EVALUATION OF PRESENT RANKING OF THE BORAGAON DUMPSITE, GUWAHATI AND PROPOSAL OF ADDITIONAL ATTRIBUTES FOR LANDFILL SITE SELECTION IN HILLY REGIONS

A dissertation submitted in
Partial Fulfillment of the Requirement for the Award of the Degree of
MASTER OF TECHNOLOGY
In
CIVIL ENGINEERING
(With specialization in Geotechnical Engineering)
Of
Assam Science & Technology University
Session: 2020-2022

By

BHANITA BARO

ROLL NO: PG/CE/015

ASTU REG. NO.:158806620 of 2020-2021

Under the Guidance of
DR. ABINASH MAHANTA
ASSISTANT PROFESSOR
ASSAM ENGINEERING COLLEGE
DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE
JALUKBARI, GUWAHATI-781013

DECLARATION

I hereby declare that the work presented in the dissertation "EVALUATION OF PRESENT RANKING OF THE BORAGAON DUMPSITE, GUWAHATI AND PROPOSAL OF ADDITIONAL ATTRIBUTES FOR LANDFILL SITE SELECTION IN HILLY REGIONS" in partial fulfillment of the requirement for the award of the degree of "MASTER OF TECHNOLOGY" in Civil Engineering (with specialization in Geotechnical Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University, is a real record of my work carried out in the said college for twelve months under the supervision of Dr. Abinash Mahanta, Assistant Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13.

Do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

Date: BHANITA BARO

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date:

DR. ABINASH MAHANTA
(Assistant Professor)
Department of Civil Engineering
Assam Engineering College
Jalukbari, Guwahati-13

CERTIFICATE

This is the certified that the work presented in the project report entitled "EVALUATION OF PRESENT RANKING OF THE BORAGAON DUMPSITE, GUWAHATI AND PROPOSAL OF ADDITIONAL ATTRIBUTES FOR LANDFILL SITE SELECTION IN HILLY REGIONS" is submitted by Bhanita Baro, Roll No: PG/CE/015, a student of M.Tech 4th semester, Department of Civil Engineering, Assam Engineering College, to the Assam Science and Technology University in partial fulfillment of the requirement for award of the degree of Master of Technology in Civil Engineering with Specialization in Geotechnical Engineering under my guidance and supervision.

Date:

Place:

DR. ABINASH MAHANTA
(Assistant Professor)
Department of Civil Engineering
Assam Engineering College
Guwahati-781013

CERTIFICATE FROM HEAD OF THE DEPARTMENT

This is to certify that the project report entitled "EVALUATION OF PRESENT RANKING OF THE BORAGAON DUMPSITE, GUWAHATI AND PROPOSAL OF ADDITIONAL ATTRIBUTES FOR LANDFILL SITE SELECTION IN HILLY REGIONS" has been submitted by BHANITA BARO, bearing Roll No: PG/CE/015, a student of M.Tech. 4th Semester, Geotechnical Engineering (Civil Engineering Department), Assam Engineering College, in partial fulfillment of the requirements for the award of the degree of Master of Technology in Geotechnical Engineering of Assam Science & Technology University.

Date:

Place:

DR. JAYANTA PATHAK

(Professor & Head of the Department)

Department of Civil Engineering

Assam Engineering College

Guwahati-781013

ACKNOWLEDGEMENT

At the very onset I would like to express my profound gratitude and sincere thanks to my respected guide Dr. Abinash Mahanta, Assistant Professor, Department of Civil Engineering, Assam Engineering College, Guwahati for his invaluable supervision, guidance and constructive suggestions throughout the course of this work and particularly for his diligent scrutiny and correction of the manuscript.

I also thank all the faculty members and staff of the Department of Civil Engineering. This project would not have been possible without immense support from them.

I am highly thankful to my classmates, who helped me a lot in doing various project related work.

I offer my heartiest thanks to my seniors, juniors and family members for their constant inspiration and encouragement.

BHANITA BARO

M.Tech, 4th Semester

(Geotechnical Engineering)

