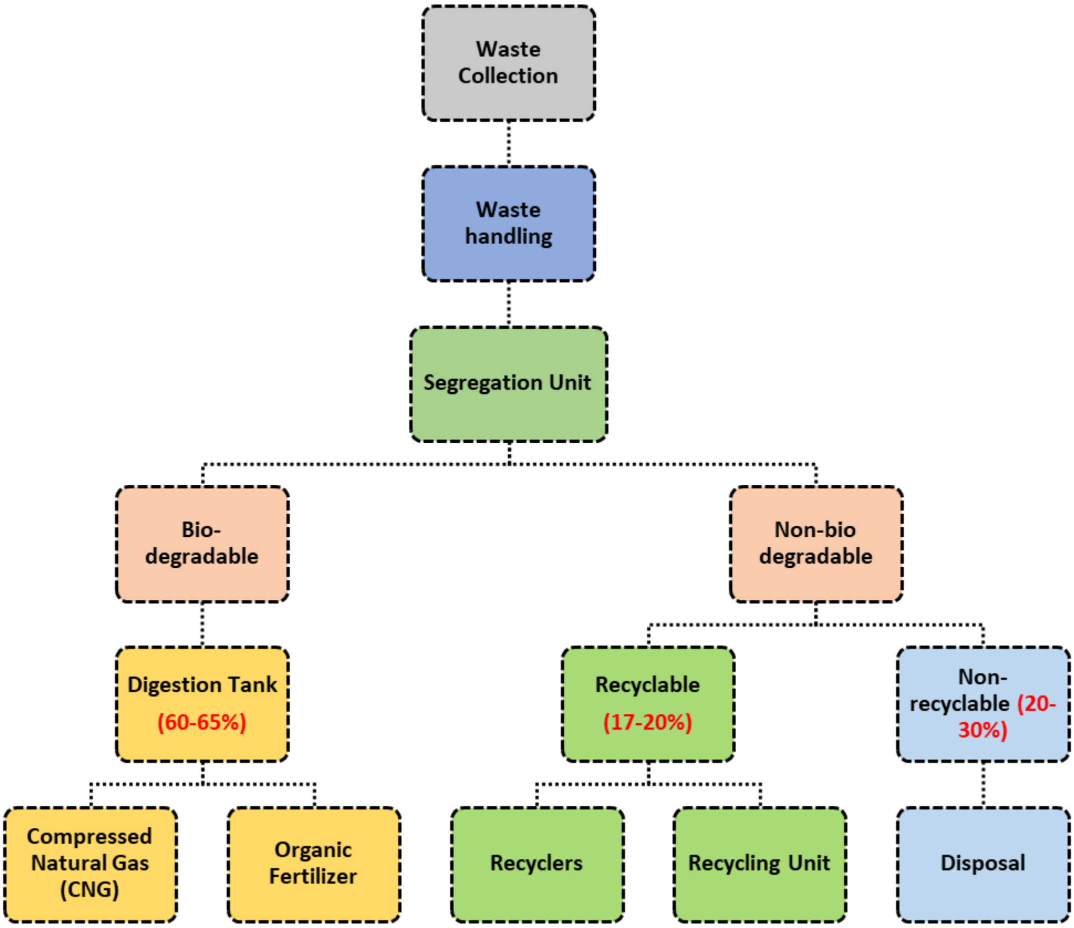

Figure 41 Waste Treatment Process, Venture WTE Pvt. Ltd

6.4.3 Waste Disposal

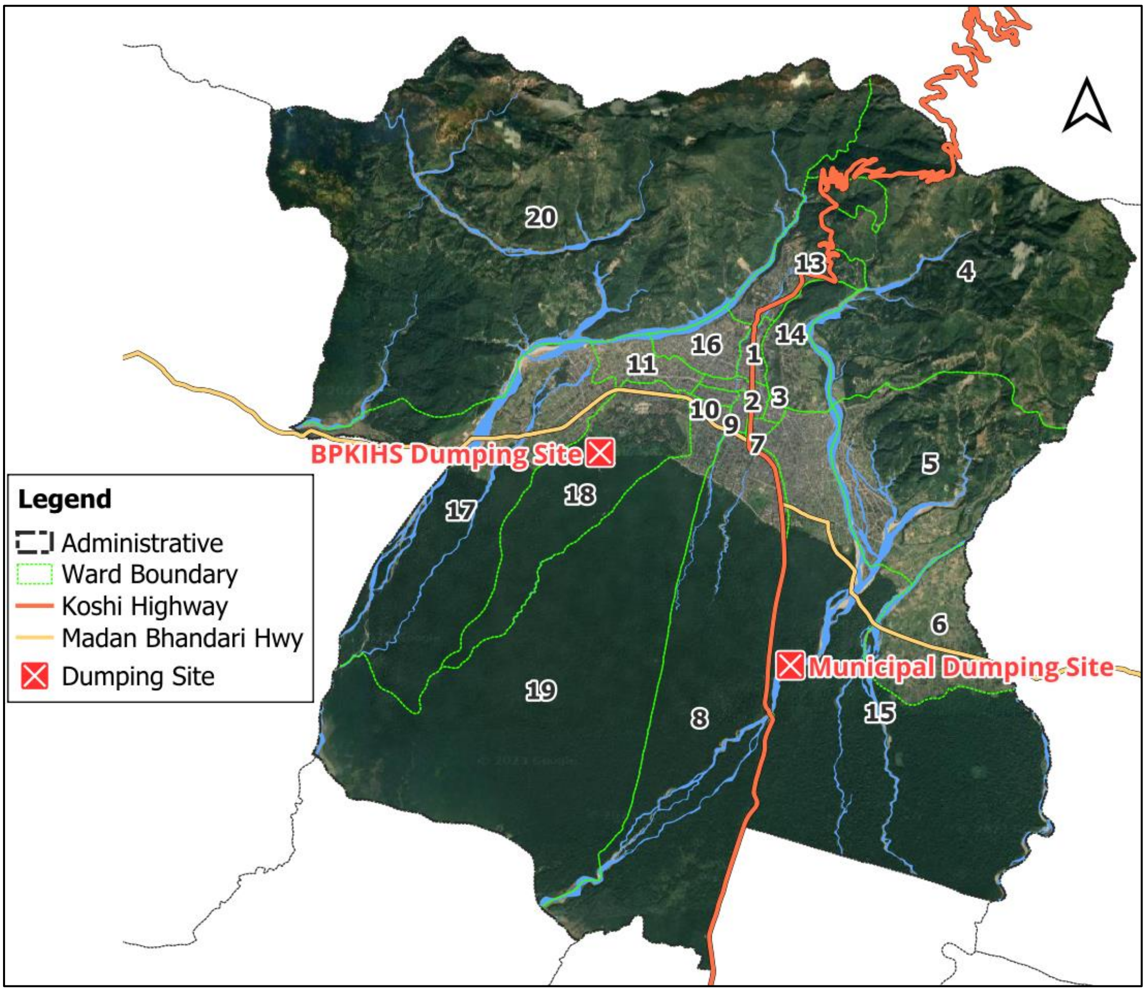

Figure 42: Map showing dumping site of Dharan

Figure 43 Access to Dumping site from Koshi highway

In Dharan, there is no official designated landfill site for waste disposal. Instead, most of the city's municipal waste is disposed of in forest areas and along the riverside. There's an informal dumping area for municipal waste in the Bajhagara forest, which is in Ward No. 15 of Dharan. The majority of the waste collected by the waste management department is directed to Venture WTE Pvt. Ltd., while the remaining portion is directly deposited in the forested areas. According to personnel responsible for solid waste management (SWM), approximately 10-13 tons of waste is directly sent to this dumping zone on a daily basis. This place is used as a dumping ground for more than three decades and was operated without the agreement or consent from the Bajhagara forest users committee. According to the Bajhagara forest users committee's chief Rajan Moktan, the municipal authority had assured to allocate a proper waste disposal facility with an environmental considerations to resolve the current haphazard dumping issues but currently, no any specific solutions, or outcomes of the research have emerged from the municipal authorities even after 3 decades later. So, this had led to the significant concern on current waste disposal practices as the present dumping practices have led emergence of lots of detrimental effects to the bio-diversity of the Bajhagara community forest. The municipal dumping site is directly accessible from the Koshi Highway. The dumping zone stretches from the highway in the west towards the bank of Seuti River in the East which demarcates the boundary of Bajhagara Community Forest. The shape of dumping zone is elongated polygon shape that is accessed with the informal road and is only operated by the Municipal waste management team or vehicles. At first, the waste was only limited to the bank of the river but as the time passed, the dumped waste kept on increasing and ultimately led towards a formation of piles of mixed waste that can be very detrimental for the public's health and bio-diversity.

Additionally, B.P. Koirala Institute of Health Sciences (BPKIHS) also manages their waste within its dumping area located inside the hospital premises, near the Chaar Kose Jhadi forest. This area is utilized for disposing of non-infectious waste and remaining waste that has not undergone incineration. The waste collected from BPKIHS is segregated to three categories, i.e. infected, non-infected and green waste (bio-products, branches, grass etc.). The infected waste is directly incinerated in the incineration plant of BPKIHS and the non-infectious waste is packed and dumped in the dumping zone and lastly the green waste are further disposed in the forests area without harming the bio-diversity.

Figure 44: Present Situation of Municipal Dumping site

Figure 45: BPKIHS Waste Disposal Method

6.5 Dumping in Urban Forests

6.5.1 Overview of Bajhagara Forest:

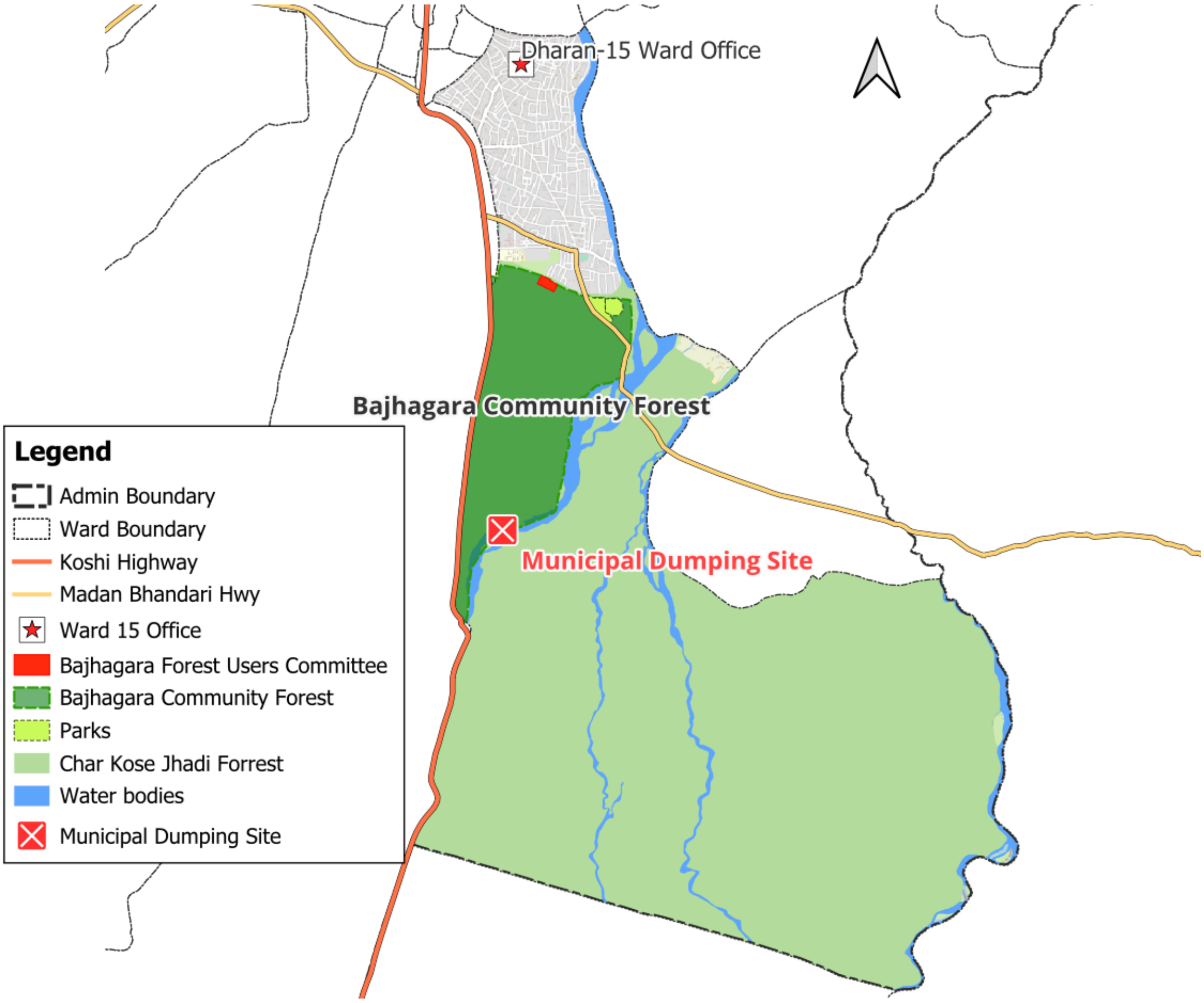

Figure 46 Bajhagara Community forest location map

Bajhagara Forest Users Committee was officially formed on 2059 B.S. It is located in the heart of the ward no 15 of Dharan sub-metropolitan city and covers the total land area of 2.88 sq. km. The boundaries of Bajhagara forest area is demarcated as follows:

- East: Seuti River
- West: Koshi Highway
- North: T.U. IOE ERC boundary wall and settlements
- South: Seuti River Bridge

Flora and Fauna: The Bajhagara community forest is home to a variety of plants, wildlife and ecosystems. The biodiversity of the Bajhagara community forest encompasses various plant species, as well as animal and bird species, along with their respective ecosystems. According to the Bajhagara forest profile and KII, the native tree species are: Sal, Karma, Banyan, Harro, Barro, Amla, Bhalayo, Hallude, Kumbhi etc. Similarly, the native wildlife species are: Leopard, Rabbit, Chhittal, Monkey, Langur, Coyote, Squirrel, Wild Cat, Porcupine, Monitor Lizard, Pangolin etc. And lastly, the native bird species are: Hornbill, Parrot, Theuwa, Mynah, Red Billed Blue Magpie, Cuckoos, Peafowl, Red Jungle fowl, Sparrow etc.

6.5.2 Extent of Haphazard Dumping

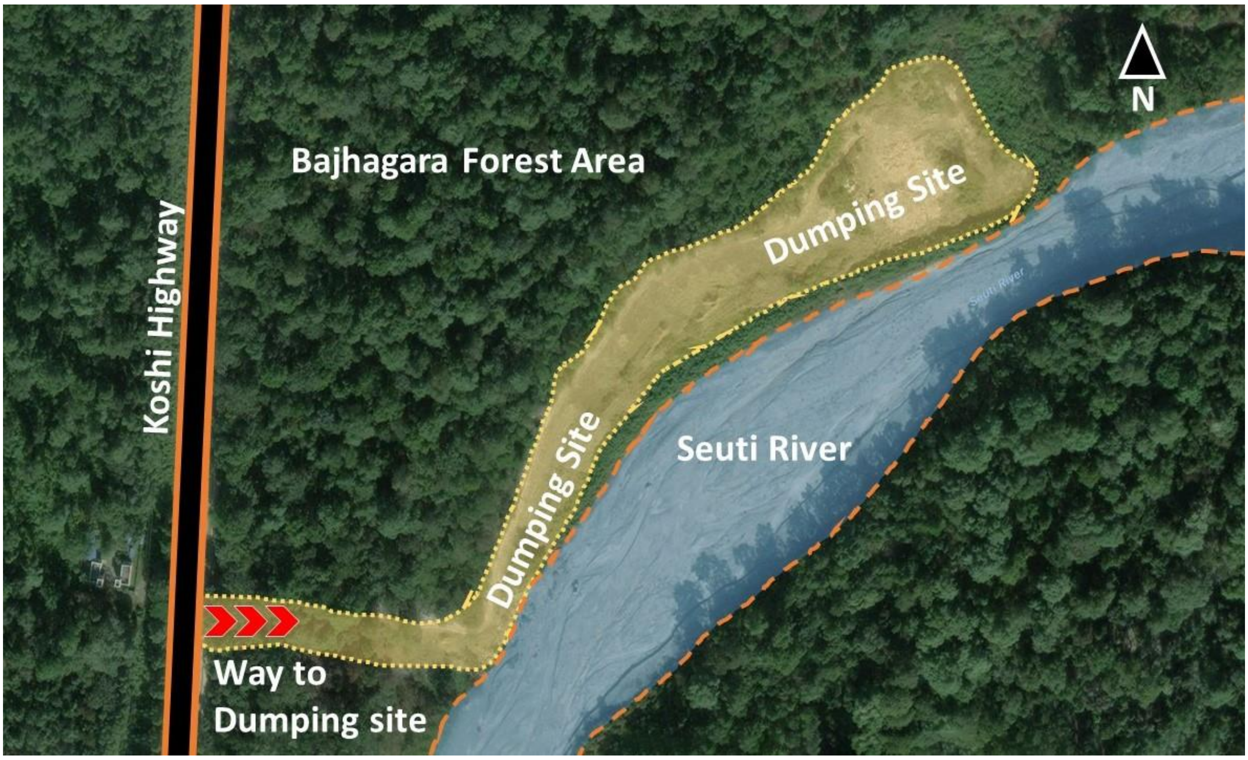

Figure 47 Dumping Site

In the current scenario, Dharan lacks an official landfill site, compelling the Solid Waste Management (SWM) authority to explore feasible and cost-effective locations for daily waste disposal. This situation has resulted in the current practice of dumping municipal waste in the urban forest of Dharan, specifically in ward no. 15. This practice has persisted since 1986 A.D. While urban forests are vital for ecological balance and the maintenance of climatic conditions in urban areas, there has been a lack of investigation or implementation of environmentally-safe solid waste disposal methods. Furthermore, waste segregation or segregated collection has not been implemented, resulting in the disposal of predominantly mixed-type waste without any pre-treatment. According to SWM personnel, approximately 10-13 tons of waste are directly deposited into the Bajhagara forest on a regular basis. No prior methods or scientific treatments are applied to this waste and is haphazardly dumped.

Figure 48: Situation of dumping site

Municipal authorities have indicated that there is an ongoing investigation to identify an environmentally-safe sanitary landfill site for waste disposal in Dharan. However, there is currently no information available regarding the outcomes of this research even after a couple of decades later.

Figure 49 Leachate contamination due to industrial discharge.

Apart from that, the industrial estate near Bajhagara forest in Dharan 8 also poses a grave environmental threat due to the uncontrolled discharge of toxic wastewater directly into the forest. Activities like rice packaging, manufacturing plastic pipes and plumbing items generate pollutants, resulting in dark, foamy water filled with harmful chemicals. This wastewater flows from the estate’s drainage and directly contaminates the nearby Bajhagara forest, located just 50 meters away. Unlike household waste, industrial wastewater is concentrated with toxins harmful to the forest's plants, animals, and biodiversity. The continuous inflow of hazardous wastewater has led to soil contamination, affecting plant growth, and groundwater pollution. This unregulated discharge disrupts the forest ecosystem, potentially causing habitat loss and harm to various species. Proximity to the industrial estate intensifies the damage. Urgent measures, including strict rules, proper waste management, and wastewater treatment, are essential to prevent irreversible damage to Bajhagara forest and the surrounding environment

Impact on flora and fauna:

Figure 50 Cattles and monkeys roaming at the dumping site

Various types of municipal waste, encompassing organic, inorganic, and bio-waste, are haphazardly deposited in this forests area, resulting in detrimental effects on both soil quality and biodiversity. This indiscriminate dumping has given rise to significant environmental complications, posing risks to the plant and animal life in the Bajhagara area and its surrounding forests. Species such as monkeys, chital, and cows have suffered severe consequences due to the presence of these dump sites. Many animals have fallen victim to toxins present in the accumulated waste, leading to a decline in their population. Primarily, monkeys, deer, and cows from nearby temples wander around these piles of debris. Additionally, the leachate produced from the accumulated waste over time has led to soil fertility degradation and the potential loss of habitats. The presence of leachate makes it challenging to access the dumping area on foot, especially during the rainy season. Moreover, it has had a profound impact on plant growth, disrupted the ecosystem, and compromised the health of recyclers, waste workers, and solid waste management staff.

