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Solid Waste Management: A Case Study of Kathmandu Valley

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Abstract

This research article focuses on solid waste management in Kathmandu Valley, Nepal, specifically on elucidating waste disposal methodologies at diverse landfill sites. The study investigates the challenges and approaches in solid waste management, including waste segregation, landfill management, and environmental impacts. The research also examines the role of social media in disseminating information about waste management practices to the public. From the study undertaken in Tokha Municipality of Kathmandu Valley around 80% of participants of the survey received information regarding the rule for waste segregation via. Social media platforms indicate the effectiveness of such platforms for information dissemination. The article presents a concise analysis of Gokarna Landfill Site (GLS), Sisdol Landfill Site (SLS), and the newly established Banchare Danda Landfill Site (BDLS) to assess their waste disposal methods and environmental consequences. On average the waste generation of the Kathmandu Metropolitan City (KMC) as of 2013 was 0.66 kg/capita/day out of which almost 100% of the waste collected ends up in landfill sites. The Geographic Information System (GIS) modeling technique was used for the analysis of the landfill capacity of BDLS and the possible waste disposal scenarios. The study's results highlight the significance of waste categorization and effective communication mediums for proficient waste administration. The study also offers perspectives on landfill architecture, leachate attributes, and the contribution of social media in fostering awareness about waste management. The sensitivity analysis of BDLS demonstrates the significance of waste segregation in optimizing landfill capacity. In order for the accommodation of waste generated in KMC by 2045 at BDLS almost 80% of the organic waste and 50% of recyclable materials need to be segregated. The paper concludes by suggesting the establishment of resilient Material Recovery Facilities (MRFs), integrating the 3R (Reduce, Reuse, Recycle) methodology, and advocating for additional research on landfill compaction and gas generation processes.

Keywords

Solid Waste Management, Waste Segregation, Social Media, Landfill Sites

1. Introduction

Solid waste management encompasses a comprehensive approach involving the handling, collection, transfer, transportation, treatment, and ultimate disposal of discarded solid materials. In ancient human societies, the non-engineered techniques for disposing of solid waste did not present a notable issue because the population density was relatively low in comparison to the abundant land available, which exhibited a rapid natural capacity to assimilate the waste. In recent days, the utilization of plastics has notably surged not only within the food industry but also across diverse manufacturing sectors. Within this dynamic technological landscape, it becomes imperative to employ all available foresight to ensure that robustness gets integrated into the facilities' designs [1].

In the conventional approach to solid waste management, a significant proportion of waste ends up at the ultimate disposal site. While the modern approach emphasizes minimizing the waste directed to landfills, focusing instead on maximizing reduction, reuse, and recycling (3R Principle) to handle the majority of the waste generated[2].

2. Literature Review

2.1 Solid Waste Management in Nepal

Before the enactment of the "Constitution of Nepal, 2015," Nepal operated under a centralized governance system. The country had also experienced a decade-long Maoist insurgency (1996-2006) that resulted in the displacement of a considerable rural population to urban areas. This abrupt urban population influx, coupled with limited urban development funds and planning, led to uncontrolled urban expansion and inadequate infrastructure management.

On June 15, 2011, the Government of Nepal (GoN) passed the Solid Waste Management Act 2011. Under this act, local governing bodies such as municipalities bear the responsibility of establishing, operating, and overseeing infrastructure for the collection, treatment, and final disposal of municipal solid waste (MSW) with an obligation to take appropriate measures to encourage the principles of reduction, reuse, and recycling (3R). Additionally, the act facilitated the involvement of private sector entities, community-based organizations (CBOs), and non-governmental organizations (NGOs) in solid waste management (SWM) through competitive bidding processes. Similarly, the Environmental Protection Rule (EPR) of 2020, defined the required environmental study levels for various waste management and disposal activities, thereby ensuring that appropriate assessments are conducted to safeguard the environment.

Local governing bodies are encountering challenges in formulating effective waste management plans due to the absence of baseline information and comprehensive data pertaining to the operational components of solid waste management (SWM). This scarcity of essential data is impeding the development of well-informed waste management strategies. It is essential to know the quantity and composition of MSW when designing and implementing proper waste management plans that include resource recovery through appropriate methods.