Department of Civil Engineering

Assam Engineering College

Jalukbari, Guwahati-13

ABSTRACT

Guwahati is one of the major metropolitan city in India and the capital city of the state of Assam. The city covers a municipal areas of 216 km^2 and a population of about 1,135,000 (2021 census) and the city generates about 550 Tones of solid waste per day. Currently, Guwahati Municipal Corporation (GMC) disposes its waste at Boragaon dumpsite which covers the area of 108 bighas where the disposal rate 190 to 300 ton/day. The dumping ground at Boragaon is not a proper landfill site as it does not conform to all specification and guidelines due to the improper segregation of the garbage being dumped from the entire city and also non availability of leachate collection facility. Hence, the disposal of waste being one of the major problems faced by the citizens. The prime study attempts to evaluate the ranking of the dumpsite at Boragaon, Guwahati based on the guidelines for site selection laid by Central Pollution Control Board, 2003. Using the methodology of Site Sensitivity Index developed by CPCB 2003 guidelines, Government of India and the Delphi technique, the dumpsite of Boragaon has been taken up as a case study and ranked based on impact of 32 attributes and their relative significance that complies with accessibility, receptor, environment, public acceptability, geological and economic criteria. Generally, the study has been observed that the calculated Site Sensitivity Index Score of the existing site in the year 2023 falls in the range of 539.96 indicating "Moderately Sensitive" categorized conditions. There is no high significant impact on the environmental quality due to the disposal site which is neither adversely affected nor lowly affected. The ranking score of Boragaon site before sitting the dumpsite is being approximately 453.495 in the year 2008 on the basis of CPCB, 2003 guidelines and clearly shows us that the Boragaon site in the year 2008 is found to be limited and it is preferable for sitting the dumping site. But as per my own perception the calculation of CPCB guidelines may not be completely correct and this might not give us final solution to it as it is not possible to placed a dumpsite in that site because the site is surrounded by a huge water body called Deepor Beel, which is a well-known of Ramsar site in the North-Eastern region of India which is located at a distance of approximately less than 500 m.This study presents the dumpsite rehabilitation including site with high health risk, maximum environmental impacts and sensitive public concerns. Apart from this site sensitivity index of 32 attributes, for hilly regions that cannot fully dependent on 32 attributes so we have defined few other attributes which are most needed.

Keywords: Site Sensitivity Index (SSI), Municipal Solid Waste Disposal, Landfill site selection, Delphi, Landfills.

LIST OF TABLES

LIST OF FIGURES

CONTENTS

4.1.3 Environmental related attributes 34-35

4.1.4 Socio-economic related attributes 36

4.1.5 Waste management practice related attributes 37

4.1.6 Climatological related attributes 37

4.1.7 Geological related attributes 37

4.2 Site score calculation 37

4.4 Additional attributes for hilly regions 43

4.4.1 Landslide susceptibility 44-45

CHAPTER 1

INTRODUCTION

1.1 General

Due to the increasing rate of municipal solid waste (MSW), it is actively producing as a result of major problems in the country. Improper waste management is also one kind of causes of solid waste pollution. Landfills are the solid waste disposal storage designed with adequate protective measures against surface water pollution, air pollution, soil pollution, ground water pollution, bad odour, dust, etc. The landfill becomes an integral part of municipal solid waste management despite the efforts of a recycling and recovery of solid wastes. Most of the cities in India are facing the problems of management of huge quantities of solid waste (SW) being generated at an ever increasing rate. The major problems of solid waste pollutions of urban areas are due to the residential houses, commercial establishments, debris from construction and demolition, agriculture and 80% are also the main integral parts of the waste pollutions for directly released on the outskirt of the city in the closest low-lying areas, wastelands, streets, and open drains in an unsatisfactory performing manner which lead to environmental problems like water-logging and clogging of drains. There might be a rapid rise in municipal solid waste due to rapid population growth, mass migration from rural to urban areas. The selection of this Landfill disposal sites are depends on availability of land and we will have to go for the public consultant process and after the public acceptance we will get a regulatory approval. But still many cities have not been able to implement the landfill site because of not being available of suitable location of landfill sites for disposal purposes. The impact of integrated solid waste on environment should be limited. People living to those adjacent landfill areas should not be suffering in their day to day life. Sitting of landfill minimizes the public health risk, they help to prevent disease transmission and minimizes the impact on environment and keep environment clean. Rules, 2000 in India, it becomes mandatory for Urban Local Bodies (ULBs) to dispose their waste in scientific manner at sanitary landfill sites. As per the rules, all the ULBs were to set up waste processing and disposal facilities by the end of March, 2003 (MoEF, 2000). All the various factors like, environmental, economic, geological and social has been considered for deciding the suitable landfill site. Increasing concern related to environment, poor financial conditions of ULBs, strict regulative laws, political interference and social opposition, all are important considerations and restraint to landfill sitting (Chang et al., 2008; CPCB, 2003; CPHEEO, 2000; Eskandari et al., 2012). In India, guidelines have been given by the Central Public Health and Environmental Engineering Organization (CPHEEO) and Central Pollution Control Board (CPCB) for selection of suitable landfill site for MSW disposal.

The Assam is the largest state in North East India. It lies in the middle reach between the river Brahmaputra and Barak. Assam covers an area of 78,438 Km^2 with total population of 34,586,234 (census 2021).The State covers nearly 2.4% of India's total geographical area. The land has uneven topography with full of hills, plains and rivers. Its longitude lies at 88.25°E to 96.0°E and latitude at 24.5°N to 28.0°N.