Impacts on the Riverside:

Similarly, the water quality of the nearby river has been significantly compromised due to the existence of the dump site along its banks. Although direct dumping into the river has ceased due to protests from affected communities, the indirect effects aroused from the nearby dumping are clearly evident along the riverside.

Figure 51 Presence of waste nearby Seuti River

Numerous non-recyclable materials such as plastics, construction debris, glass, and metal parts are noticeable along the riverbank. This river, classified as an Ephemeral River, typically flows only during the rainy season. Consequently, waste particles continuously accumulate along the riverside throughout the year, and during the monsoon season, the river sweeps these accumulated waste particles downstream, ultimately affecting water quality and impacting the surrounding municipalities.

Dumping area coverage:

The dumping area extends over a distance of 585.76 meters along the riverside. It is characterized by varying widths, measuring 20 meters, 30 meters, and 90 meters. The dumping site is partitioned into three sections: the initial segment serves as the entrance to the site and has a width of 20-25 meters, the middle part functions as a transportation zone with an 8-meter-wide road for the movement of waste from the city to the primary dumping site using tractors and trippers, and the final section constitutes the primary dumping area where the majority of waste accumulates. Waste workers and recyclers operate in this section, sorting and handling some portions of recyclable waste. This site has served as a municipal dumping ground for over three decades and continues to be operational. Consequently, the dumping site has expanded over time. Currently, it occupies a total land area of 17,785 square meters constituting 0.017 sq.km i.e. 0.69% of the overall Bajhagara forest land area.

Figure 52 Dumping Coverage Area

Figure 53 Dumping site segments

Analysis for future landfill requirements:

For the calculation of landfill area requirements, data from various field study, research, journals, articles, online portals etc. were studied and proper method of landfill space calculation was employed. The estimation method was adopted from annex report published in the website of (MOHUA, 2023).

Landfill Area Coverage:

(i) Current population of Dharan (P): 166,531 (CBS 2021)

(ii) Average per capita MSW generation (g/capita/day): 424.62 (ADB 2013)

(iii) Previous daily waste generation: 50.92 tons/day (ADB 2013)

(iv) Current Daily waste generation: Recent population x avg. MSW Generation

= 70.7 tons/day

(v) Estimated rate of increase of waste generation per year (x)

= 50.92tons/day to 70.7tons/day in 10 years (2011-2021)

= Approx. 2 tons/day each year (2.85%)

(vi) Current Waste Generation = 70.7 tons/day

(vii) Current Annual Waste Generation (W): 70.7 x 365 days

= 25,805 tons/year

For 5 years:

a) Estimated Waste Generation after 5 Years = $25,805 (1 + 2.85/100)^5$

= 29,700 tons/year (80 tons/day)

b) Total Waste Generation in 5 Years (T)

= $\frac{1}{2} [W + W (1 + x/100)^{n]} n$ (tons)

= ½ [25,805 + 29,700] x 5

= 138,762.5 tons

c) Total Waste Volume (assumed density 0.85 t/cu.m.)

= (138,762.5)/0.85

= 163,250 cu.m.

Similarly, the average MSW composition of Dharan SMC shows 35.4% of waste as organic, assuming 100% source segregation and removing the organic portion of the waste, the volume of landfill-bound waste can be minimized to net volume of:

= T – Organic portion of T

= 163,250 – 35.4% of 163,250

V_w = 105,460 cu.m.

d) Volume of Daily Cover

$V_{dc} = 0.1\ V_w$ (cu.m.)

= 0.1 x 105,460

= 10,546 cu.m.

e) (f) Volume of Liner and Cover Systems (assuming maximum landfill height of 5m and taking k = 0.5)

$V_c = k\ V_w$ (cu.m.)

= 0.5 x 105,460

= 52,730 cu.m.

f) Volume reduced due to settlement (V_s) = m V_w

= 0.05 x 105,460

= 5,273 cu.m.

g) First Estimate of Landfill Volume

$Ci = V_w + V_{dc} + V_c - V_s$ (cu.m.)

= (105,460 + 10,546 + 52,730 – 5,273)

= 163,463 cu.m.

h) Landfill space requirements:

Assuming the maximum height of 5m, and partly below ground level (2m),

- Possible Maximum Landfill Height = 7 m
- Area Required (A_r) = (163,463)/7

  = 23,351 sq.m.

For 10 years:

a) Estimated Waste Generation after 10 Years = 25,805 $(1 + 2.85/100)^{10}$

= 34,180 tons/year (93.6 tons/day)

b) Total Waste Generation in 10 Years (T)

$= ½ [W + W (1 + x/100)^{n]} n$ (tons)

= ½ [25,805 + 34,180] x 10

= 299,925 tons

c) Total Waste Volume (assumed density 0.85 t/cu.m.)

= (299,925)/0.85

= 352,850 cu.m.

Similarly, the average MSW composition of Dharan SMC shows 35.4% of waste as organic, assuming 100% source segregation and removing the organic portion of the waste, the volume of landfill-bound waste can be minimized to net volume of:

= T – Organic portion of T

= 352,850 – 35.4% of 352,850

V_w = 229,350 cu.m.

d) Volume of Daily Cover

$V_{dc} = 0.1\ V_w$ (cu.m.)

= 0.1 x 229350

= 22,935 cu.m.

e) Volume of Liner and Cover Systems (assuming maximum landfill height of 5m and taking k = 0.5)

$V_c = k\ V_w$ (cu.m.)

= 0.5 x 229,350

= 114,675 cu.m.

f) Volume reduced due to settlement (V_s) = m V_w

= 0.05 x 229,350

= 11,467.5 cu.m.

g) First Estimate of Landfill Volume

$Ci = V_w + V_{dc} + V_c – V_s$ (cu.m.)

= (229,350 + 22,935 + 114,675 – 11,467.5)

= 355,492.5 cu.m.

h) Landfill space requirements:

Assuming the maximum height of 5m, and partly below ground level (2m),

- Possible Maximum Landfill Height = 7 m

- Area Required (A_r) = (355,492.5)/7

= 50,784.6 sq.m.

Therefore,

The estimated future landfill space requirements of Dharan is calculated as,

- For next five years: 23,351 sq.m.
- For next ten years: 50,784.6 sq.m.

6.6 Community Perception and Concerns

A survey involving more than 50 respondents from Ward No. 15 of Dharan was conducted to study the community's sentiments and attitudes towards solid waste management. The survey aimed to understand the extent of people's involvement, their awareness of eco-friendly waste management initiatives, and their aspirations for a cleaner and greener urban environment. In the research study, random sampling techniques were employed, involving a sample size of approximately 50 respondents. The sample size was determined based on various classifications, including age, gender, class, type of building use, location (Tole), and tenancy status. It is important to note that the survey was capped at 50 respondents once the saturation level was achieved.

Methods like household questionnaires, survey and interviews were adopted to assess and visually represent factors such as people's awareness and participation in waste management, efforts to reduce waste, challenges in waste management, and their preferred methods for waste disposal.

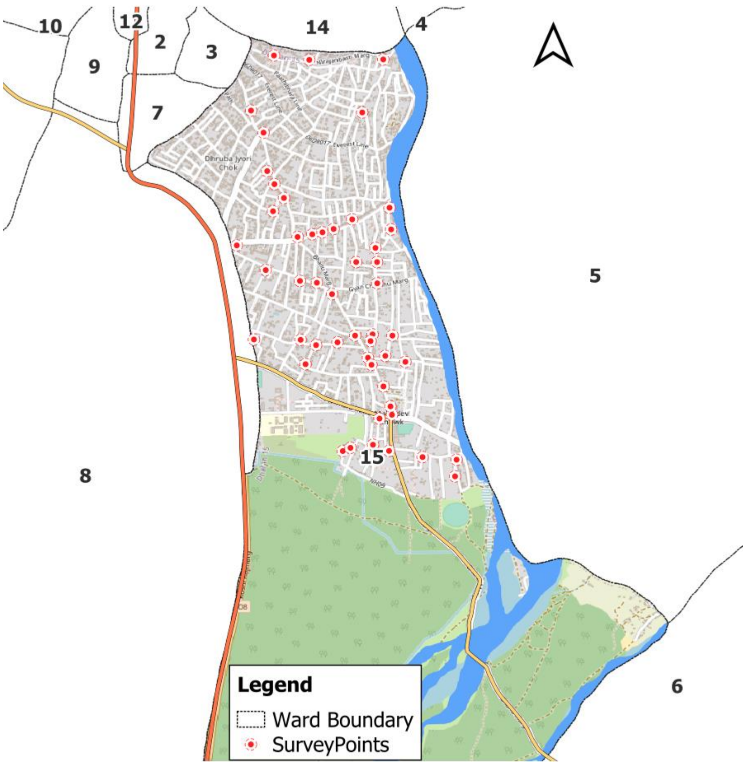

Figure 54 Surveyed points, ward 15

Table 23 Demographic details:

Demographic information of respondents: 50 respondents			
Category	**Value**	**Number**	**Percentage (%)**
Gender	Male	22	44
	Female	28	56
	Others	0	0
Age	15-24	3	6
	25-50	34	26
	Above 50	13	68
Occupation	Housewife	11	22
	Student	4	8
	Service	19	38
	Business	13	26
	Others	3	6
Marital Status	Married	45	90
	Unmarried	5	10
Household Ownership	Owned	29	58
	Rented	21	42
Education	Under SLC	9	18
	SLC	13	26
	Intermediate	18	36
	Bachelor	7	14
	Masters	3	6

The data acquired from household surveys and interviews is presented in the provided charts.

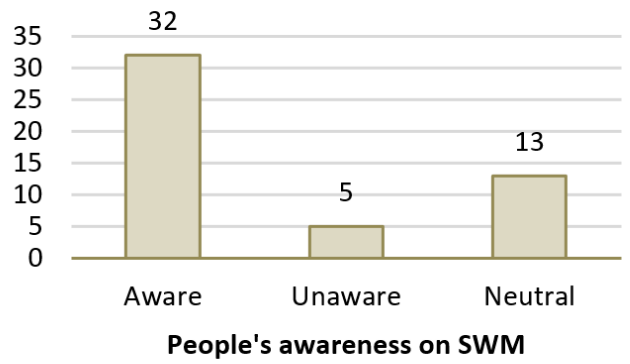

Figure 55 People's awareness on Solid Waste Management.

The survey on people's awareness on current municipal waste management and dumping revealed that 64% respondents were aware of the present situation, while 10% were unaware and the rest 26% were neutral.

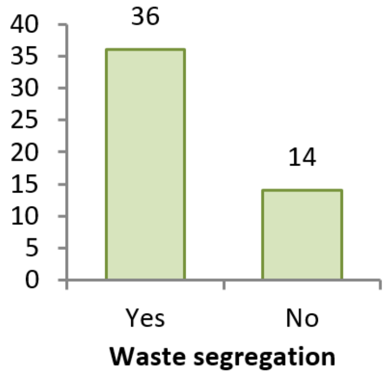

Figure 56 Waste segregation practices

The survey revealed that 72% of the respondents were implementing the waste segregation strategy while the rest 28% were not involved in any kind of segregation practices.

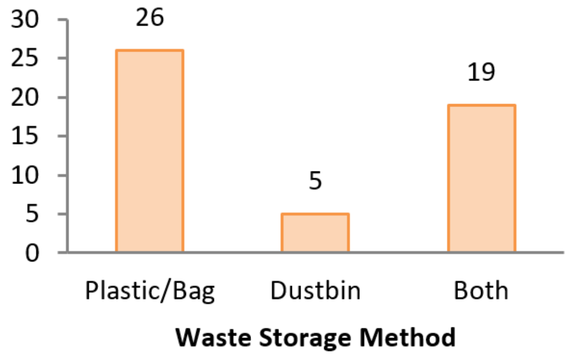

Figure 57 Preferred waste storage method

More than 50% respondents use plastic bag to store their waste and 38% of the respondents use both plastic bag and dustbin while the rest 10% use dustbin only for storing the household waste.

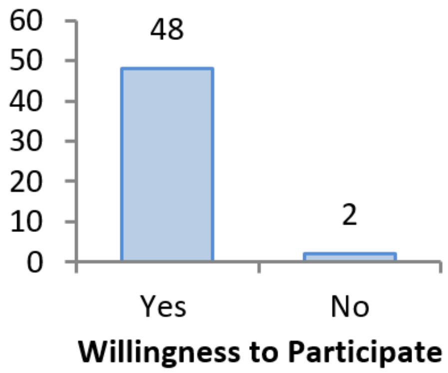

Figure 58 Willingness of the respondents

According to the field survey report, more than 95% respondents were willing to participate in the waste management practice and waste reduction initiatives.

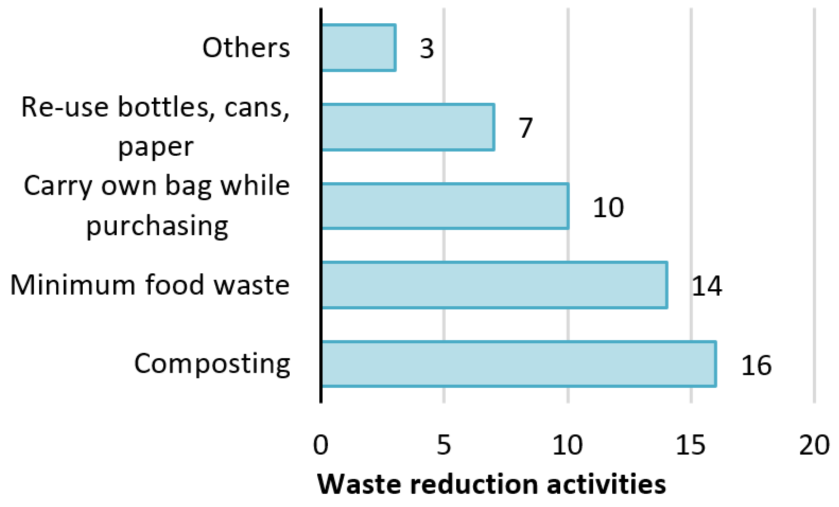

Figure 59 Waste reduction initiatives

Through the field survey, respondents were found out to be involved in different waste reduction initiatives like composting, minimum food waste, carry own bag etc. This showcases the willingness of respondents to cooperate in waste management aspect individually. Additionally, barriers in waste management according to the respondents' perception was also examined. It was found that open dumping was most significant barrier followed by irregular collection, then implementation of segregation strategy and so on.

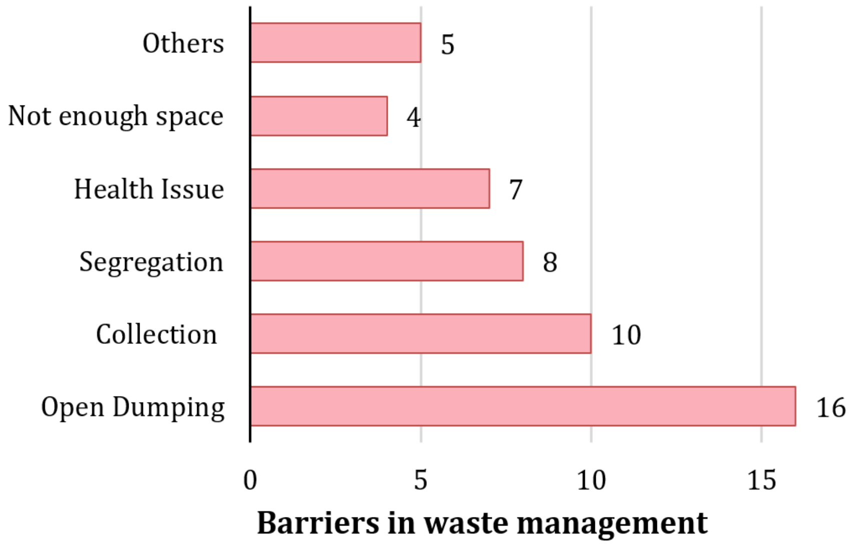

Figure 60 Barriers in Waste management

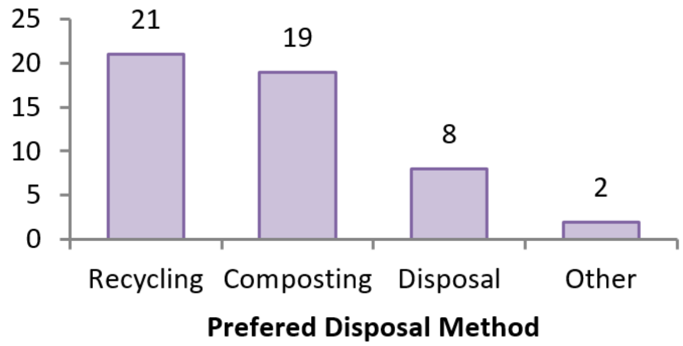

Figure 61 Preferred Disposal Method

Similarly through the field survey, the preferred waste disposal method according to the respondents was also uncovered. Recycling was the most preferred method of waste disposal followed by composting, and so on. Which reveals the awareness and viewpoint of the respondents regarding environmental-friendly waste disposal methods.

The study examined the community's views on current waste management practices and disposal in nearby forests. It was found that the community was unsatisfied with the consequences from open dumping and disposal activities. Community engagement revealed that there is a willingness among residents to support eco-friendly waste management initiatives and a desire for cleaner, greener urban spaces in Dharan. Additionally, it was observed that certain level waste management practices, such as segregation and composting, were being implemented at the household level, indicating an initial step towards sustainable waste management within individual households. These insights emphasize the importance of community engagement in shaping effective and environmentally conscious waste management strategies.

6.7 Key Informant Interview

1. Solid waste management division, Dharan	
• Dharan SWM division has been collecting waste of around 25 tons/day from the different wards of Dharan. Various waste such as organic, medical, plastic, and paper are collected from residential, commercial, medical, institutional, etc. • The waste is collected in mixed and packaged form. The collected waste is inspected for segregation of recyclable wastes and other recyclable goods and is sold to kabadiwalas or recyclers.	 **Mangal Pariyar** In-charge at Dharan fohor byabasthapan

<table>
<tr><td>

- Various incentives were carried out for segregation and distribution of separate bins, and reuse and recycle programs were also conducted.
- Challenges in reuse, recycle: mix waste and difficult to reuse and recycle/ less money in recyclable products.
- Waste load to the landfill: 10-12 tons/day.