As per a research study[3] conducted by the Asian Development Bank (ADB) in 2013, the mean daily household solid waste production in Nepal stood at 170 grams per individual. The dominant component of the solid waste was primarily organic, constituting a significant portion of 56% overall and a notably higher proportion of 66% at the household scale. Concerning institutional waste, the most prominent segment in the composition was related to Paper and paper products, contributing to 45% of the total composition.

2.2 Waste Disposal of Kathmandu Valley

2.2.1 Gokarna landfill site (GLS)

The Gokarna Landfill Site (GLS) established in 1986 A.D., functioned as the designated disposal site for solid waste generated in Kathmandu and Lalitpur Metropolitan Cities until 1994 A.D; originally constructed as an open dump landfill site, lacking proper containment measures. This absence of a barrier layer and the high inflow rate of leachate from the landfill site posed a significant risk of contaminating the shallow aquifer thereby polluting the surrounding shallow wells, dug wells, and springs.

The waste composition study[4] carried out in 2007, 7 years after the landfill closure, highlighted that the composition was primarily dominated by organic matter (88.47%), with plastic (3.14%) as the subsequent major component. Observing the composition, it's evident that packaging for food was not as prevalent, and the utilization of plastic bags was less pronounced compared to the present scenario. The leachate's characteristics (Table 1) align with those typically observed in a matured landfill with the pH lying in neutral range as the acid and hydrogens get converted to carbon dioxide and methane. From the analysis of the chemical characteristics of leachate, parameters such as BOD, COD, and Ammonia exhibit lower values[1].

Table 1: Leachate characteristics of GLS

Parameters	Unit	Leachate
pH		6.70
BOD	mg/L	75.67
COD	mg/L	567.67
Ammonia-N	mg/L	0.05
Iron	mg/L	10.80

However, the iron content in the leachate suggests that the biological processes within the landfill are still in an acidic phase[1].

2.2.2 Sisdol landfill site (SLS)

The land for the Sisdol Landfill Site (SLS) was initially leased by the Government for a period of two years as a temporary waste disposal site in 2005 AD but continued to be operated up to 2021 AD until the Banchare Danda Landfill Site (BDLS) commenced operations. During its peak operational period, approximately 75% of the daily waste (equivalent to 1200 tons) generated in the Kathmandu Valley was disposed of at the SLS, with transportation facilitated by around 200 vehicles[5].

The landfill site, SLS, was equipped with a comprehensive leachate management system including a leachate collection network comprising a pipe network and a re-circulation system. Gas vents were also incorporated into the landfill, and these were integrated with a clay liner system to manage landfill gases.

A significant concern regarding the SLS was its leachate management. The untreated leachate discharge practice raised serious environmental and public health apprehensions due to the potential contamination of the river water by untreated leachate. The chemical composition of leachate analyzed in 2018 (Table 2), near closure exhibited notably elevated levels of both BOD and COD[6].

Table 2: Leachate characteristics of SLS

Parameters	Unit	Leachate
pH		8.55
BOD	mg/L	3,700.00
COD	mg/L	7,560.00
Ammonia-N	mg/L	3,268.00
Iron	mg/L	13.31

This elevation can be attributed to the excessive use of the landfill beyond its intended capacity along with improper waste handling and soil capping. Consequently, this overuse has disrupted the typical biological, chemical, and physical reactions taking place within the landfill, diverging from the expected trends based on its age. In addition, the compaction and design components of the landfill could have further played a role in the divergence trend. Furthermore, the substantial iron content present in the leachate signifies that the decomposition processes within the landfill are currently situated in an acidic phase. The pH value of 8.55 lies in the neutral to acidic range indicating that the acid and hydrogen formed by acid producers in the acidic phase have been converted to methane and carbon dioxide[1].

2.2.3 Banchare danda landfill site (BDLS)

The BDLS is a sanitary landfill facility that commenced operations on May 24, 2022 and serves as the disposal site for waste generated by 16 municipalities. The design of this landfill allows for an operational period of up to 100 years, assuming waste segregation is practiced[7]. Situated approximately 27 km north of the Kathmandu Valley, the construction cost of the landfill was supported by a total budget of NRs. 1.56 billion[8].