</td><td>Covered area: all wards except 5,6,20 and BPKIHS area
Supported by Venture WTE Pvt. Ltd.</td></tr>
<tr><td colspan="2">2. Venture WTE Pvt. Ltd. (Private sector)</td></tr>
<tr><td>

- Venture waste to energy plant has been processing the waste of around 7-12 tons/day from the various places of Dharan. Various waste such as organic waste, plastic, paper, non-organic waste etc. are collected from Dharan and deported to Venture WTE Plant.
- Out of the total waste processed, 60-65 per cent of waste can be turned into manure, 17-20 per cent waste is reusable and recyclable and 20 per cent can be managed into sanitary landfill. If fully operated, the plant itself can handle more than 50 tons of waste daily.
- Financial mechanism: No financial support from the municipality, private investment, revenue is generated through CNG and fertilizer products.
- Challenges in reuse, recycle: No Segregation in individual level. Policy implication has limited the production and consumption of the product. Lack of skilled and determined manpower. Profit is also less (recycled product is not that much in use.
- Waste load to the landfill: 15-20% of total waste.

What must be done?

a. Political cooperation within the stakeholders and policy makers
b. Market accessibility to alternative fuels
c. Public support in source reduction and household segregation
d. Capital investment (vehicles, machines, manpower)
e. The local government must take the responsibility

</td><td>
Hari Upreti
Plant Manager
Established date: 2022
Location: Panbari</td></tr>
<tr><td colspan="2">3. Bajhagara Ban Upabhokta Samiti</td></tr>
<tr><td>

- Waste is collected from the forest committee and nearby 661 households and is segregated according to the recyclability of the waste products. Non-recyclable waste and paper products are disposed by burning.
- Waste reduction training such as composting is provided in collaboration with the society and TLO.

What must be done?

</td><td></td></tr>
</table>

• Reduce the dumping of waste into forest area • Policy regarding the proper waste disposal • Carry out regular surveillance of the forest area • Set up fine or charges for anyone illegally dumping the waste directly into the forest	 **Maya Devi Rai** Secretary Established date: 2059 Covered area: ward 15
Dharan Sub-metropolitan City	
• Wards covered: all wards except 5,6 and 20 • Household Waste composition: organic:58%, plastic:15.4%, paper products: 11.3% glass:2.43% • Municipal Waste generation rate: 424.6 gm/per/capita/day (68% of waste is collected) **Role of the municipality:** a. Monitoring b. Generate awareness among public to be a part of the waste management operation c. Provide proper equipment and incentives to the people involved in waste management d. Provide training and financial support on composting and recycling **What steps need to be taken for effective waste management?** a. Allocation of Official Landfill site b. Segregation of the waste from the source and segregated waste collection strategy c. Promote composting and resource recovery d. Better cooperation and coordination among stakeholders e. Reuse and recycle plastic products f. Integrated solid waste management **Initiatives** a. Awareness program at the community level	**Bhes Raj Ghimire** Environment Officer Dharan Sub-metropolitan city

BPKIHS, Dharan	
• Waste generated: 13 tons per day (more than 100 bags a day) • Hospital area: 3tons, VIP area: 3tons, Civil line: 3tons, Hostel: 2tons, Golf Club: 2tons • Type of waste: Infected, Uninfected and Organic • Infected waste: Incineration, handled by hospital itself • Uninfected waste: Dumped • Organic waste: Dumped separately • Dumping site: No landfill site, the waste is dumped directly into the forest in designated dumping area	Pushpa Nepali (Waste Management Personnel, BPKIHS) Established date: 1993 Area Covered: 700 Acre

CHAPTER 7. DISCUSSION

7.1 Assessment of Current Waste Management Patterns:

Overview of Existing Practices:

- Waste Segregation: Not implemented
- Collection Efficiency: 70%
- Door to door collection: Daily, Weekly & 15 days interval
- Waste Processing (WtE): approx. 50% of total collected municipal waste
- Waste Disposal: Open Dumping in Bajhagara forest, ward 15

In Dharan, a registered solid waste management team, supervised by an environmental officer, oversees municipal designated areas, excluding specific wards and the BPKIHS area. With 63 field workers and 12 office staff, the team manages household waste from 16 wards, leaving ward 4, 5, 6 and BPKIHS area to handle their waste independently. With over 50 tons generated daily, there is no implementation of waste segregation or a segregated waste collection strategy, complicating further disposal process. It was observed that the existing SWM strategy faced challenges in efficiently managing and disposing the increasing urban-generated waste. Dharan generates 22 tons of organic and 15-20 tons of inorganic waste daily. However, collection efficiency stands mere at 70%, and only half of the collected waste undergoes treatment before final disposal. The Venture Waste to Energy plant, established in 2017 can process 50 tons of waste daily but operates at only 50% capacity due to policy complications. The plant produces CNG gas and organic fertilizer, but the market access for these products is limited. Collection efficiency is at 70%, with only half of the waste undergoing treatment. According to the plant manager Hari Upreti, currently there is no any policy that addresses the sales and use of alternative fuels like CNG and natural gases, limiting the market access for WTE plant produced fuels, further limiting waste-to-energy production. Furthermore, the absence of a designated landfill site results in haphazard waste dumping in the Bajhagara forest, posing environmental hazards. To improve the current situation, comprehensive policies for segregation, efficient collection, WTE optimization, proper landfills, and support for alternative fuels are crucial for a more sustainable waste management system in Dharan.

7.2 Review of Efficient Waste Management Strategies:

To curb dumping activities and minimize landfill requirements, waste must be decentralized and managed from its source. Implementing source segregation is the pivotal initial step for an effective solid waste management system. Encouraging green practices like the 3R approach (Reduce, Reuse, and Recycle) promotes decentralized waste management, significantly reducing landfill-bound waste in Dharan. Prioritizing proper waste collection and transportation, equipped with a smart monitoring system, ensures efficient tracking, treatment, and disposal, preventing indiscriminate dumping in urban forests. Eco-friendly methods like bioremediation can effectively address leachate and hazardous substances in the legacy waste of Bajhagara, reducing dumped waste volume and facilitating the restoration and recycling of non-biodegradable and recyclable materials. Collaboration between communities and government support can enable the clearing and effective management of the existing dumping ground in Bajhagara forest. Following the clearing of the dumping area, a small scale sanitary landfill site or Fukuoka landfill method with environmental considerations can be studied and implemented in the current dumping area in the forest which can be an alternative for waste disposal for up to some few years. This provides time to study and identify a feasible long-term sanitary landfill site, curbing dumping activities and minimizing landfill requirements in the process.

7.3 Community perception and preference:

The study explored community perspectives on current waste management practices and waste disposal in nearby forests. Results revealed community's dissatisfaction with the adverse effects of open dumping and disposal activities. Community engagement highlighted residents' willingness to support eco-friendly waste management and a desire for cleaner, sustainable urban environments in Dharan. Additionally, household-level adoption of waste management practices like segregation and composting were being adopted at the household level, indicating an initial move toward sustainability. These findings emphasize the importance of community involvement in shaping effective and environmentally conscious waste management strategies.

CHAPTER 8. CONCLUSION AND RECOMMENDATION

In conclusion, Dharan is experiencing rapid urbanization, leading to increased waste generation. The conventional waste management approach of collection, transport, and disposal is insufficient and merely relocates problems. With over 50 tons generated daily, there is no implementation of waste segregation or a segregated waste collection practices, complicating further disposal process. Absence of an environmentally sound landfill has resulted in indiscriminate dumping of solid waste in Bajhagara forest. Ward 15 faces significant waste management challenges due to its location of municipal dumping site. Despite the presence of a waste-to-energy (WTE) plant in Dharan, operated by Venture WTE Pvt. Ltd., it has not successfully handled the entire volume of the city's waste. The plant's maximum daily processing capacity exceeds 50 tons, but the absence of policies addressing alternative fuel sales hinders its operation at full capacity. To address these issues, the environmental impacts of waste on dumping areas, particularly in Bajhagara forest, should be studied for proper management and clearing. For the minimization of dumping activities and decrease the need for landfills, waste should be handled in a decentralized manner, starting from its source. The key starting point for an efficient solid waste management system is the implementation of source segregation. Implementing source segregation is the pivotal initial step for an effective solid waste management system. Emphasizing a decentralized waste management approach, starting with source segregation, and promoting the 3R principles (Reduce, Reuse, and Recycle) can ultimately minimize landfill-bound waste. Similarly, addressing and improvising the policies regarding use and sales of alternative fuels like CNG etc. can pave a way for unleashing the full potential of WtE plants like Venture WtE Pvt. Ltd. Which can in turn process and reduce a huge portion of landfill-bound waste, ultimately reducing landfill needs and impacts on the environment. Investing on proper collection and transportation, equipped with a smart monitoring system, can ensure efficient tracking, treatment, and disposal, preventing indiscriminate dumping in urban forests. Feasibility study and implementation of eco-friendly methods like bioremediation can address leachate and hazardous substances present in the legacy waste of dumping site. Reducing organic volume of dumped waste can facilitate the restoration and recycling of non-biodegradable and recyclable materials. Communities' participation and support from the government plays a vital role in succession of any waste management system. Through the collaborative efforts between communities and governmental authorities, waste management initiatives regarding clearing and managing of existing dumping grounds can be implemented. Following the clearing of the dumping area, a feasibility analysis for environmentally-safe waste disposal methods or a potential sanitary landfill site should be conducted, leading to a preferred approach that enhances the environmental quality of the Bajhagara forest and maintains the disposal activities. This can allocate time to study and identify a feasible long-term sanitary landfill site, curbing dumping activities and minimizing landfill requirements in the process.

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APPENDICES

ANNEX 1: List of Key Informants

- Bhes Raj Ghimire: Environment Officer, Dharan SMC
- Mangal Pariyar: Dharan Solid Waste Management In-charge
- Pushpa Nepali: BPKIHS SWM Personnel
- Hari Upreti: Plant manager, Venture WtE Pvt. Ltd.
- Maya Devi Rai: Secretary, Bajhagara Forest Users Committee
- Rajan Moktan: Chairman, Bajhagara Forest Users Committee

ANNEX 2: Questionnaire for Household Survey

Respondents detail:

- Name of Respondent:
- Education level:
- Family member:
- Ownership:
- Total no. of renters, if any:
- Gender:
- Occupation:
- Age of respondent:

Questions

i. What is the main source of waste generated?

a. Residential
b. Industrial
c. School
d. Shops/Restaurant
e. Mixed-use

ii. Generally, what includes your waste?

a. Bio-degradable waste (kitchen waste)
b. Non bio-degradable waste (Paper, plastic, glass, metal)
c. Medical waste (expired medicines, bandages, ointments)
d. Domestic hazardous waste

e. Electronics waste

iii. Weight of waste/week?

iv. How do you store waste at your home?

a. Plastic bag/container
b. Metallic container
c. Both
d. Any other, please specify

v. Do you use separate bins for different kinds of waste?

a. yes
b. no

If yes, how do you manage segregated waste?

a. Dispose of in landfill
b. Reuse
c. Recycle
d. Composting
e. Incinerate

If no, don't you think segregation is important?

a. Yes
b. No

vi. Is there any provision of segregated waste collection?

a. Yes
b. No

vii. Which is your preferable method of waste disposal?

a. Recycling
b. Composting
c. Dispose of in landfill
d. Other

viii. What are the barriers for the waste segregation?

a. Collection
b. Segregation
c. Not enough space
d. Open Dumping
e. Health risks
f. Other

ix. Do you take steps for waste reduction?

a. Yes
b. No

If yes, what steps do you take for waste reduction?

a. Carry my bag for grocery shopping
b. Reuse of paper
c. Composting
d. Any other, please specify

x. What is the frequency of waste collection?

a. Daily
b. Per week
c. 2 times a week

xi. Is community composting practiced in your locality?

a. yes
b. No

xii. Have you received guidelines from the municipality to practice composting at your house?

a. yes
b. no

If yes, how are you applying it?

xiii. Are you willing to participate in waste reduction practices?

a. yes
b. no

xiv. Is there any incentive or training provided for waste reduction at the household level?
a. yes
b. no

xv. What are the challenges in storing waste?
a. Less space
b. Bad smell
c. Any other

xvi. What are the challenges in reusing & recycling waste?

xvii. Do you attend programs/training for waste reduction?
a. Yes
b. No

xviii. What can be done so that solid waste can be managed properly?

ANNEX 3: Questionnaire for KII

a. Name of Interviewer
b. Name of organization
c. Established date
d. Covered area
e. Waste collection/day
f. Waste composition
g. Waste source
h. Waste load to the landfill site(residue)
i. Waste collection method
j. Waste storage method
k. Waste segregation methods
l. Waste reuse/recycling practices
m. Waste reduction training provided at the household level or incentives provided?

n. Institutional setup
o. Stakeholders role
p. The willingness of people to participate in waste reduction
q. Awareness level
r. Challenges in storing waste
s. Challenges in reuse, recycle
t. Challenges in co-operation of various stakeholders
u. Waste recycle/day
v. Initiatives/program

ANNEX 4: IOE Graduate Conference Acceptance Letter, Paper and Slides

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Date: November 26, 2023

To Whom It May Concern:

This is to certify that the paper titled "***Integrating Urban Forests and Parks in Solid Waste Management in the Growing Urban Areas (A Case of Ward 15 of Dharan)***" (Submission# **587**) submitted by **Chudamani Karki** as the first author has been accepted after the peer-review process for presentation in the 14th IOE Graduate Conference being held during Nov 29 to Dec 1, 2023. Kindly note that the publication of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon the author's presence for presentation during the conference and timely response to further edits during the publication process.

Bhim Kumar Dahal, PhD
Convener,
14th IOE Graduate Conference

IOE Graduate Conference
[Placeholder for Publication Information]

Integrating Urban Forests and Parks in Solid Waste Management in the Growing Urban Areas (A Case of Ward 15 of Dharan)

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Abstract

With cities rapidly growing worldwide, effective waste management has become a substantial challenge in both developed and developing urban settings. According to projections by the World Bank, global waste generation is expected to increase from 2.01 billion tons in 2016 to 3.40 billion tons in 2050, with low-income countries facing a threefold increase, amplifying challenges related to waste mismanagement. Dharan, a city in eastern Nepal, facing similar challenges, produces about 50.92 tons of municipal waste daily. Due to the absence of an official landfill site, a significant portion of this waste is disposed of in the Bajhagara forest area. Since unsanitary dumping is an unsustainable solution, it poses various adverse effects on the environment. This study seeks to evaluate the current state of solid waste management practices in Dharan, focusing on the prevalent use of forest areas for disposal. The research also reviews existing literature on similar initiatives worldwide, drawing valuable lessons and insights. Additionally, it explores how the community perceives and engages with current waste management and disposal methods, focusing on Ward No. 15, where the municipal dumping site is located. Employing a mixed-methods approach, incorporating literature review, surveys, GIS mapping, and analysis, this research investigates the present Dharan's solid waste management system. It aims to explore the potential for improving waste management to enhance the environment, biodiversity, and community well-being. The findings of this research can provide valuable lessons and insights into sustainable waste management practices, underscoring the significance of urban forests and parks in growing urban areas.

Keywords

Urban Planning, Solid Waste Management, Urban Forestry, Urban Parks, Sustainable Development, Environmental Sustainability, Dharan, Nepal.

1. Introduction

Solid waste tends to increase with rapid urbanization, improved living standards and changing consumption patterns. As a result, coping with the growing volume of solid waste has emerged as a significant challenge in numerous cities in developing countries. [1]. Solid waste can become a valuable resource when handled appropriately; however, inadequate handling can result in substantial negative impacts on the environment and public health. Therefore, municipalities play a crucial role in delivering an essential and resource-intensive service through effective solid waste management. [2]. In a global scenario, 54% of the world's population currently resides in urban areas, and this figure is projected to escalate 66% by 2050. As urbanization continues, waste generation is projected to rise from 2.01 billion tons in 2016 to 3.40 billion tons by 2050, with a more than threefold increase in waste generated in low-income countries [1]. Unfortunately, at least 33% of global waste is mismanaged through open dumping or burning, prevalent in lower-income countries where landfills are yet to be available [1]. In recent times, cities and urban areas in Nepal have faced considerable challenges in managing their increasing waste due to rapid and uncontrolled urban expansion, lack of public awareness, and insufficient governance by local authorities. These issues have heightened environmental concerns in Nepalese towns, resulting in unhygienic waste handling and disposal problems. Consequently, waste management has become a major priority for Nepal's municipalities [3]. As per the survey conducted by Nepal's Central Bureau of

Statistics (CBS), solid waste is a prominent environmental concern in Nepal, constituting 59% of prevalent issues, followed by sewerage at 25%, air pollution at 7%, and water pollution at 5% [4]. Dharan, a city in Nepal, is no exception to these environmental challenges. As per the survey conducted by the IUDP, Dharan in 2017 identified unmanaged waste as the primary environmental concern, accounting for 27% of the issues, followed by air pollution and parking problems. According to a report published by the Asian Development Bank in 2013, Dharan sub-metropolis generates approximately 50.92 tons of municipal waste daily. Of this, 56% consists of biodegradable solid waste, 39.18% comprises non-biodegradable waste, and the remaining 2.86% includes other waste types [3]. Lack of an official landfill site further exacerbates the issue, leading to unsanitary dumping in Bajhagara forest, causing air, water, and soil pollution, wildlife impact, habitat loss, health concerns for residents and adverse affect in neighboring municipalities. The main aim of this research is to assess the current municipal solid waste management practices/strategy and explore the ways to manage the unsanitary disposal of solid waste in urban forests taking the case of Bajhagara forest of ward no 15 of Dharan. Also the specific Objective are;

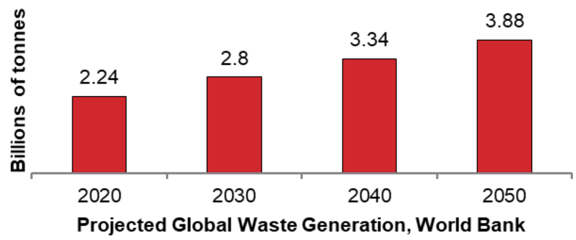
- To assess the current waste management pattern in Dharan.
- To review strategies and methods for efficient management of solid waste in forested areas.
- To gain insight into the perspectives and preferences of the local communities regarding the waste management and disposal in the urban forest.

Also the research is limited to aspects of municipal solid waste management pattern and potential of managing the haphazard dumping in Urban Forest, taking the case of ward 15, Dharan. Ward 15 holds particular significance in this context as it is home to the Bajhagara forest area, which serves as the location for current municipal solid waste disposal. This forest area plays a crucial role in the preservation of urban green spaces and biodiversity but the haphazard dumping of waste without any pre-treatment has aroused a lot of environmental complications and challenges.

2. Literature Review

2.1 Urbanization and Solid Waste Management:

Globally, waste generation rates are rising. In 2020, it was estimated that the world produced 2.24 billion tons of solid waste, equating to a footprint of 0.79 kilograms per person per day [1]. Due to rapid population growth and urbanization, annual waste generation is expected to rise 73% from 2020 levels,reaching 3.88 billion tons in 2050. [1].



Projected Global Waste Generation, World Bank					
	Unit	**2020**	**2030**	**2040**	**2050**
Projected waste	*Billions of tons*	2.24	2.8	3.34	3.88

Figure 1: Projected global Waste Generation [1]

The total quantity of waste generated in low-income countries is expected to increase by more than threefold by 2050 [1]. In low-income or developing countries, over 90% of waste is often disposed of in unregulated dumps or openly burned [1]. These practices contribute to health hazards, methane emissions, climate change, and urban problems [1]. Efficient waste management is vital for sustainable cities, presenting a major challenge for developing nations like Nepal [2]. In high-income countries, about one-third of waste is recycled or composted, but the cost is substantial, consuming 20% to 50% of municipal budgets [1]. Waste collection rates differ by income levels, with high- and upper-middle-income countries typically offering universal waste collection. In low-income countries, approximately 48% of urban waste is collected, dropping to around 26% outside urban areas. Middle-income countries show varied rural waste collection rates from 33% to 45% [1]. As per the World Bank survey report, global waste disposal methods include 37% in landfills, 33% openly dumped, 19% recycled or composted, and 11% incinerated [1]. Adequate waste disposal is primarily found in high- and upper-middle-income countries, while lower-income countries often resort to open dumping, with 93% of waste dumped in low-income countries and only 2% in high-income countries [1].