The landfill site is equipped with lined cells that incorporate a leachate collection system and a leachate retention pond, providing a containment area for collected leachate. To address the management of landfill gases, the site is fitted with landfill gas wells, allowing for the controlled collection and treatment of gases generated during waste decomposition. A study conducted in 2022 AD for the determination of Leachate characteristics (by Aastha Scientific Research Service Pvt. Ltd.) of BDLS yielded the following results shown in Table 3.

Table 3: Leachate characteristics of BDLS

Parameters	Unit	Leachate
pH		5.64
BOD	mg/L	2,430
COD	mg/L	8,300

The Banchare Danda Landfill Site (BDLS) exhibited a lower Biochemical Oxygen Demand (BOD) in contrast to the Sisdol Landfill Site (SLS) nearing its closure. However, there was a significantly higher Chemical Oxygen Demand (COD) observed in BDLS compared to SLS. This disparity in COD levels might be attributed to an escalated biological breakdown of organic waste within BDLS, resulting in increased methane production, as opposed to SLS. Such variance could be linked to the landfill leachate's recirculation process, potentially intensifying the biodegradation of perishable materials. This recycling procedure notably augments the biological decomposition of organic matter. The decreased pH value can also be ascribed to this phenomenon, given that an increased formation of acids accompanies the decomposition of organic waste within the landfill.

During the study period (2022), the leachate treatment unit (except the recirculation system with leachate collection pond) had not yet been designed and constructed at the landfill site. Research and development of the units were being undertaken by various governmental and private institutions to determine the most effective and suitable approach for treating leachate generated at the landfill.

3. Methodology

3.1 Data Collection

A brief analysis was conducted concerning the management of solid waste in Tokha Municipality, focusing on Ward-4 and Ward-6 specifically. The municipality was selected rather than the Kathmandu Metropolitan City (KMC) as the municipality comprised of both urban and semi-urban settings. The evaluation encompassed the practice of segregation within the municipality and the identification of efficient means to communicate solid waste management information to the residents of these wards. A random sampling was undertaken, involving a total of 10 samples collected from each ward. The sampling conducted exclusively during weekdays imposed a limitation on the number of participants available for the survey. In Ward 4, the respondents comprised 40% females and 60% males, whereas an equal distribution of male and female respondents was observed in Ward 6. In both Ward 4 and Ward 6, 70% of the respondents were below the age of 46 years.

3.2 GIS Modeling

Using QGIS software, the data collected were processed to produce a) a landuse map, b) a solid waste segregation map, and c) an information map. A Geographic Information System (GIS) model of the Banchare Danda Landfill Site (BDLS) was created, utilizing the freely accessible STRM DEM (3 arc-second) data. This data was utilized to generate contour lines of 5m intervals (Figure 1) which were processed to calculate the available volume for waste disposal at BDLS.