Global waste disposal method, World Bank		
S.N.	Disposal method	Percent (%)
1	*Composting*	33
2	*Landfill*	25.2
3	*Recycling*	13.5
4	*Incineration*	11.1
5	*Sanitary Landfill*	7.7
6	*Open Dumping*	5.5
7	*Controlled Landfill*	3.7
8	*Others*	0.3

Figure 2: Global waste disposal methods [3]

As per the ADB survey report of 2013, out of 58 surveyed municipalities of Nepal, majority of them were dumping their waste haphazardly in open areas and riverside [3]. Similarly, a 2017 IUDP Dharan survey identified unmanaged waste as a major issue, accompanied by concerns like bad smells, air pollution, parking, and drainage problems [5].

2.2 Importance of Urban Forests and Parks:

Urban forests, defined by FAO (2016), comprise all woodlands, clusters of trees, and individual trees located in urban and peri-urban areas, contributing significantly to physical and mental well-being. This encompasses forests, street trees, trees in parks and gardens, as well as trees in neglected areas [6, 7]. Recognized for enhancing air quality, social well-being, and overall urban life, cities globally are prioritizing the conservation and expansion of green spaces [6, 7]. Urban forests serve as a foundation for green infrastructure, connecting rural and urban areas and reducing a city's environmental impact [6]. They play a crucial role in purifying air, influencing urban climates, and supporting local livelihoods [7, 8]. Urban forests, from a social perspective, play a vital role in strengthening community bonds, enhancing food security for marginalized communities, connecting urban dwellers with nature, and promoting equity. Transforming small areas into pocket parks with trees and seating creates spaces for social interaction [7]. In Nepal, urban forestry has a rich history dating back to the Malla dynasty, with King Jayasthiti Malla initiating planting of trees along streets and wells [9]. This tradition continued, and in the 1960s and 1970s, significant tree planting initiatives were undertaken in Kathmandu during the Rana regime and the ring road plan [9]. Presently, the government remains committed to prioritizing urban forestry through diverse programs, such as the 'Nepal Clean Environment Grand Expedition 2075 AD' and the 'Forest Decade Program (2014-2023).' that promotes afforestation with the theme 'one house: one tree, one village: one forest, and one town: several parks' [9].

2.3 Existing Solid Waste Management System and Practices

2.3.1 Solid Waste Source

In most situations, the primary sources of solid waste include [10]:

- Residential (domestic or household)
- Commercial
- Institutional
- Construction waste
- Treatment plant Waste
- Solid Industrial Waste
- Solid Agricultural Waste
- Medical wastes
- Mining wastes
- Hazardous wastes

Appropriate solid waste management strategies may vary for institutional, communal and domestic sources, depending on types and volumes of waste[10].

2.3.2 Waste Characteristics

Understanding the waste characteristics is crucial for effective waste management strategies. The characteristics of Municipal Solid Waste (MSW) collected from any given area are influenced by a range of factors, including consumer patterns, food habits, cultural traditions, lifestyles, climate, and economic status.

Nepal's Municipal Solid Waste Composition, ADB-2013			
Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	*66*	*43*	*22*
Plastics	*12*	*22*	*21*
Paper Products	*9*	*23*	*45*
Glass	*3*	*4*	*1*
Metals	*2*	*2*	*1*
Textiles	*2*	*2*	*2*
Rubber and Leather	*1*	*1*	*1*
Others	*5*	*4*	*8*

Figure 3: Nepal's MSW composition [3]

In Nepal, studies have consistently shown that the majority of municipal waste is organic. A comprehensive study across 58 municipalities conducted by the Solid Waste Management &

Resource Mobilization Center (SWMRMC) revealed the average composition of MSW as follows: organic waste 56%, plastics 16%, paper and paper products 16%, glass 3%, metals 2%, textiles 2%, rubber and leather 1%, and other materials 4% [3].

2.3.3 Waste Generation

According to [11], the waste generation rate in municipalities of Nepal is about 3023 tons per day and the average per capita waste generation is 0.223 kg/person/day. Waste generation rates could also vary depending on the season, month, day of the week, population distributions, ecological regions economic status, and consumption patterns [3].

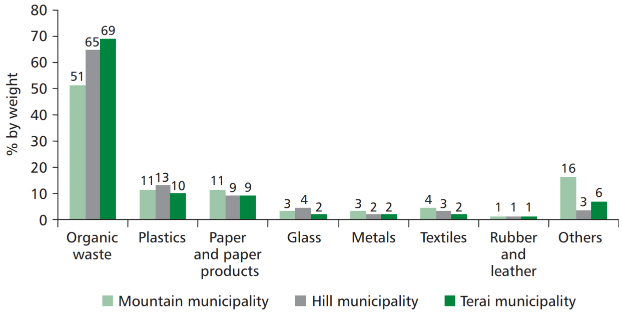


Figure 4: Regional MSW composition [3]

Households with monthly expenditures of NRs40,000 ($417) and above produce an average of 1.25 kilograms (kg) of waste per household per day, which is more than twice the 0.57 kg per household per day generated by households with monthly expenditures of less than NRs5,000 ($52) [3]. Likewise, the average household waste generation was observed to be higher in Terai municipalities (0.88 kg/household) and lower in mountain municipalities (0.49 kg/household) [3].

2.3.4 Collection and Segregation

According to a survey conducted by the ADB in 58 municipalities, it was noted that approximately 70% of households dispose of their waste directly into the main stream for collection and disposal without prior segregation. The remaining 30% of households, mainly in rural areas, engage in segregating kitchen waste for their specific needs [3]. The estimated average collection efficiency is 62%, but accuracy is hindered by the lack of a comprehensive recording system [2]. Many municipalities lack effective segregation programs, leading to the re-mixing of segregated waste during collection due to the absence of separate treatment methods [3].

2.3.5 Transport and Final Disposal

Nepal's waste disposal method, ADB 2013

S.N.	Disposal method	No. of municipality
1	*Open Dumping*	25
2	*Riverside Dumping*	13
3	*Open Dumping/Riverside Dumping*	6
4	*Sanitary Landfill*	6
5	*Controlled Dumping*	5
6	*Roadside Dumping*	1
7	*No Municipal System*	2

Figure 5: Nepal's Waste disposal method [3]

The availability of vehicles and equipment for waste collection and transportation varies significantly among municipalities in Nepal [3]. Primary waste collection typically involves rickshaws and carts, while tractors handle secondary collection or transportation, and dump trucks transport waste to disposal sites [3]. Not all municipalities have access to all three vehicle types, impacting the efficiency of waste transfer, from initial collection to processing centers or final disposal sites. Unfortunately, many municipalities have yet to identify suitable locations for treatment facilities and sanitary landfill sites [3]. As a result, waste is frequently discarded without undergoing treatment in makeshift dumping sites, presenting hazards to public health and contributing to environmental issues. Open dumping practices was observed in 45 out of the 58 municipalities, including Dharan Sub-metropolitan City, involve dumping waste in forest areas, along riversides, and on roadsides [3]. Only six municipalities, including KMC, Lalitpur, Pokhara, Ghorahi, Dhankuta, and Tansen, have taken steps to construct sanitary landfill sites [2].

2.4 Methods and Strategies for Efficient Waste Management in Forested Areas:

2.4.1 Source Reduction

Source reduction, also referred to as waste prevention, involves minimizing waste at its origin and is considered the most environmentally preferred strategy. This approach can manifest in various ways, such as reusing or donating items, purchasing in bulk, minimizing packaging, redesigning products, and decreasing toxicity [12]. Engaging in source reduction practices provides environmental benefits by lowering energy consumption and pollution, conserving natural resources, and prolonging the lifespan of valuable landfill space. Additionally, it can yield economic advantages by reducing costs related to the transportation, disposal, or recycling of waste [12].

2.4.2 Reduce, Reuse, Recycle (3R)

The waste hierarchy—Reduce, Reuse, Recycle—guides waste management based on environmental impact and resource efficiency, promoting sustainability.[13]. The first of the 3Rs, Reduction, is a key strategy in maintaining a cleaner environment by addressing waste at its source [14]. It involves generating less waste initially, and if households collectively adopt this approach, the overall waste problem will be reduced [14]. Reuse, the second aspect, involves re-purposing items to prevent unnecessary waste, encouraging creativity, and conserving resources [14]. Recycling, the third "R," entails reclaiming materials from waste, like recycling scrap metal or transforming waste plastic and paper into new products [15]. Recycling as a waste minimization strategy offers three advantages: it reduces the demand for new resources, decreases transportation and production energy expenses, and utilizes waste that would otherwise end up in landfills [16].

2.4.3 Bioremediation:

Leachate, a harmful liquid from landfills, poses a global threat by contaminating nearby soil and groundwater [17]. The extent of this contamination varies across countries and regions, presenting significant environmental and human health risks. To address this, essential measures must be implemented to reduce and control the impact of landfill leachate on soil and groundwater contamination [17]. Bioremediation, an eco-friendly, cost-effective, and efficient technology, is suitable for treating industrial wastewater and leachates [18]. It involves the utilization of microorganisms to diminish the toxicity of harmful wastes, heavy metals, hydrocarbons, polymers, and organic pollutants in both soil and water. Industries and power plants typically emit hazardous waste, which has a significant impact on human health. To combat this type of problems, bioremediation is often used [19]. Bioremediation falls into two primary types: in-situ bioremediation, treating contaminated sites without excavation, and ex-situ bioremediation, involving excavation and transportation of contaminated soil for additional treatment. Both types have further specific categories. [19]:

- Bioventing
- Biosparging
- Bioaugmentation
- Biopiling
- Landforming
- Bio-composting

2.4.4 Composting:

Composting is a controlled biological process converting the organic fraction of waste into stable, humus substances, ideal for soil amendments [20, 21]. With landfills reaching capacity and restricting organic waste, composting emerges as a more viable method for managing organic waste [21]. Microbes reduce organic waste volume by up to 50%, resulting in compost or humus, resembling potting soil, suitable as a soil conditioner or mulch. This contributes to improved soil quality, essential for ecological balance and increased food production [22]. Studies show that composting inherently reduces metal availability compared to alternative methods [22]. The process relies on microbial factors, compost composition, and environmental conditions [22]. Bio-solid compost and sugar beet lime enhance vegetative cover and biomass production by reducing metal concentrations in contaminated soil [22].

2.4.5 Sanitary Landfill:

The sanitary landfill method involves the disposal of solid waste on land without causing disturbances or hazards to public health or safety. This technique utilizes engineering principles to confine the solid waste to a practical area, reduce its volume, and cover it with a layer of earth, either daily or at more frequent intervals as needed [23]. The important considerations in obtaining and operating a sanitary landfill requires [23]:

- Site selection
- Topographic map
- Geological studies
- Site capacity
- Water resources
- Land Reclamation
- Landfill operation

2.4.6 Waste-to-Energy (WtE) Technologies:

Waste-to-Energy (WtE) technologies involve various processes that extract energy from different waste sources, such as electricity, heat, or transport fuels. While applicable to various waste types, the predominant use is in treating Municipal Solid Waste (MSW) [24]. According to Mitsubishi Heavy Industries Environmental and Chemical Engineering incineration emits carbon dioxide and land-filling generates methane gas, which is 25 times as potent as a greenhouse gas. Shifting to incineration reduces the amount of landfill waste and the effect on the environment [24]. WtE technologies can convert the energy content of different waste types into valuable forms of energy, generating power for local and national grid systems. The produced heat can serve district heating purposes or specific thermodynamic processes, and bio-fuels can be derived from the organic components of waste, refined, and introduced to the market [24].

2.4.7 Community-Led Cleanup Initiatives:

Community participation is vital in solid waste management for ongoing maintenance systems [3]. Promoting this involvement requires information, education, and communication campaigns to raise awareness of sustainable principles like Reduce, Reuse, and Recycle (3R) and effective waste management. Clean Up Australia, founded in 1989, is a nationwide community-led initiative focusing on environmental conservation and cleanliness. Originating in Sydney, it has grown into a national event, mobilizing millions to remove tons of waste from natural environments, emphasizing community engagement, active citizenship, cleanliness, health, biodiversity preservation, and accessibility. Nepal's 'Sithi Nakha' is also a remarkable annual community cleanup initiative in the Newar community, fostering unity and traditions by cleaning water sources, spouts, taps, and surroundings [25]. Likewise, Dharan's newly elected mayor, Harka R. Sampang, has induced noteworthy community-led initiatives that have made substantial contributions to plantation, afforestation, and the introduction of water supply in the city. The active involvement of the community enabled the importation of water from a source over 40 kilometers away from the city, serving as a powerful example of what collective community participation can accomplish, particularly in the context of solid waste management.

2.5 Community participation in Solid Waste Management

Waste (1996) defines a community as a group of individuals residing together within a certain framework of social organization and cohesion. [26]. Community participation, as described by Gotame (2012), is the process by which individuals and families assume responsibility for both their personal well-being and that of their community, actively contributing to development [27]. Anschutz (1996) underscores the crucial role of community participation in solid waste management [26]. The Brundtland Commission highlights its importance in achieving sustainable development, especially in solid waste management [1, 3]. Relying only on local authorities is insufficient for maintaining clean towns. Promoting community participation through campaigns on 3R principles and enhanced solid waste management (SWM) is crucial [3]. When establishing new waste disposal sites, it's vital to engage nearby communities by considering their opinions and concerns in the planning process, ensuring proper site management, and incorporating social programs that benefit the local residents. Similarly, effective waste segregation and collection methods should involve close consultation and collaboration with communities to address their specific needs [3].

3. Methodology

The research paradigm combines both positivism and interpretivism. Positivism, linked with quantitative research, addresses solid waste management, while interpretivism explores the social and human aspects of urban forests and parks integration. The ontological claim asserts an objective reality in municipal solid waste management, shaped by human perceptions. The epistemological claim asserts that insights into integration of forest with SWM can be validly discerned through a comprehensive analysis of relevant literature, case studies, or survey data in real-world scenarios. Two types of data collection methods were employed; primary and secondary. Primary data collection involves surveys, interviews, field notes, and observations, complemented by secondary data from literature, journals, articles, maps, and municipal profiles. A random stratified sampling approach in the field survey was adopted to ensure representation across diverse demographic groups within Ward 15.

4. Study Area

The study area for this research encompasses Dharan Sub-Metropolitan City located in province no.1 of Nepal, with a primary focus on Bajhagara forest, Ward 15.

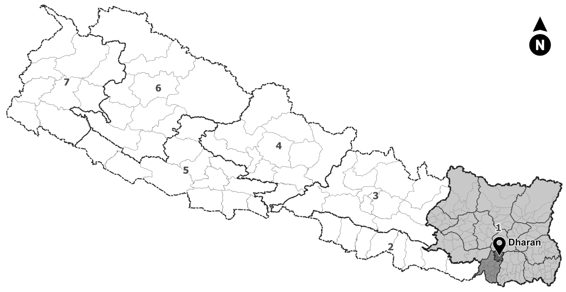


Figure 6: Study area location

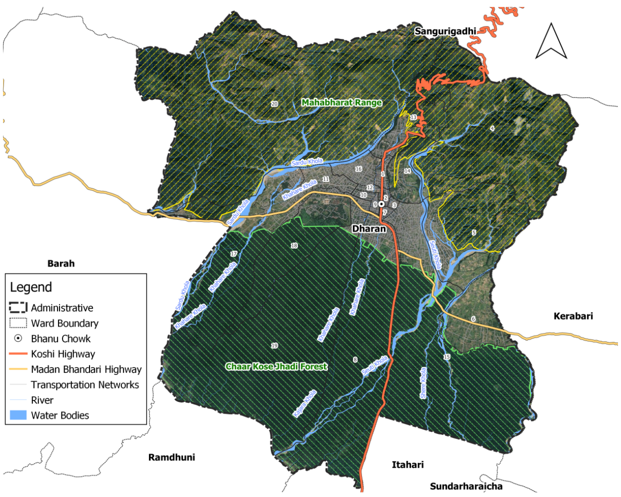


Figure 7: Physical setting

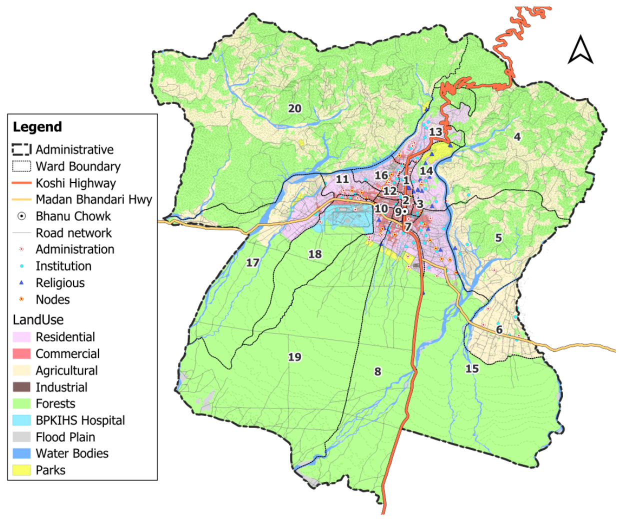


Figure 8: Land Use Map of Dharan

According to the IUDP 2017, forests cover more than 70% of the total land area of Dharan. Forests play a major role in balancing the ecosystem and maintaining the climatic and livable conditions of Dharan [5].

Categories	Area (sq.km)	Percentage (%)
Built area	3.45	1.78
Forest	135.74	70.33
Water Body	0.01	0.67
Agriculture	45.98	23.82
River bed	7.09	3.67
Cutting cliff	0.87	0.45

Figure 9: Land Use Categories [5]

However, since it has been used as a dumping ground for municipal waste disposal since 1986 A.D., adverse effects on its environment and biodiversity can be observed. This situation has directly impacted the adjacent river body and the health of people in surrounding municipalities.

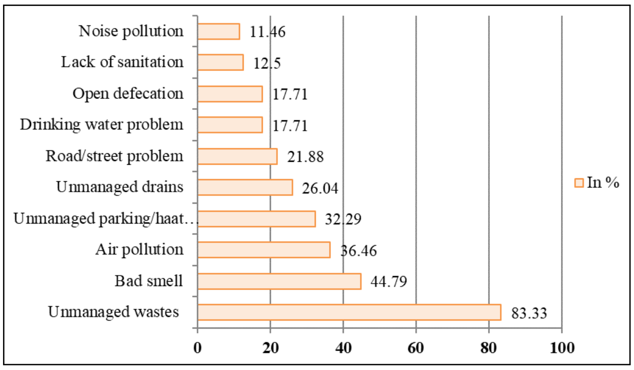


Figure 10: Community problems, Dharan [5]

According to the survey conducted by IUDP Dharan in 2017, unmanaged waste is the major communal and environmental problems experienced by the inhabitants; followed by bad smell, air pollution, parking, drainage etc [5].