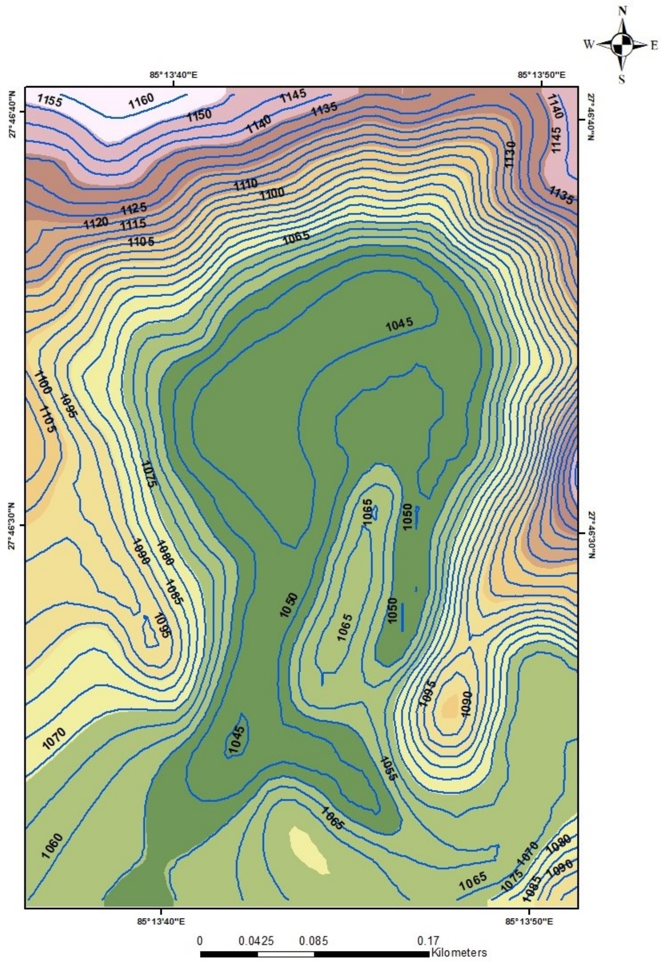

Figure 1: Contour Map of BDLS

3.3 Sensitivity Analysis

A sensitivity analysis of waste generation and disposal of Kathmandu Metropolitan City (KMC) for a 25-year period from 2020 A.D. was carried out and assessed for the change in the volume of waste disposed in the BDLS using the following parameters (Table 4):

The KMC being the largest Metropolitan City having the highest population within the Kathmandu Valley was selected for the assessment out of the 16 municipalities that dispose of their waste at the BDLS.

A 30m total available depth was assumed for the storage of disposed solid waste. No consideration of the solid waste

Table 4: Analysis parameters

Parameters	Value	Unit	Remarks
Population	1,442,000		2020 A.D.
Growth Rate	1.51	%	NPHC 2021
Growth Rate	1.5	%	Adopted
Waste Generation	0.66	k/c/d	[9]
Design Period	25	years	
Bulk Density of Waste	211	g/L	[3]
Adopted Depth of Compacted Solid Waste	30	m	Assumed

compression ratio in the landfill was taken during the analysis. The sensitivity analysis was carried out based on the following criteria: 1. No Segregation is done, 2. 40% of the total organic waste is carried out, 3. 60% of the total organic waste is segregated, 4. 80% of the total organic waste is segregated, and 5. 80% of the total organic waste is segregated and 50% of recyclable material is segregated.

4. Results and Discussions

4.1 Segregation Practice and Effective Communication Channel

Based on the field survey carried out at the proposed locations the following data tabulated (Table 5) were obtained.

Table 5: Survey results

Particular	Quantity	Unit
Collection frequency	2	per week
Average cost of collection service	400	NRs
Major district of migrants	Nuwakot	
Major Occupation	Daily wage workers	
Most web-based application used	Facebook	

A significant portion of the area's inhabitants are migrants from neighboring districts, primarily Nuwakot District. These residents often reside in rental accommodations where proper waste management and segregation are not easily achievable, particularly in smaller flats or living spaces. There is also a significant difference in the cost of collection which is solely based on the landlord's decision, which ranged from NRs 60 up to 200 per tenant. This lack of suitable facilities and discrepancy in collection cost poses a challenge to implementing effective waste management practices.

in Ward 4, nearly 60% of the population practices solid waste segregation, whereas this percentage drops to 40% in Ward 6. The difference can be related to the fact that Ward 6 is comparatively more urbanized than Ward 4 (Figure 2), which still retains larger agricultural areas and lower population density. In these households, waste segregation practices are observed, with organic waste being composted and subsequently utilized as fertilizers or soil conditioners on the land.

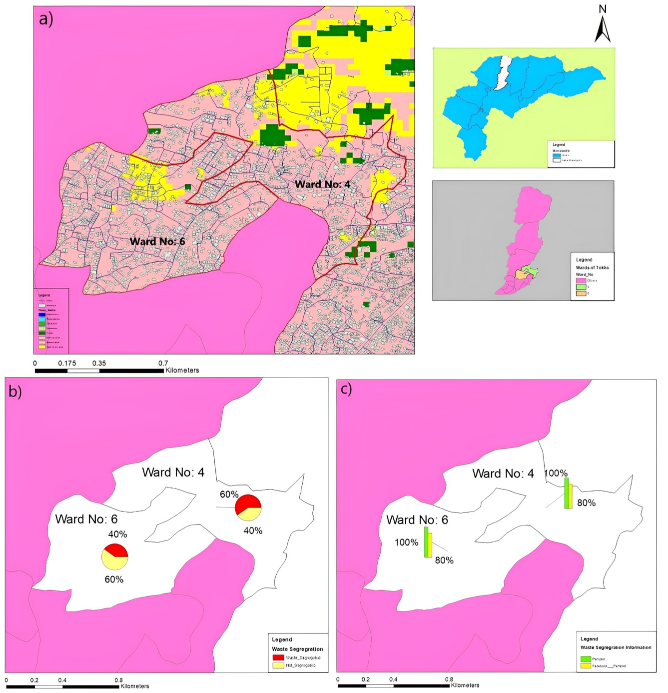

Figure 2: Tokha Municipality: a) Landuse Map, b) Solid waste segregation Map, and c) Information Map

Remarkably, around 80% of households acquired information about segregation rules through Facebook. Concurrently, all households received pamphlets from the municipality concerning solid waste segregation. To facilitate segregation, the municipality distributed separate dustbins for collecting segregated waste at the household level. These efforts underline the municipality's dedication to promoting proper waste management practices within the community.

From the context of solid waste management in public places, the solid waste collection vessels or bins (Figure 3) placed in these areas were found to be in a state of disrepair, with a significant portion of them being damaged to the extent that they were no longer functional for the public to be used for waste disposal. The resources allocated for solid waste management have not been effectively implemented across the entire municipality. This lack of proper operation and maintenance of the public solid waste collection system has presented a considerable challenge for the authorities in effectively managing solid waste in these areas within the municipality.

4.2 Sensitivity Analysis of Banchare Danda Landfill Site

The cumulative volume needed for the land-filling of solid waste generated solely in Kathmandu Metropolitan City (KMC) over a 25-year period, without any segregation, amounts to 2,303,551.38 cubic meters while the computed total landfill capacity at the Banchare Danda Landfill Site (BDLS), utilizing GIS, is determined to be 812,600 cubic meters. An overall deficit volume of 1,490,911.38 cubic meters is revealed.

To address this limitation, a sensitivity analysis (Figure 4) was conducted. Based on the information presented in the figure, it can be deduced that the Banchare Danda Landfill Site

Figure 3: Roadside waste collection bin

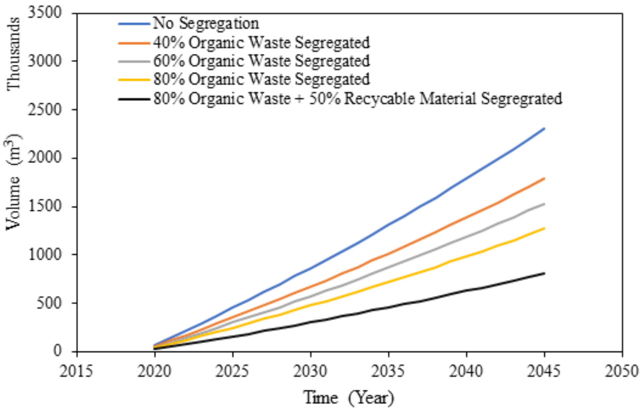

Figure 4: Volume of waste to be disposed at BDLS at different percentages of segregation

(BDLS) possesses adequate capacity for waste disposal from Kathmandu Metropolitan City (KMC) under the following conditions: when 80% of the organic waste and 50% of the recyclable material are effectively segregated from the total solid waste. Highlighting the need for a properly organized Material Recovery Facility (MRF) which can considerably reduce the amount of waste (approx greater than 50%) sent to landfills[10].

5. Conclusions and Recommendations

To sum up, it is crucial to incorporate the Reduce, Reuse, and Recycle (3R) approach throughout the waste management process along with the construction of robust MRF (having the characteristics: a)Efficient Sorting Technology,b)Quality Control Measures, c) Safety Protocols, and d)Adaptability and Flexibility, etc.) that can not only reduce the waste whose character changes with time and development of technologies but also be able to produce valuable byproducts such as raw materials for industries. These actions together work towards lessening the strain on landfills, fostering sustainability, and enhancing waste management techniques. Municipalities can utilize various social media platforms such as Facebook, X, and TikTok to disseminate information and enhance awareness among residents about solid waste management using their official media handles.

It is recommended to undertake additional research regarding the impact of waste compaction and transformation on the overall landfill capacity. Furthermore, conducting a study on sensitivity analysis concerning the generation of landfill gas and leachate due to waste segregation would be beneficial. Detailed sensitivity analysis may be further conducted through the use of actual field survey data of BDLS.

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