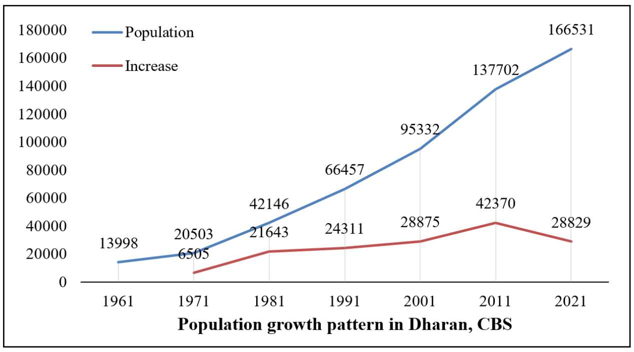


Figure 11: Population growth trend

Dharan is experiencing rapid urbanization and along with the population growth, the waste generation pattern is also arising. This makes it a pertinent case study for gaining insights into the challenges and opportunities associated with urban development and environmental conservation.

4.1 Case Area: Bajhagara Forest, Ward no. 15

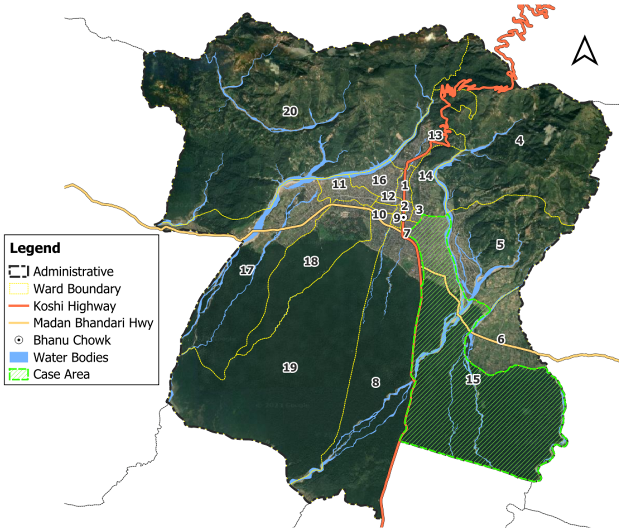


Figure 12: Map of designated case area

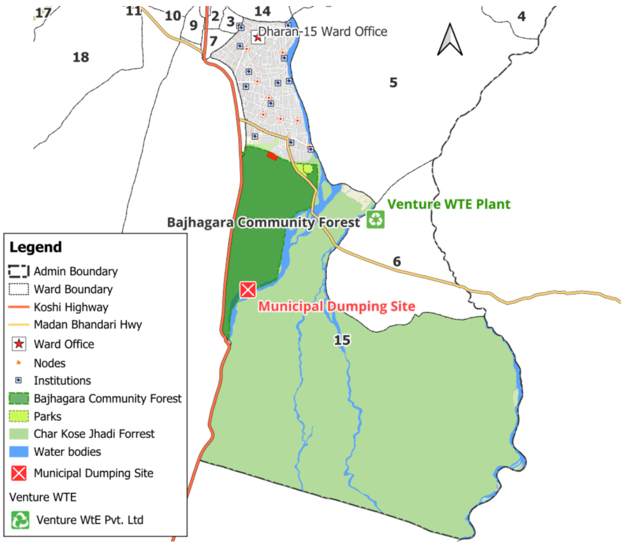


Figure 13: Ward-15, Dharan

Ward no.	Household (2017)	Population	Male	Female	Area (Sq. Km)	Density
15	4,726	27441	12845	14596	25.544	1074
Total	32,683	166531	78410	88121	192.98	866

The study site is the Ward 15 of Dharan Sub-metropolitan city and has a population of 27,411, including 12,845 males and 14,596 females (CBS 2021). Covering 25.54 square kilometers, it comprises 4,726 household [5]. Site features (Ward no. 15):

- Location of Bajhagara community forest (Municipal Dumping site)
- Location of Seuti River (affected area)
- Ward wise highest number of population

Ward 15 raise concerns due to its proximity to the municipal dumping site, causing adverse effects on nearby forests and rivers. The ward is also experiencing rapid growth and new developments. Sustainable waste management goes beyond the traditional approach of collection and disposal, as it only relocates issues rather than resolving them. Waste management involves more than crisis management associated with these activities [28]. Hence, it is crucial to evaluate the efficiency of the existing waste management system and find ways to alleviate the adverse impacts of solid waste on these forests.

5. Analysis and Findings

The waste generation rate of municipal waste is 424.62gm/capita/day and household waste is 212.31gm/capita/day in Dharan city which results in a total waste generation to be 50.92 tons/day [3]. Commercial areas generate 7.53 tons/day, and households contribute 25.46 tons/day [3]. According to the Dharan SWM team, 10-15% of bio-degradable waste is individually composted by households, while 20-30% of non-bio-degradable waste is collected or sold to recyclers and kabadiwalas. The SWM team collects the remaining waste daily, weekly, or every 15 days, depending on location and frequency of waste generation. Dharan's municipal waste includes residential, commercial, mixed-use, school, and cottage industry waste, with households being the primary source, followed by commercial and institutional waste.

Municipal Waste Generation Rate, ADB 2013

Municipality	Dharan
Average HH Waste (kg/day)	*1.17*
Average HH size(number of members)	*5.53*
Average per Capita HH Waste (g/capita/day)	*212.31*
Total HH Waste (tons/day)	*25.46*
Total Commercial Waste (tons/day)	*7.53*
Total Institutional Waste (tons/day)	*0.44*
Average per Capita MSW (g/capita/day)	*424.62*
Total MSW Generation (tons/day)	*50.92*
Estimated Waste Collection (tons/day)	*35.0*
Collection Efficiency (%)	*68.7*

Figure 14: MSW Generation, Dharan [3]

Municipal Solid Waste Composition of Dharan, ADB-2013			
Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	*58.34*	*25.57*	*22.39*
Plastics	*15.49*	*18.27*	*21.29*
Paper Products	*11.30*	*17.09*	*37.81*
Glass	*2.43*	*7.99*	*3.70*
Metals	*6.24*	*6.76*	*3.89*
Textiles	*2.96*	*4.23*	*2.26*
Rubber and Leather	*0.75*	*0*	*1.18*
Others	*2.48*	*20.09*	*7.47*

Figure 15: Dharan's MSW Composition [3]

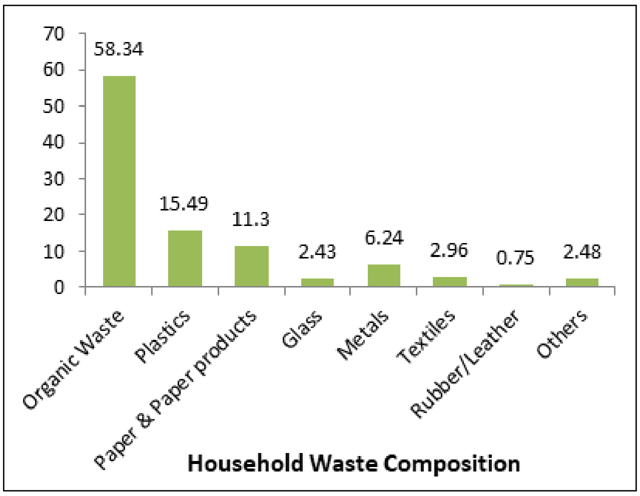


Figure 16: Household Waste Composition, [3]

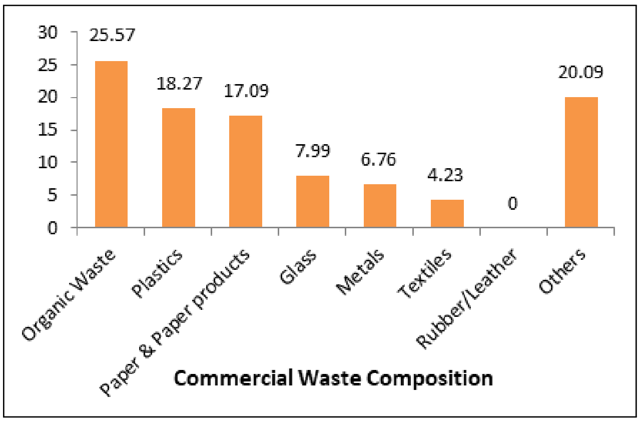


Figure 17: Commercial Waste Composition, [3]

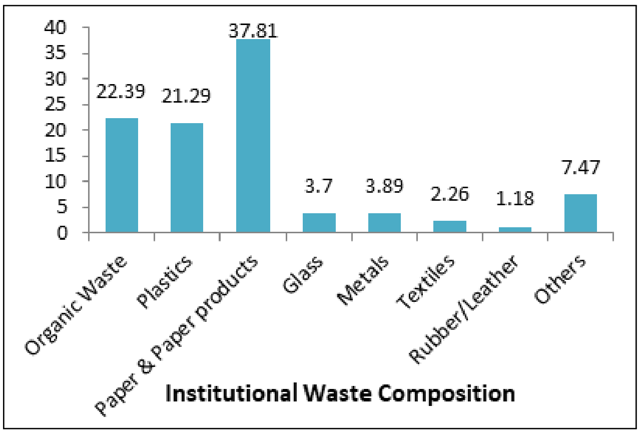


Figure 18: Institutional Waste Composition, [3]

5.1 Existing Solid Waste Management System and Practices

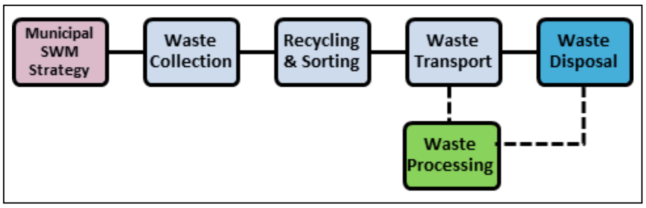


Figure 19: Municipal SWM strategy

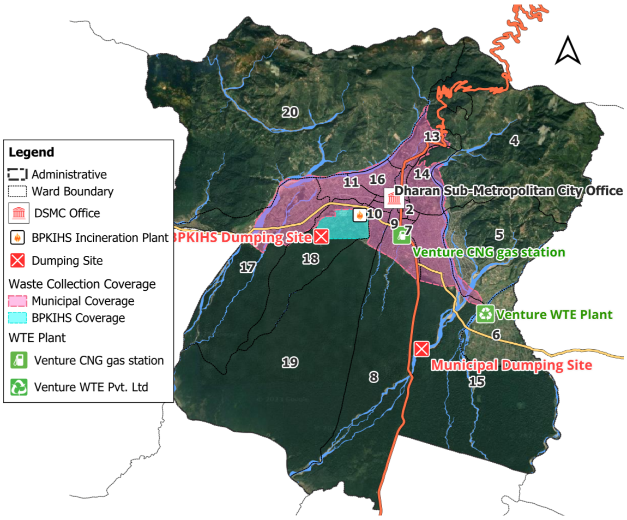


Figure 20: Solid Waste Management System, Dharan

The sub-metropolitan city has department of forest, environment and risk management to analyze and control all the relevant forest and environmental issues and hence is responsible for regulating the policies and managing all the activities that is concerned with solid waste management of the overall city. The sub-metropolitan city has enlisted service providers responsible for managing solid waste, operating under the oversight of an environmental officer and a team led by an in-charge. According to the SWM in-charge Mangal Pariyar, the SWM team comprises 9 waste collection vehicles and 75 members, with 63 actively engaged in fieldwork and 12 handling office-related tasks. They are responsible for managing solid waste within areas designated by the municipality, but wards 5, 6, and 20 are excluded from present collection coverage area, as well as the BPKIHS area, handle their waste independently. Among the 42,396 households in the city, about 32,891 households have access to services provided by solid waste management organizations. This implies that a majority, consisting of 9,505 households, are responsible for disposing of or managing their waste independently. At present, only Venture WTE Pvt.

Ltd segregates organic waste from non-organic waste. Approximately 50% of organic waste and 30% of recyclable waste are segregated for composting and recycling, while the remaining 15-20% non-recyclable waste is transported to the Bajhagara forest dumping site near the Seuti River in Dharan-15. The recovered non-biodegradable waste undergoes recycling, while the processed biodegradable waste is converted into CNG gas and fertilizers. The CNG gas is priced at up to Rs 130 per kilogram and is currently utilized in vehicles such as scooters and auto rickshaws. The fertilizer is packaged in 2kg, 5kg, and 10kg bags, retailing for Rs 60 per kilogram. The remaining municipal waste is disposed of in the Bajhagara forest dumping area located in ward no. 15.

5.1.1 Waste Collection and Transportation

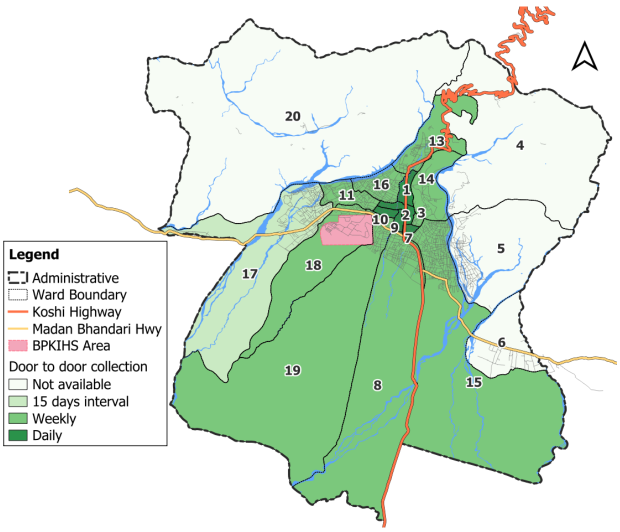


Figure 21: Door to door collection

Dharan city offers door-to-door waste collection services, covering all wards except ward numbers 5, 6, 20, and the BPKIHS area. Waste collection occurs on a daily, weekly, or 15-day interval basis, depending on the location and the volume of waste generated. The SWM team operates with a fleet of 9 vehicles, consisting of 3 trippers and 6 tractors, for waste collection. The crew members engage in waste collection from early morning to late evening, adjusting their schedules based on demand and necessity. On average, the city collects approximately 25-35 tons of waste daily, subject to varying circumstances. Of the collected waste, 10-13 trips are directed to the Venture WTE plant for further processing, while the remainder is transported to the dumping zone located in the Bajhagara forest area, ward-15.

5.1.2 Waste to Energy Initiative:

Figure 22: Venture WtE plant Pvt. Ltd.

Dharan is home to the Venture WTE Pvt. Ltd waste-to-energy plant, located in Panbari, which was inaugurated in 2022. This facility has a daily processing capacity of 50 tons of waste. A significant portion of household waste in Dharan is directed to the Venture WTE plant. The solid waste management (SWM) team collects an average of 25-35 tons of waste daily but as of present, only 8-12 trips is transported to the waste to the processing plant. The remaining waste is disposed of at a dumping site located in Bajhagara forest, ward 15.

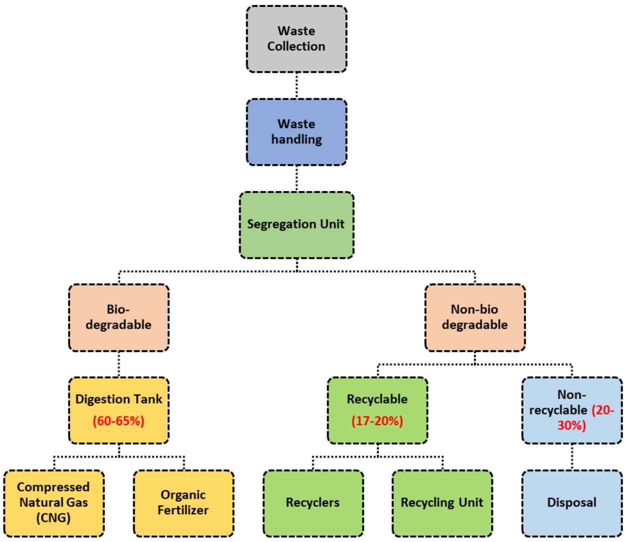


Figure 23: Waste Treatment Process, Venture WTE Pvt. Ltd

Figure 24: Waste segregation and processing, Source:Venture WTE, Pvt. Ltd.

Venture WTE Pvt. Ltd separates organic and non-organic waste, processes the organic waste and turn it into CNG gas and fertilizer, selling them at Rs. 130 per kilogram and Rs. 60 per kilogram, respectively. The remaining non-recyclable waste goes to a landfill, and recyclables are sorted and sold. According to plant manager Hari Upreti, about 60-65% of the waste could become valuable manure, with 17-20% being reusable, and 20% going to a landfill. The plant is not operating at full capacity due to policy issues affecting efficiency, particularly the absence of policies addressing the sale and use of alternative fuels like CNG and natural gases, hindering market access for these fuels.

5.1.3 Waste Disposal:

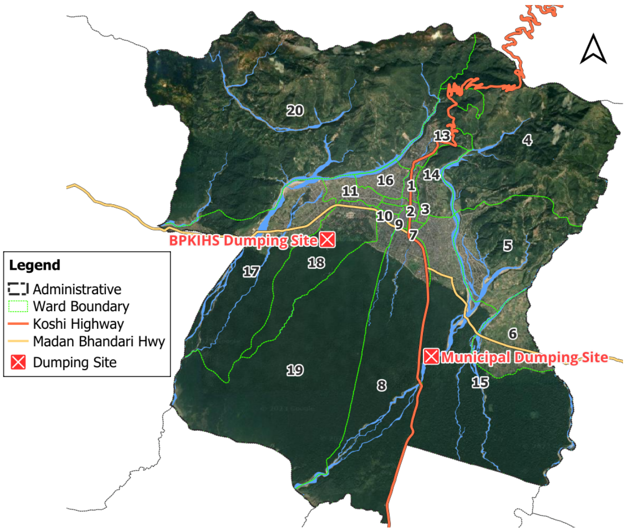


Figure 25: Waste Disposal Site, Dharan

Figure 26: Municipal Dumping Site Status

In Dharan, there is no official designated landfill site for waste disposal. Instead, most of the city's municipal waste is disposed of in an informal dumping zone located in Bajhagara community forest and along the bank of river Seuti. Though the majority of the waste collected by the waste management department is directed towards Venture WTE Pvt. Ltd., the remaining portion is directly deposited in the forested areas.

5.2 Dumping in Urban Forests: A Case Study of Bajhagara Forest

5.2.1 Overview of Bajhagara Forest:

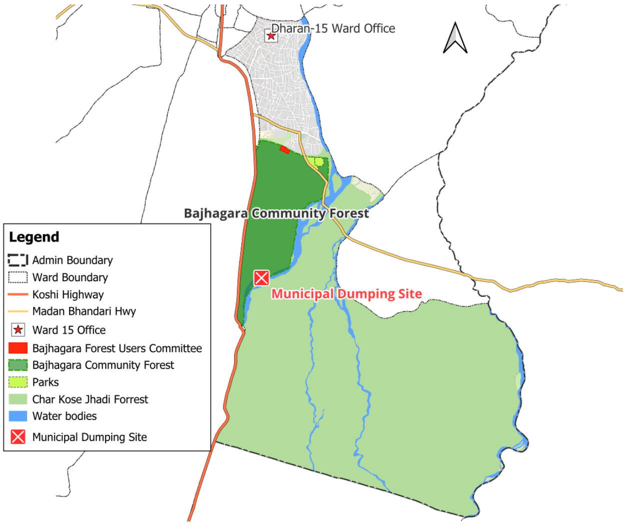


Figure 27: Location of Bajhagara Forest, Dharan-15

Bajhagara Forest Users Committee was officially formed on 2059 B.S. It is located in the heart of the ward no 15 of Dharan sub-metropolitan city and covers the total land area of 2.88 sq. km. The boundaries of Bajhagara forest area is demarcated as:

- East: Seuti River
- West: Koshi Highway
- North: T.U. IOE ERC boundary wall and settlements
- South: Seuti River Bridge

Flora and Fauna: The Bajhagara community forest is home to a variety of plants, wildlife and ecosystems. The biodiversity of the Bajhagara community forest encompasses various plant species, as well as animal and bird species, along with their respective ecosystems. According to the Bajhagara forest profile and KII, the native tree species are: Sal, Karma, Banyan, Harro, Barro, Amla, Bhalayo, Hallude, Kumbhi etc. Similarly, the native wildlife species are: Leopard, Rabbit, Chhittal, Monkey, Langur, Coyote, Squirrel, Wild Cat, Porcupine, Monitor Lizard, Pangolin etc. And lastly, the native bird species are: Hornbill, Parrot, Theuwa, Mynah, Red Billed Blue Magpie, Cuckoos, Peafowl, Red Jungle fowl, Sparrow etc.

5.2.2 Extent of Haphazard Dumping

In Dharan, the absence of an official landfill site has led to the dumping of municipal waste in the Bajhagara forest of ward no. 15 . This practice has persisted since 1986 A.D.

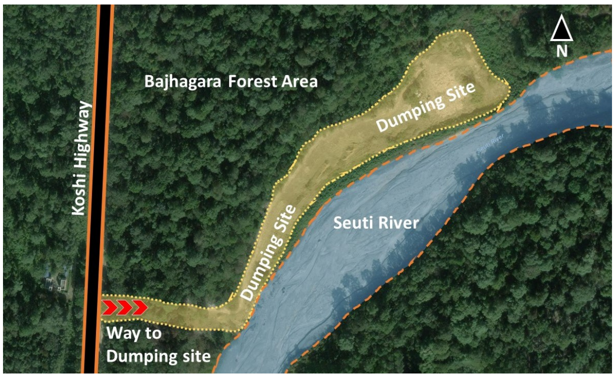


Figure 28: Location of Municipal Dumping Site

Figure 29: Access from Koshi highway

While urban forests are vital for ecological balance and the maintenance of climatic conditions in urban areas, there has been a notable absence of exploration and implementation of environmentally safe solid waste disposal methods in these areas. According to SWM personnel, approximately 10-13 tons of waste are directly deposited into the Bajhagara forest on a regular basis. Furthermore, waste segregation or segregated collection has not been implemented, resulting in the disposal of predominantly mixed-type waste without any pre-treatment. The indiscriminate dumping in Dharan has resulted in significant environmental complications. Leachate produced from the waste has degraded soil fertility, posing risks to the flora and fauna of the Bajhagara and surrounding forested regions. The presence of leachate makes accessing the dumping area difficult and has adverse health impacts on recyclers, waste workers, and Solid Waste Management (SWM) staff. Though municipal authorities are investigating an eco-friendly landfill site in Dharan, outcomes are currently unknown.

Figure 30: Present status of Municipal Dumping Site

Additionally, the industrial estate near Bajhagara forest in Dharan 8 poses a significant environmental threat. The uncontrolled discharge of toxic wastewater from industrial activities such as rice packaging and manufacturing plastic pipes directly contaminates the nearby Bajhagara forest area. The wastewater, filled with harmful chemicals, flows from the estate's drainage, creating dark, foamy water that poses serious environmental risks to the forest, located just 50 meters south.

Figure 31: Waste water discharge from Dharan Industrial estate

Unlike household waste, industrial wastewater is concentrated with toxins and chemicals that pose a severe threat to the forest's plants, animals, and biodiversity. Continuous discharge can contaminate soil, hinder plant growth, and contribute to groundwater pollution, disrupting the forest ecosystem and causing habitat loss. Proximity to the industrial estate further intensifies the problem.

Figure 32: Leachate contamination due to industrial discharge

Urgent measures, including strict rules, proper waste management, and wastewater treatment, is essential to prevent irreversible damage to Bajhagara forest and the surrounding environment.

5.2.3 Impact on flora and fauna

Figure 33: Animal's presence in dump site

Various types of municipal waste, encompassing organic, inorganic, and bio-waste, are haphazardly deposited in this forests area, resulting in detrimental effects on both soil quality and biodiversity. This indiscriminate dumping has given rise to significant environmental complications, posing risks to the plant and animal life in the Bajhagara area and its surrounding forests. Species such as monkeys, chital, and cows have suffered severe consequences due to the presence of these dump sites. Many animals have fallen victim to toxins present in the accumulated waste, leading to a decline in their population. Primarily, monkeys, deer, and cows from nearby temples wander around these piles of debris. Additionally, the leachate produced from the accumulated waste over time has led to soil fertility degradation and the potential loss of habitats. The presence of leachate makes it challenging to access the dumping area on foot, especially during the rainy season. Moreover, it has had a profound impact on plant growth, disrupted the ecosystem, and compromised the health of recyclers, waste workers, and solid waste management staff.

5.2.4 Impact on the riverside

Figure 34: Presence of waste nearby riverside

Similarly, the water quality of the nearby river has been significantly compromised due to the existence of the dump site along its banks. Although direct dumping into the river has ceased due to protests from affected communities, the indirect effects aroused from the nearby dumping are clearly evident along the riverside. Numerous non-recyclable materials such as plastics, construction debris, glass, and metal parts are noticeable along the riverbank. This river, classified as an Ephemeral River, typically flows only during the rainy season. Consequently, waste particles continuously accumulate along the riverside throughout the year, and during the monsoon season, the river sweeps these accumulated waste particles downstream, ultimately affecting water quality and impacting the surrounding municipalities.

5.2.5 Dumping area coverage:

The dumping area extends over a distance of 585.76 meters along the riverside. It is characterized by varying widths, measuring 20 meters, 30 meters, and 90 meters. The dumping site is partitioned into three sections: the initial segment serves as the entrance to the site and has a width of 20-25 meters, the middle part functions as a transportation zone with an 8-meter-wide road for the movement of waste from the city to the primary dumping site using tractors and trippers, and the final section constitutes the primary dumping area where the majority of waste accumulates. Waste workers and recyclers operate in this section, sorting and handling some portions of recyclable waste.

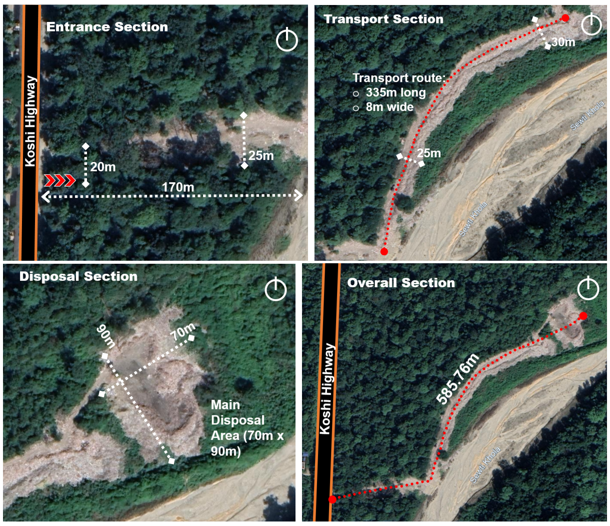


Figure 35: Segments of Dumping Site

Figure 36: Dumping Coverage Area

This site has served as a municipal dumping ground for over three decades and continues to be operational. Consequently, the dumping site has expanded over time. Currently, it occupies a total land area of 17,785 square meters (approximately 0.017 square kilometers or 0.02 square kilometers), constituting 0.69% of the overall Bajhagara forest land area.

5.3 Community Perception and Concerns

A survey involving more than 50 respondents from Ward No. 15 of Dharan was conducted to study the community's sentiments and attitudes towards solid waste management. The survey aimed to understand the extent of people's involvement, their awareness of eco-friendly waste management initiatives, and their aspirations for a cleaner and greener urban environment. The research study utilized random sampling techniques, involving an approximate sample size of 50 respondents. The sample size was determined based on various classifications, including age, gender, class, type of building use, location (Tole), and tenancy status. It is important to note that the survey was capped at 50 respondents once the saturation level was achieved.

Demographic information of respondents: 50 respondents

Category	Value	Number	Percentage (%)
Gender	Male	22	44
	Female	28	56
Age	15-24	3	6
	25-50	34	26
	Above 50	13	68
Occupation	Housewife	11	22
	Student	4	8
	Service	19	38
	Business	13	26
	Others	3	6
Marital Status	Married	45	90
	Unmarried	5	10
Household Ownership	Owned	29	58
	Rented	21	42
Education	Under SLC	9	18
	SLC	13	26
	Intermediate	18	36
	Bachelor	7	14
	Masters	3	6

Figure 37: Demographic information

Methods like household questionnaires, survey and interviews were adopted to assess and visually represent factors such as people's awareness and participation in waste management, efforts to reduce waste, challenges in waste management, and their preferred methods for waste disposal. The data acquired from household surveys and interviews is presented in the provided charts.

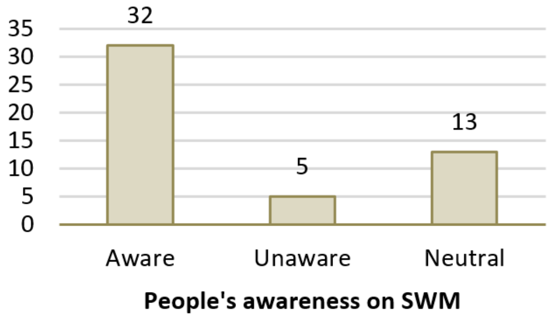


Figure 38: People's awareness on Solid Waste Management.

The survey on people's awareness on current municipal waste management and dumping revealed that 64% respondents were aware of the present situation, while 10% were unaware and the rest 26% were neutral.

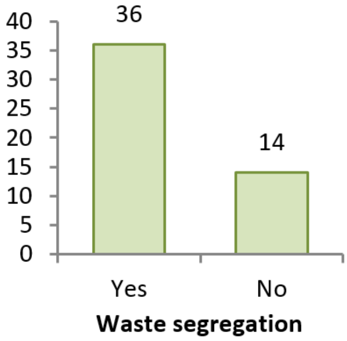


Figure 39: Waste segregation practices

The survey revealed that 72% of the respondents were implementing the waste segregation strategy while the rest 28% were not involved in any kind of segregation practices.

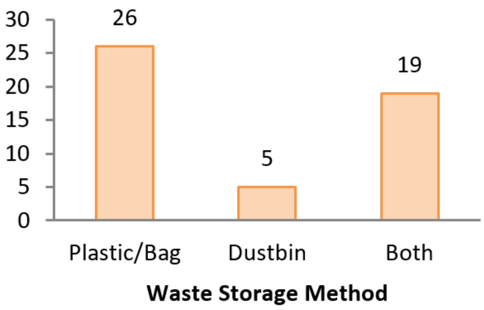


Figure 40: Preferred waste storage method

More than 50% respondents use plastic bag to store their waste and 38% of the respondents use both plastic bag and dustbin while the rest 10% use dustbin only for storing the household waste.

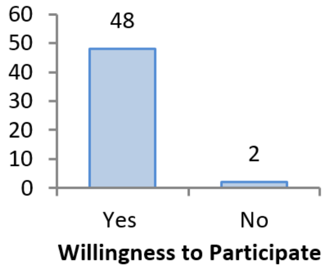


Figure 41: Willingness of the respondents

According to the field survey report, more than 95% respondents were willing to participate in the waste management practice and waste reduction initiatives.

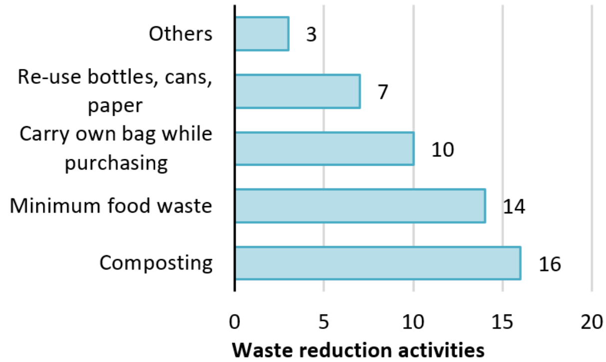


Figure 42: Waste reduction initiatives

Through the field survey, respondents were found out to be involved in different waste reduction initiatives like composting, minimum food waste, carry own bag etc. This showcases the willingness of respondents to cooperate in waste management aspect individually.

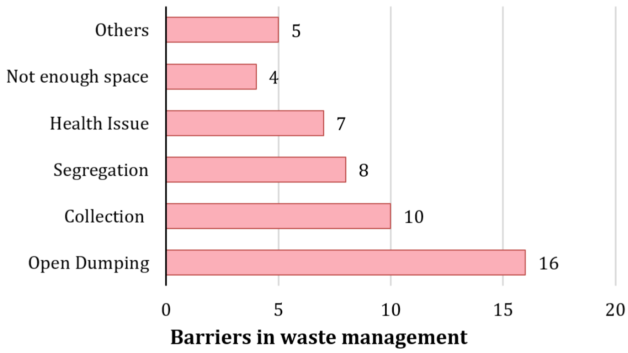


Figure 43: Barriers in Waste management

Barriers in waste management according to the respondents' perception was also examined. It was found that open dumping was most significant barrier followed by irregular collection, then implementation of waste segregation strategy and so on.

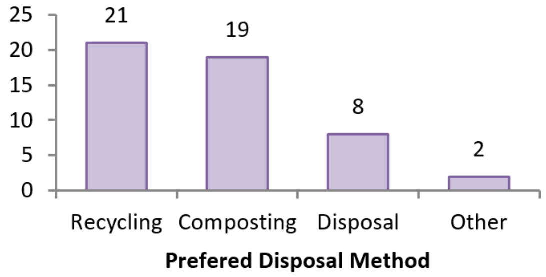


Figure 44: Respondent's preferred wast disposal method

Similarly through the field survey, the preferred waste disposal method according to the respondents was also uncovered. Recycling was the most preferred method of waste disposal followed by composting, and so on. Which reveals the awareness and viewpoint of the respondents regarding environmental-friendly waste disposal methods. The study examined the community's views on current waste management practices and disposal in nearby forests. It was found that the community was unsatisfied with the consequences from open dumping and disposal activities. Community engagement revealed that there is a willingness among residents to support eco-friendly waste management initiatives and a desire for cleaner, greener urban spaces in Dharan. Additionally, it was observed that certain level waste management practices, such as segregation and composting, were being implemented at the household level, indicating an initial step towards sustainable waste management within individual households. These insights emphasize the importance of community engagement in shaping effective and environmentally conscious waste management strategies.

6. Discussion

6.1 Assessment of Current Waste Management Patterns:

In Dharan, a registered solid waste management team, supervised by an environmental officer, oversees municipal designated areas. With 63 field workers and 12 office staff, the team manages household waste from 16 wards, leaving ward 4, 5, 6 and BPKIHS area to handle their waste independently. With over 50 tons generated daily, there is no implementation of waste segregation or a segregated waste collection strategy, complicating further disposal process. It was observed that the existing SWM strategy faced challenges in efficiently managing and disposing the increasing urban-generated waste. Dharan generates 22 tons of organic and 15-20 tons of inorganic waste daily. However, collection efficiency stands mere at 70%, and only half of the collected waste undergoes treatment before final disposal. The Venture Waste to Energy plant, established in 2017 can process 50 tons of waste daily but operates at only 50% capacity due to policy complications. The plant produces CNG gas and organic fertilizer, but the market access for these products is limited. According to the plant manager Hari Upreti, currently there is an absence of policy that addresses the sales and use of alternative fuels like CNG and natural gases, limiting the market access for WTE plant produced fuels, further limiting waste-to-energy production. Furthermore, the absence of a designated landfill site results in haphazard waste dumping in the Bajhagara forest, posing environmental hazards. To improve the current situation, comprehensive policies for segregation, efficient collection, WTE optimization, proper landfills, and support for alternative fuels are crucial for a more sustainable waste management system in Dharan.

6.2 Review of Efficient Waste Management Strategies:

To curb dumping activities and minimize landfill requirements, waste must be decentralized and managed from its source. Implementing source segregation is the pivotal initial step for an effective solid waste management system. Encouraging green practices like the 3R approach (Reduce, Reuse, and Recycle) promotes decentralized waste management, significantly reducing landfill-bound waste in Dharan. Prioritizing proper waste collection and transportation, equipped with a smart monitoring system, ensures efficient tracking, treatment, and disposal, preventing indiscriminate dumping in urban forests. Eco-friendly methods like bioremediation can effectively address leachate and hazardous substances in the legacy waste of Bajhagara, reducing dumped waste volume and facilitating the restoration and recycling of non-biodegradable and recyclable materials. Collaboration between communities and government support can enable the clearing and effective management of the existing dumping ground in Bajhagara forest. Following the clearing of the dumping area, a small scale sanitary landfill site with environmental considerations can be studied and implemented in the current dumping area in the forest which can be an alternative for waste disposal for up to some few years. This provides time to study and identify a feasible long-term sanitary landfill site, curbing dumping activities and minimizing landfill requirements in the process.

6.3 Community perception and preference:

The study explored community perspectives on current waste management practices and waste disposal in nearby forests. Results revealed community dissatisfaction with the adverse effects of open dumping and disposal activities. Community engagement highlighted residents' willingness to support eco-friendly waste management and a desire for cleaner, sustainable urban environments in Dharan. Additionally, household-level adoption of waste management practices like segregation and composting were being adopted at the household level, indicating an initial move toward sustainability. These findings emphasize the importance of community involvement in shaping effective and environmentally conscious waste management strategies.

7. Conclusion and Recommendation

In conclusion, Dharan is experiencing rapid urbanization, leading to increased waste generation. The conventional waste management approach of collection, transport, and disposal is insufficient and merely relocates problems. With over 50 tons generated daily, there is no implementation of waste segregation or a segregated waste collection practices, complicating further disposal process. Absence of an environmentally sound landfill has resulted in indiscriminate dumping of solid waste in Bajhagara forest. Ward 15 faces significant waste management challenges due to its location of municipal dumping site. Despite the presence of a waste-to-energy (WTE) plant in Dharan, operated by Venture WTE Pvt. Ltd., it has not successfully handled the entire volume of the city's waste. The plant's maximum daily processing capacity exceeds 50 tons, but the absence of policies addressing alternative fuel sales hinders its operation at full capacity. To address these issues, the environmental impacts of waste on dumping areas, particularly in Bajhagara forest, should be studied for proper management and clearing. For the minimization of dumping activities and decrease the need for landfills, waste should be handled in a decentralized manner, starting from its source. The key starting point for an efficient solid waste management system is the implementation of source segregation. Implementing source segregation is the pivotal initial step for an effective solid waste management system. Emphasizing a decentralized waste management approach, starting with source segregation, and promoting the 3R principles (Reduce, Reuse, and Recycle) can ultimately minimize landfill-bound waste. Similarly, addressing and improvising the policies regarding use and sales of alternative fuels like CNG etc. can pave a way for unleashing the full potential of WtE plants like Venture WtE Pvt. Ltd. Which can in turn process and reduce a huge portion of landfill-bound waste, ultimately reducing landfill needs and impacts on the environment. Investing on proper collection and transportation, equipped with a smart monitoring system, can ensure efficient tracking, treatment, and disposal, preventing indiscriminate dumping in urban forests. Feasibility study and implementation of eco-friendly methods like bioremediation can address leachate and hazardous substances present in the legacy waste of dumping site. Reducing organic volume of dumped waste can facilitate the restoration and recycling of non-biodegradable and recyclable materials. Communities' participation and support from the government plays a vital role in succession of any waste management system. Through the collaborative efforts between communities and governmental authorities, waste management initiatives regarding clearing and managing of existing dumping grounds can be implemented. Following the clearing of the dumping area, a feasibility analysis for environmentally-safe waste disposal methods or a potential sanitary landfill site should be conducted, leading to a preferred approach that enhances the environmental quality of the Bajhagara forest and maintains the disposal activities. This can allocate time to study and identify a feasible long-term sanitary landfill site, curbing dumping activities and minimizing landfill requirements in the process.

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M.Sc. In Urban Planning
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Pulchowk Campus, Institute of Engineering
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Kathmandu, Nepal

Thesis final presentation on:

Integrating Urban Forests and Parks in Solid Waste Management in the growing Urban Areas (A Case of Ward 15 of Dharan)

Thesis Supervisor:
Prof. Dr. Sangeeta Singh

Presented By:
Chudamani Karki (078MSUrP004)

Presented To:
Department of Architecture
IOE, Pulchowk Campus

TABLE OF CONTENT

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Chudamani Karki

078MSUrP004

INTRODUCTION

What is Solid Waste ?

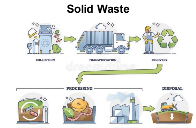
- Discarded by-products of consumers
- No longer useful, wanted, or needed.
- Also refers as garbage, refuses

Solid waste management

Refers to the complete process of:

- Collecting,
- Treating and
- Eco-friendly disposing of solid waste

Solid Waste

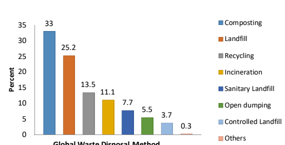


Solid Waste Management Process

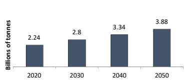
Background

Early pre-industrial age
- Low population density
- Less consumption
- Less waste generated

Post industrial age
- High population density
- High consumption
- High waste generated



Global Waste Disposal Method



Projected Global Waste Generation, World Bank

- ❖ Global waste generation is projected to rise from 2.24 billion tons in 2020 to 3.88 billion tons by 2050, with a more than threefold increase in waste generated in low-income countries
- ❖ with at least 33% not managed in an environmentally safe manner

Source: (World Bank)

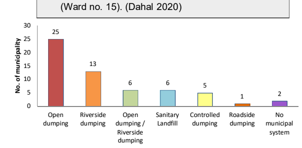
Background

In recent years, cities and urban areas of Nepal have been facing significant challenges in managing their increasing amounts of waste (ADB 2013).

❖Out of the total waste generated < 50 % is collected while most of the waste is haphazardly dumped (Shakya and Tuladhar, 2013).

According to Dharan sub-metropolis,

- of 47 tons of waste produced daily,
- about 35 tons is dumped in an area belonging to the Bajhagara Community Forest and Seuti River (Ward no. 15). (Dahal 2020)



Nepal's Waste Disposal Method (ADB 2013).

Problem Statement


Dharan and Itahari dumping waste recklessly

Published On: August 12, 2018 10:00 AM NPT By: Rohit Rai

Workers belonging to Enviro Care dumping waste collected from Itahari Sub-Metropolitan City in Bajhgara Community Forest, Sunsari in this recent picture. Photo: Rohit Rai/Republica

Waste issue published in Annapurna Post, 2018


The Himalayan

HOME KATHMANDU NEPAL COVID-19 COVID CONNECT WORLD OPINION BUSINESS SPORTS ENTERTAINMENT MORE

Nepal

Dharan dumping waste in Charkoshe jhadi

By SANTOSH KAFLE

Published: 11:03 am Aug 29, 2022

Waste issue published in The Himalayan times, 2022

- Dharan has been dumping garbage in Bajhagara since 1986
- Dumping in the Seuti River stopped after protests from Baklauri residents.
- Efforts, including a waste-to-energy plant, haven't adequately addressed the persistent problem of haphazard waste dumping.
- Unsanitary waste disposal in Bajhagara has become a critical urban challenge, adversely affecting the environment, wildlife, and public health.

Hence, the major concerning problem is:

- Indiscriminate dumping and disposal of municipal solid waste in Bajhagara forest area.

Research Question

Major concerning problem:

- Indiscriminate dumping and disposal of municipal solid waste in Bajhagara forest area.

Formulated Research questions:

- ✓ What causes indiscriminate dumping in the first place?
- ✓ What can be done to minimize its impact?
- ✓ How does the community perceive this issue?

Need of the research

Rapid urbanization and Economic development → **Population growth and increased consumption pattern** → **Higher ratio of per capita household waste generation** → **Indiscriminate Dumping Issue** → **Urgency to assess the current municipal SWM practices**

Importance of Research

- Waste management is a global issue that requires immediate attention and research in order to limit its consequences.
- With global waste predicted to increase by 70% in 2050, Dharan experiences a significant challenge in waste due to rapid urbanization and population growth.
- This research aims to assess the working framework of the municipal SWM of Dharan sub-metropolitan city and review suitable methods for minimizing dumping activities.

Research Objective

- To assess the current municipal solid waste management strategy and prevalent use of forest for disposal
- To review methods and strategies for efficiently managing urban-generated waste in forested areas
- To understand local perspectives and preferences on current waste management and disposal in the urban forest.

Research Limitation

- The main focus is on ward no. 15 of Dharan, specifically the Bajhagara forest dumping zone, limiting the study's scope to this area.
- Due to the saturation in data, the household survey is limited to 50 respondents only.
- The research heavily relies on secondary sources such as literature, articles, academic papers, official reports, and case studies.

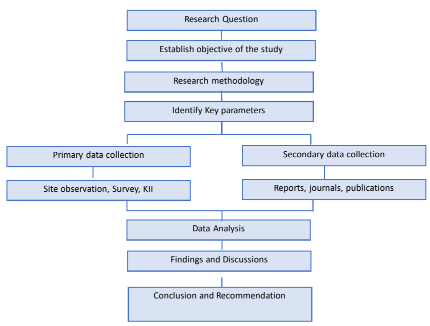
CONCEPTUAL FRAMEWORK

CONCEPTUAL FRAMEWORK

Ontology
- The waste generated by rapid urbanization results in various problems upon disposal. However, these issues can be successfully mitigated by adopting environmentally friendly waste management methods.

Epistemology
- Insights into integration of forest with SWM can be validly discerned through a comprehensive analysis of relevant literature, case studies, or survey data in real-world scenarios.

Research paradigm
- Blend of both Positivism and Interpretivism
- Positivism, linked with quantitative research, addresses solid waste management, while Interpretivism explores the social and human aspects of urban forests and parks integration



Research Methodology Framework

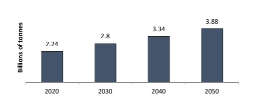
LITERATURE REVIEW

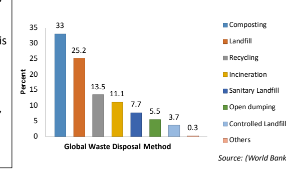
LITERATURE REVIEW

- Urbanization and Solid waste management
- Importance of Urban Forests and parks
- Existing Solid Waste Management System and Practices
- Methods and Strategies for Efficient Waste Management in Forested Areas
- Community participation in Solid Waste Management

Urbanization and Solid waste management:

- Due to rapid population growth and urbanization, annual waste generation is expected to rise 73% from 2020 levels, reaching 3.88 billion tons in 2050.
- The total quantity of waste generated in low-income countries is expected to increase by more than threefold by 2050
- In low-income or developing countries, over 90% of waste is often disposed of in unregulated dumps or openly burned
- As per the ADB survey report of 2013, out of 58 surveyed municipalities of Nepal, majority of them including Dharan, were dumping their waste haphazardly in open areas and riverside



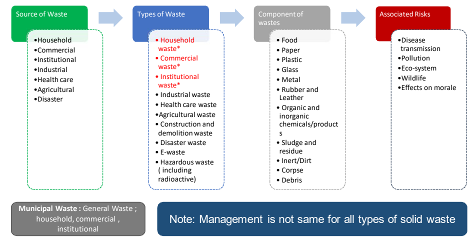


Source: (World Bank)

Importance of Urban Forests and Parks:

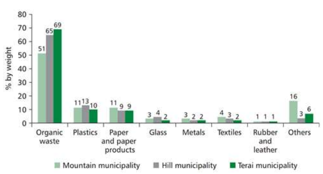
- FAO (2016) defines urban forests as woodlands, tree clusters, and individual trees in urban and peri-urban areas.
- Significantly contributes to the physical and mental well-being of urban residents.
- Has the potential for positive transformations in cities by improving health and overall urban life.
- Crucial for air purification, influencing urban climates, and supporting local livelihoods.
- Strengthens community bonds, enhances food security, and promotes equity in green spaces.

Existing Solid Waste Management System and Practices

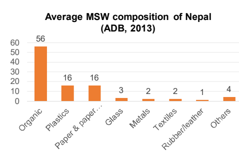


Waste Characteristics

- Understanding the waste characteristics is crucial for effective waste management strategies.



Waste composition according to ecological regions (ADB, 2013)



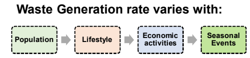
Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	66	43	22
Plastics	12	22	21
Paper Products	9	23	45
Glass	3	4	1
Metals	2	2	1
Textiles	2	2	2
Rubber/ Leather	1	1	1
Others	5	4	8

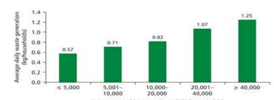
Waste Generation

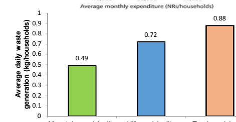
Waste Generation:

- Waste generation in municipalities of Nepal is about 3023 tons per day and the average per capita waste generation is 0.223 kg/person/day. (Maharjan and Lohani, 2019)

Waste Generation rate varies with:

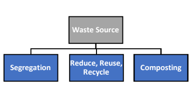






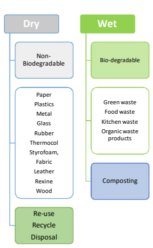
Average Household Waste Generation Pattern in Different Ecological Regions
Source: ADB 2013

Waste Segregation



Decentralization of Waste

Segregated waste collection bins



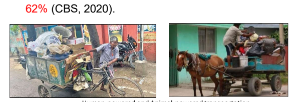
- ❑ Approximately 70% of households dispose of waste directly into the main stream without prior segregation (ADB, 2013).
- ❑ The remaining 30% of households, mainly in rural areas, practice segregation of kitchen waste for specific needs (ADB, 2013).

Waste Collection & Transportation

Primary and Secondary Collection Methods:

- Primary collection involves rickshaws and carts, while tractors handle secondary collection, and dump trucks transport waste to disposal sites (ADB, 2013).
- Availability of vehicles and equipment for waste collection varies across municipalities in Nepal (ADB, 2013).
- The average collection efficiency is estimated to be around 62% (CBS, 2020).

Waste Collection



Human-powered and Animal-powered transportation

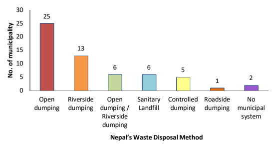
Waste collection system, Waling Municipality

Waste Disposal

- Numerous municipalities in Nepal face challenges in locating suitable areas for treatment facilities and sanitary landfill sites (ADB, 2013).
- The lack of appropriate sites leads to the disposal of waste in makeshift sites, posing health risks and contributing to environmental problems.
- Open dumping is prevalent in 45 out of 58 municipalities, including Dharan Sub-metropolitan City, where waste is dumped in forest areas, riversides, and roadsides (ADB, 2013).
- Only six municipalities, namely KMC, Lalitpur, Pokhara, Ghorahi, Dhankuta, and Tansen, have taken steps to initiate the construction of sanitary landfill sites (CBS, 2020).

Nepal's Waste Disposal Methods (ADB, 2013)

S.N.	Disposal method	No. of municipality
1	Open Dumping	25
2	Riverside Dumping	13
3	Open Dumping/Riverside Dumping	6
4	Sanitary Landfill	6
5	Controlled Dumping	5
6	Roadside Dumping	1
7	No Municipal System	2



Review of methods for Efficient Waste Management in Forested Areas:

Source Reduction
Source reduction, also referred to as waste prevention,
- involves minimizing waste at its origin
- considered the most environmentally preferred strategy

Reduce, Reuse and Recycle (3R)
The waste hierarchy—Reduce, Reuse, Recycle—guides waste management based on environmental impact and resource efficiency and promotes sustainability (Hezri, 2010).

Bioremediation
An eco-friendly, cost-effective, and efficient technology, suitable for treating industrial wastewater and leachates (Coelho et al., 2020).
involves the utilization of microorganisms to diminish,
- toxicity of harmful wastes
- organic pollutants in both soil and water

Composting
Composting is a controlled biological process converting the organic fraction of waste into stable, humus substances, ideal for soil amendments (Adani et al., 1995; Cooperband, 2002).
Ideal for treating organic waste.

Sanitary Landfill:
The sanitary landfill method involves the disposal of solid waste on land without causing disturbances or hazards to public health or safety (Bell, 1973).

Review of methods for Efficient Waste Management in Forested Areas:

Waste-to-Energy (WtE) Technologies:
Waste-to-Energy (WtE) technologies encompass diverse waste treatment processes that capture energy, such as electricity, heat, or transport fuels, from different waste sources.
Is applicable to different types of waste including,
- semi-solid waste,
- liquid waste, and
- gaseous waste (e.g., refinery gases).

Fukuoka Method (Semi-aerobic)
The Fukuoka method landfill, developed through a collaborative effort between Fukuoka University and Fukuoka City in Japan, stands out as the optimal choice for replacing open dumpsites (Amiri et al., 2016). Applicable in both temperate and tropical climates.

Sensor-Based Monitoring Systems (IoT):
In recent years, Internet of Things (IoT) has become a pivotal technology in the twenty-first century (Vishnu et al., 2021). IoT-enabled waste management systems offer several key benefits (Vishnu et al., 2022):
- No Missed Pickups
- Waste Production Analysis
- Route Optimization

Community-Led Cleanup Initiatives:
In the context of solid waste management, community participation is vital because it's an ongoing maintenance system (ADB, 2013).

Community participation in Solid Waste Management

- Waste (1996) defines a community as individuals residing within a social framework (Anschütz, 1996).
- Anschütz (1996) emphasizes the vital role of community participation in effective solid waste management,
- The Brundtland Commission emphasizes its significance in achieving sustainable development, particularly in solid waste management compared to other urban services.
- For succession of any effective SWM, it's crucial to promote community participation through campaigns emphasizing the 3R principles and improved solid waste management (ADB, 2013).

Case study

National Case Study

Pokhara SMC
- Waste management section with 90 personnel to undertake management and on-ground operations
- Part of biodegradable/organic waste is segregated by the residents and composted.
- Second level of sorting takes place at the landfill site where PMC has appointed a private contractor.

Waling Municipality
- "Waling Nagarpalikako Sarsafai Kendra" was established in 2012 AD.
- Suggested every household to segregate the 3 different type of waste: Dry Recyclables, Wet Compostable and Glass.
- Waste is collected in alternate days by organic and non-organic waste
- "Didi Bahini Tatha Samaj Utthan Sanstha" a women group has been working since the end of 2074 in the field of SWM

Dhankuta Municipality
- Received the cleanest city award in Nepal in 2017, showcasing successful waste management practices.
- With a daily production of 10 tons, over 50% of Dhankuta's waste is segregated as organic, used for fodder and compost.
- Recycling generates revenue and employment, transforming the dumping site into a park with a fee for government officials.
- Dhankuta faces challenges in waste disposal, using an informal site, and plans for a new landfill site are hindered by political interference, requiring attention.

International Case Study

Indore city, India

- 100% door to door collection & segregation at source.
- Participation of stakeholders and good governance
- Robust monitoring system and enforcement
- Cleanest city in India.

Singapore

- Limited landfill site (Sempakau Island)
- Launched the National Recycling Programme (NRP) in 2001
- Aim: reducing and recycling the solid waste.
- Since the launch of the NRP, the total recycling rate has increased from 40% in 2000 to 61% in 2015.

Study area

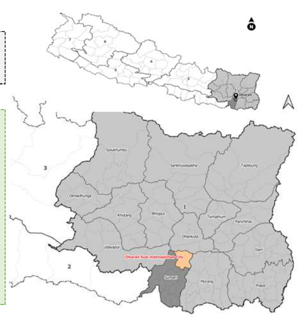
STUDY AREA

The study area is located in Dharan sub-metropolitan city, Sunsari district of Province no. 1 Nepal.

The Dharan Sub-Metropolitan City encompasses,

- Area: 192.61 km2
- Population density: 866 per km2, (CBS 2021)
- Latitude: 26.8065° and longitude: 87.2846°.

Based on census 2021, a total of 166,531 population; 78,410 (47.1%) male and 88,121 (52.9%) female is living in 42,396 households within the city.

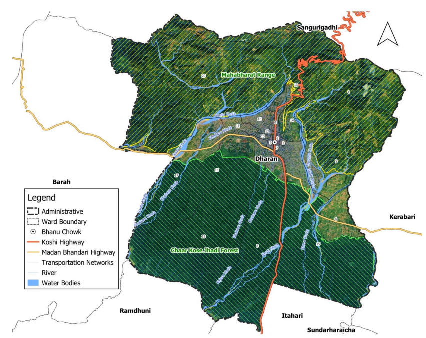


Location map showing Dharan

Physical profile

Altitude:1148 ft (349m).
East: River Seuti, Kerabari
West: Sardu River, Baraha
North: Mahabharata Range
South: Chaar Kose Jhadi Forest

North-South Connection: Koshi Highway
East-West Connection: Madan Bhandari Highway



Physical profile

Municipality Profile

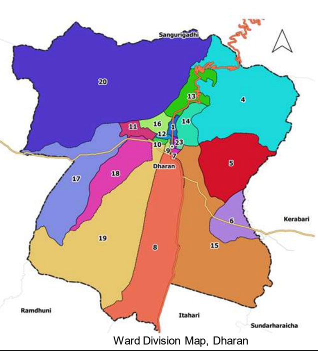
The Dharan municipality has been expanded by addition of two VDCs Panchkanya and Bishnupaduka and declared sub-metropolitan city in 2016,

- Updated total area: 192.61 sq. km
- After the recent ward readjustment, DSMC has total 20 wards.

According to the surface area:

Ward no. 20 is the largest ward (49.156 Sq.Km)

Ward no. 3 is the smallest ward (0.131 Sq.Km)



Ward Division Map, Dharan

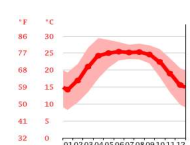
Climatic Profile

Dharan, the climatic conditions are categorized as mild and moderate.

Mean temperature: 21.6 °C

Annual precipitation: 1796 mm

This climate is considered to be Cwa according to the Köppen-Geiger climate classification

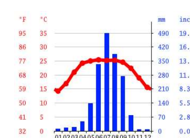


Temperature pattern, Source: Climatedata.org

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	14.2 °C (57.6) °F	16.9 °C (62.5) °F	21 °C (69.8) °F	24.2 °C (75.6) °F	25 °C (77) °F	25.4 °C (77.8) °F	25.2 °C (77.3) °F	25.3 °C (77.5) °F	24.6 °C (76.2) °F	22.4 °C (72.3) °F	18.9 °C (66.1) °F	15.6 °C (60.1) °F
Min. Temperature °C (°F)	8.2 °C (46.8) °F	10.5 °C (50.9) °F	13.5 °C (56.3) °F	17.5 °C (63.5) °F	20.7 °C (69.2) °F	22.9 °C (73.2) °F	23.2 °C (73.8) °F	23.1 °C (73.7) °F	21.9 °C (71.5) °F	17.9 °C (64.3) °F	13.4 °C (56.2) °F	9.8 °C (49.6) °F
Max. Temperature °C (°F)	19.3 °C (66.8) °F	21.8 °C (71.3) °F	26.6 °C (79.9) °F	29.4 °C (85) °F	28.9 °C (84) °F	28.3 °C (82.9) °F	27.5 °C (81.5) °F	27.8 °C (82) °F	27.3 °C (81.1) °F	26.2 °C (79.1) °F	23.5 °C (74.2) °F	20.5 °C (69) °F
Precipitation / Rainfall mm (in)	10 (0)	15 (0)	17 (0)	46 (1)	136 (5)	334 (13)	490 (19)	383 (15)	273 (10)	78 (3)	8 (0)	6 (0)
Humidity(%)	71%	64%	51%	53%	71%	83%	87%	86%	85%	79%	71%	71%
Rainy days (d)	1	2	3	7	14	20	21	21	18	7	1	1
avg. Sun hours (hours)	7.7	8.3	9.8	9.6	9.0	7.8	7.3	7.8	7.9	8.8	8.6	7.9

Data: 1991 - 2021 Min. Temperature °C (°F), Max. Temperature °C (°F), Precipitation / Rainfall mm (in), Humidity, Rainy days. Data: 1999

Annual Climate data of Dharan, Climatedata.org



Rainfall pattern, Source: Climatedata.org

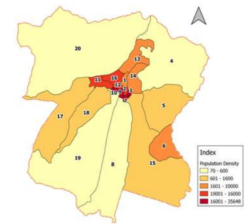
Demographic Profile

Demographic Information: IUDP 2017 and CBS 2021

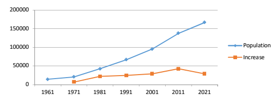
Ward no.	Household	Population	Male	Female	Area (Sq.Km)	Density
1	1,199	4962	2413	2549	0.494	10044
2	540	2275	1124	1151	0.172	13226
3	1,034	4662	2304	2358	0.131	35587
4	713	3783	1822	1961	23.012	164
5	1779	13651	6380	7271	10.632	1283
6	1371	8455	3983	4472	4.589	1842
7	777	2967	1480	1487	0.194	15293
8	2,818	12126	5829	6297	19.616	618
9	1,022	3564	1727	1837	0.211	16891
10	1,384	4612	2144	2468	0.222	20774
11	2,708	17168	7904	9264	1.352	12698
12	796	3029	1468	1561	0.276	10974
13	2,034	9138	4167	4971	3.397	2690
14	851	4803	2286	2517	2.468	1946
15	4,726	27441	12845	14596	25.544	1074
16	2,763	14665	6835	7830	1.429	10262
17	2,610	15912	7509	8403	14.578	1091
18	1,620	4579	2072	2507	7.21	635
19	1,154	5313	2415	2898	28.297	187
20	784	3426	1703	1723	49.156	69
Total	32,683	166531	78410	88121	192.98	866

	1961	1971	1981	1991	2001	2011	2021
Population	13,998	20,503	42,146	66,457	95,332	1,37,702	1,66,531
Increase		6,505	21,643	24,311	28,875	42,370	28,829

Population Growth Trend (IUDP 2017)



Population Density Map, Dharan



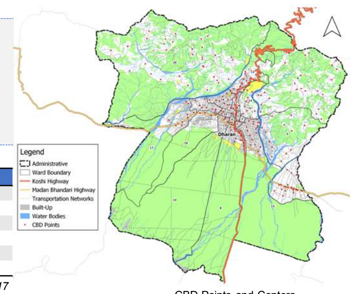
Economic Profile

The economy of Dharan is based on,

- Transport sector / Auto services
- Hotels and restaurants
- Banking and finance
- Industries and Business
- Agro-business
- Health sectors
- Education sectors

Trade and Industries	No.
Medium Scale Industry	24
Small Scale Industry	104
Hotel/Lodge/Guest House	78
Restaurants	45
Shops	1950
Other business	400

Source: IUDP 2017

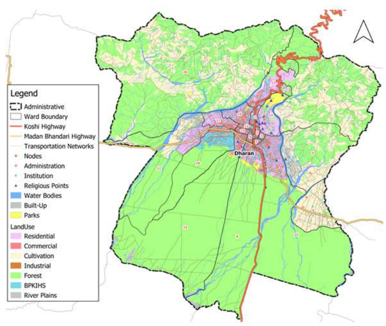


CBD Points and Centers

Land Use Pattern

The forest area covers the most of the land area (70.33%) followed by Agricultural area (23.82%). The Built up area covers 1.78% only and the least is water bodies (0.67%)

Categories	Area (sq.km)	Percentage (%)
Built area	3.45	1.78
Forest	135.74	70.33
Water Body	0.01	0.67
Agriculture	45.98	23.82
River bed	7.09	3.67
Cutting cliff	0.87	0.45



Land Use Map, Dharan

Analysis and Findings

Methodology for data collection

Literature review/study: Established knowledge on solid waste management and its related policy.

KII: Information from key people and stakeholders involved in the solid waste management of Dharan.

Site observation: Through site visit and observations, take detailed notes, record observations, and capture any relevant visuals that presents the current situation of ward no. 15

Survey: A survey questionnaire that aligns with the research objectives includes both closed-ended and open-ended questions to collect quantitative and qualitative data

Objective Framework for data collection

Main objective	Specific objective	Variables or Research questions	Sources
To assess the current municipal solid waste management pattern and explore the ways to manage the unsanitary disposal of solid waste in urban forests taking the case of Bajhagara forest, ward no 15 of Dharan	Assessment of current waste management pattern of Dharan with prevalent use of forest for disposal	Nature of waste and composition	Literature study
		Current state of Municipal Solid Waste Management	Literature study KII FGDs Observation
		Current state of Dumping area	KII Survey FGDs Observation
	Review of methods and strategies for efficiently managing urban-generated waste in forested areas	Relevant methods/practices	Literature Journals, Articles
		Case Studies	National Case Studies International Case Studies
	Perception and insight of the public regarding SWM	Analysis and findings from case area survey	Field Observation Household Survey Questionnaire Data Analysis

Waste Generation Pattern:

- Municipal waste: 424.62 gm/capita/day, Household waste: 212.31 gm/capita/day, resulting in a total of 50.92 tons/day (ADB, 2013).
- Commercial areas generate 7.53 tons/day, households contribute 25.46 tons/day (ADB, 2013).
- 10-15% of bio-degradable waste is individually composted, and 20-30% non-bio degradable waste is either collected or sold to recyclers.

Municipality	Dharan
Average HH Waste (kg/day)	1.17
Average HH size(number of members)	5.53
Average per Capita HH Waste (g/capita/day)	212.31
Total HH Waste (tons/day)	25.46
Total Commercial Waste (tons/day)	7.53
Total Institutional Waste (tons/day)	0.44
Average per Capita MSW (g/capita/day)	424.62
Total MSW Generation (tons/day)	50.92
Estimated Waste Collection (tons/day)	35.0
Collection Efficiency (%)	68.7

"About 70% of total waste is collected by SWM sectors"

Mangal Pariyar

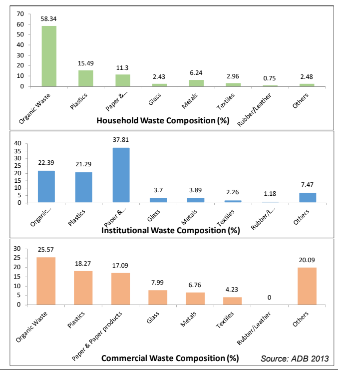
Household waste is the primary source, followed by commercial and institutional waste in the municipality.

Waste characteristics

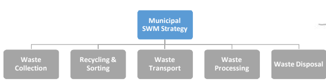
Waste composition

Dharan's Municipal Solid Waste Composition, ADB-2013

Waste Type	Household Sector (%)	Commercial Sector (%)	Institutional Sector (%)
Organic Waste	58.34	25.57	22.39
Plastics	15.49	18.27	21.29
Paper Products	11.30	17.09	37.81
Glass	2.43	7.99	3.70
Metals	6.24	6.76	3.89
Textiles	2.96	4.23	2.26
Rubber/Leather	0.75	0	1.18
Others	2.48	20.09	7.47



Solid waste management in Dharan



- Registered service providers for solid waste management.
- Works under the supervision of environment officer and respective authorities
- Overall team is led by an assigned in-charge

Current SWM Fleet Comprises of:

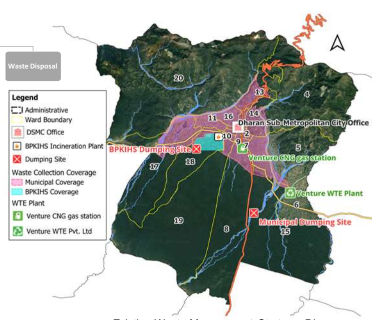
9 Waste collection vehicles (3 tripper and 6 tractors)

75 members (63 active and 12 official)

Collection coverage: all wards except 5,6,20 and BPKIHS

Waste Processing: Venture WTE Pvt. Ltd

Disposal: Bajhagara Forest



Existing Waste Management Strategy, Dharan

Collection and transportation

The frequency of collection depends upon the location and the amount of waste generated.

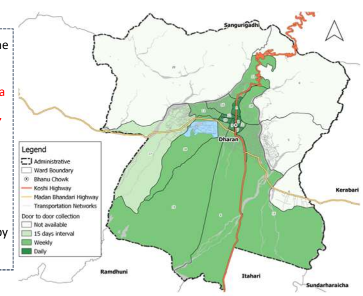
Excluded Areas: Ward no. 4,5,6,20 and BPKIHS Area

Daily Collection: Core areas, Ward no. 1,2,3,7,9,10, and 12

Weekly Collection: Ward no. 8,11, 13, 14, 15, 16, 18, and 19

15 days interval: Ward no 17

Aim: Planning to include ward no. 5,6 and 20 also by adding 15 more manpower



Door to door collection

Waste to Energy Initiative

Waste segregation and processing

Waste Processing Plant: Venture WTE Pvt. Ltd

Location: Panbari (Ward 6)

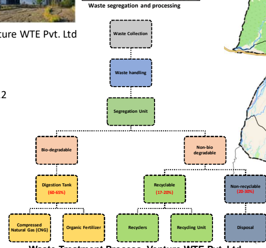
Plant capacity: 50+ tons

Inauguration Date: Jan 4,2022

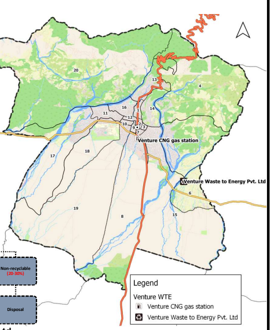
Typology: Waste to Energy

Contract duration: 20 years

Tripartite Agreement



Waste Treatment Process, Venture WTE Pvt. Ltd



Waste Disposal

Landfill: No official landfill site for waste disposal

Disposal Method: Direct Dumping

Treatment before dumping: No any treatment

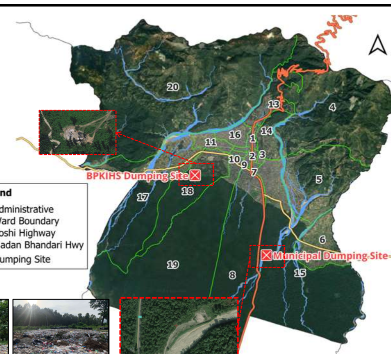
Total dumping site: 2 (Municipal and BPKIHS)

Municipal Dumping Site: Bajhagara Forest

Location From the highway: 10 metres

Negative Impacts:
- Environmental pollution
- Depletion of wildlife
- Eco-system
- People's health

Vision:
Allocation of environmentally safe landfill site, Feasibility analysis going on



Dumping sites

Case Area (Ward 15)

Ward no. 15 of Dharan is selected.

Total population: 19879

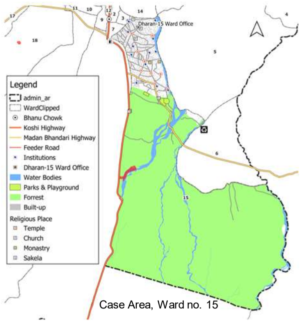
(9213 males and 10666 females)

Area: 25.54 Sq. Km

Dwellings: 4726

Site selection criteria:

- Location of municipal dumping site
- Location of Bajhagara community forest
- Location of Seuti river
- Ward wise highest number of population



Case Area, Ward no. 15

Dumping in Urban Forests

Overview of Bajhagara Forest:

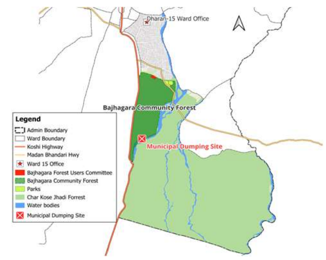
Officially formed: 2059 B.S.

Location: Dharan, ward no. 15

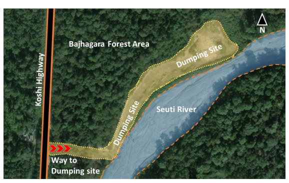
Total land area: 2.88 sq. km.

Orientation:

- East: Seuti River
- West: Koshi Highway
- North: T.U. IOE ERC boundary wall and settlements
- South: Seuti River Bridge



Extent of Haphazard Dumping



Access to dumping site from Koshi Highway

- ➢ The haphazard dumping of municipal waste in the urban forest has persisted since 1986 A.D.
- ➢ Around 10-13 tons dumped daily, without proper treatment, adversely affecting soil, biodiversity, and causing environmental complications.
- ➢ All types of municipal waste, including organic, inorganic, and bio-waste, are haphazardly dumped, posing health risks to recyclers, waste workers, and SWM staff.

Extent of Haphazard Dumping

- ➢ Indiscriminate dumping results in significant environmental complications, with leachate degrading soil fertility and potentially causing habitat loss.
- ➢ The industrial estate near Bajhagara forest in Dharan also poses a severe environmental threat, discharging toxic wastewater directly into the forest.
- ➢ The estate's drainage directly contaminates Bajhagara forest, causing soil contamination, affecting plant growth, and groundwater pollution.
- ➢ Strict rules, proper waste management, and wastewater treatment are urgently needed to prevent irreversible damage to Bajhagara forest and the surrounding environment.

Result-Household Survey (ward 15)

A survey was conducted in Ward No. 15 of Dharan involving more than 50 respondents.

Study Objectives:
Aimed to understand the community's sentiments and attitudes towards solid waste management.

Sampling Techniques:
Random sampling techniques were employed in the research study.

Sample Size:
The sample size comprised approximately 50 respondents.

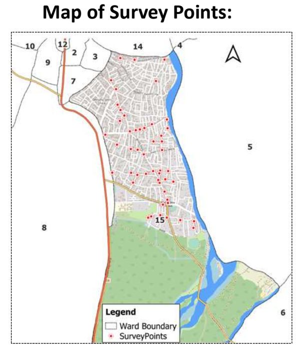
Classification Criteria:
Sample classification included age, gender, class, type of building use, location (Tole), and tenancy status.

Saturation Level:
It's important to note that the survey was capped at 50 respondents once the saturation level was achieved.

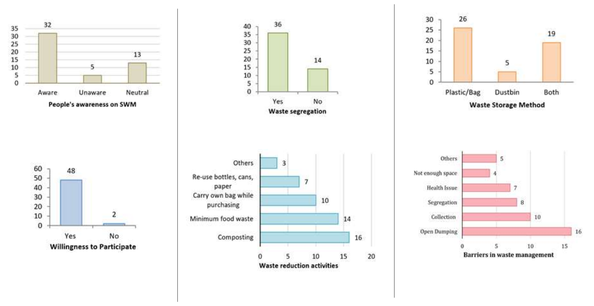
Demographic information of respondents: 50 respondents

Category	Value	Number	Percentage (%)
Gender	Male	22	44
	Female	28	56
	Others	0	0
Age	15-24	3	6
	25-50	34	26
	Above 50	13	68
Occupation	Housewife	11	22
	Student	4	8
	Service	19	38
	Business	13	26
	Others	3	6
Marital Status	Married	45	90
	Unmarried	5	10
Household Ownership	Owned	29	58
	Rented	21	42
Education	Under SLC	9	18
	SLC	13	26
	Intermediate	18	36
	Bachelor	7	14
	Masters	3	6

Map of Survey Points:



Results from Household surveys



Key Informant Interviews:

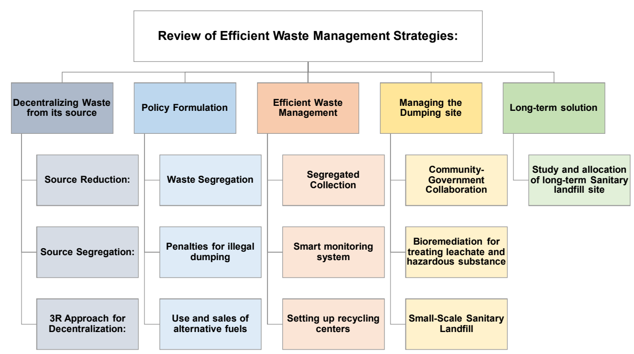
Dharan Sub-metropolitan City	Solid waste management division, Dharan	Bajhagara Ban Upabhokta Samiti	Venture WTE Pvt. Ltd. (Private sector)	BPKIHS, Dharan
• **Bhes Raj Ghimire** • Environment Officer • Dharan Sub-metropolitan city	• **Mangal Pariyar** • In-charge at Dharan waste management • Covered area: all wards except 5,6,20 and BPKIHS area • Supported by Venture WTE Pvt. Ltd.	• **Maya Devi Rai** • Secretary • Established date: 2059 • Covered area: ward 15	• **Hari Khatri** • Plant Manager • Established date: 2022 • Location: Panbari • Capacity: 50 TPD	• **Pushpa Nepali** (Waste Management Personnel, BPKIHS) • Established date: 1993 • Area Covered: 700 Acre

Discussion:

Assessment of Current Waste Management Patterns:

Overview of Existing Practices:

- **Daily waste generation:** 50.92 TPD
- **Collection coverage:** Every ward (except 4,5,6 & 20)
- **Waste Segregation:** Not implemented
- **Collection Efficiency:** 70%
- **Door to door collection:** Daily, Weekly & 15 days interval
- **Waste Processing (WtE):** Venture WtE Pvt. Ltd. (approx. 50% of total collected municipal waste)
- **Waste Disposal:** Open Dumping in Bajhagara forest, ward 15



Community perception and preference:

Explored community views on current waste management and disposal in nearby forests.

Results revealed:

- Dissatisfaction with the adverse effects of open dumping and disposal.
- Support for eco-friendly waste management and a desire for cleaner, sustainable urban environments.
- Household-level adoption of waste management practices like segregation and composting indicates an initial move toward sustainability.

Conclusion and Recommendation:

Conclusion

- Dharan is experiencing rapid urbanization, leading to increased waste generation pattern.
- The conventional waste management approach of collection, transport, and disposal is proving insufficient
- Absence of waste segregation practices further complicates the disposal process
- Despite a WTE plant, policy limitations hinder its full capacity in handling the city's waste.
- Lack of a proper landfill leads to indiscriminate dumping in Bajhagara forest, posing significant challenges in Ward 15.

Recommendation

- ✓ Adopt policies for source reduction, segregation, 3R principles, and alternative fuel, to significantly minimize landfill requirements.
- ✓ Invest in smart monitoring for efficient waste collection, transportation, tracking, treatment, and disposal.
- ✓ Implement methods like bioremediation to address leachate and hazardous substances in legacy waste.
- ✓ Emphasize the essential role of community-government collaboration in waste management initiatives.
- ✓ Study and identify an environmentally feasible landfill site for long-term waste management.

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