Guwahati is the biggest city in the North East Indian State of Assam which is located beside the Brahmaputra River. It is the largest metropolis in northeastern India with a current population of 1,135,000 (census 2021) and the city covers a municipal area of 216 Km^2. The geographical coordinates of Guwahati are (26°10′45″N Latitude and 91°45′0″ E Longitude). Guwahati is situated at an elevation of 53.33 meters above sea level, it has a humid (70%) subtropical, dry winter climate typically receives about 83.75 millimeters of precipitation annually with an annual temperature of 23°c. There are about 60 municipalities with urban population of 1,135,000 (census 2021) and the total solid waste generation by all the municipalities within the city is 550 tons/day. Guwahati Metropolitan City is the most urbanized city of Assam. The fastest decadal population growth rate is found in Guwahati 1.61% increases from 2020.

This rapid rising in urbanization directly effects the waste generation and waste disposal. With rapid urbanisation and increasing population, a high distressing problem of solid waste generation and disposal has emerged in Guwahati city. Due to the lack of an efficient solid waste disposal system people tend to dump on open streets, drains that lead to environmental problems like clogging of drains, waterlogging etc. in day to day life. For a city like Guwahati sitting an engineered landfill is a major issue due to the lack of area availablity as well as public objection effect. Hence it is mandatory purpose to go for the public consultant process and after the public acceptance we will get a regulatory approval. But still many cities have not been able to implement the landfill site because of not being available of suitable location of landfill sites for disposal purposes. As we know construction of an engineered landfill is an environmental issue. The landfill site selection is the mandatory and it has become a major concerned with due effect to concentrate the waste product in compacted layers to reduce the volume and for the control of liquid and gaseous effluent in order to protect the environment and human health hazard. Hence we can say landfill site selection is essential for Guwahati city.

1.2 Solid waste management practices in Guwahati

In Guwahati city the waste material collection is basically done in collaboration with NGOs and for this purpose labourers are employed for the collection by the NGOs. The labourers use to visit to collect the waste material in the form of door to door and ward to ward collection from the locality of residents. This working group consists of total 60 wards and 26 NGOs and the waste material collection is done under the initiative of 60 wards and 26 NGOs. The household disposals of the waste materials are observed by the supervisors of the respective NGOs. There are many bin-points within the city areas where the NGOs labours collect the waste materials in the dustbin areas. The bin- points are provided to every ward for collection of wastes dumped and after that is transported to the site. The rapid increasing population causes a severe havoc for the generation and disposal of solid waste materials that arise in Guwahati city.

The Boragaon dumping site is the only one disposal site for municipal solid waste for the entire city that is being dumped every day with a load of approximately 190-300 tons/day of waste materials. The consistently quantity of municipal solid waste generated in Guwahati has been rapidly exceeding over the years. The rapidly rising quantity of municipal solid waste can be attributed to the rapid population growth, mass migration of population from rural to urban areas change in the lifestyle of the people and increase in economic activities in general in the city. The dumping ground at Boragaon is not a proper landfill site as it does not conform to all specification and guidelines due to the improper segregation of the garbage being dumped from the entire city and also non availability of leachate collection facility. The environment in and around the site particularly the soil quality, ground water quality, surface water and sub surface water becomes contaminated because of all types of garbage are dumped in that particular site. Deepor Beel is in close to the dumping site. The leachate from the dumping site may contaminate the Deepor Beel water. The study of groundwater and soil quality around the dumping site may provide more useful insight to the issue. The study on the groundwater, surface water, sub surface water and soil characteristics around solid waste dumping ground has become essential for the existence of such a dumping ground.

1.3 Objective of the study

1.The prime objective of this study is to evaluate the present ranking of the existing dumpsite at Boragaon, Guwahati based on the guidelines for site Selection laid by central pollution control board (CPCB),

2. Identification of additional attributes for landfill site selection specially for hilly regions.

1.4 Scope of the work

The scope of the work includes:

1. Acceptability check for existing Boragaon dumpsite as per present scenario.

CHAPTER 2

LITERATURE STUDY

2.1 Research work related to the landfill site selection using site sensitivity index is as follows

Few references have been taken from various research papers, journals from various research workers to get an idea of the same. Few major works are briefly reviewed in the following:

Ohri et al., (2009) The work in this paper is focusing on the landfill site selection of Varanasi, City in India using the method of site sensitivity index. The methods in this paper includes the two possible landfill sites of Varanasi have been taken up as a case study and ranked based on impact of 32 attributes and their relative significance. The method in this paper included the segment of study of the attribute is considered, keeping in view the environmental impacts, cost of the site, accessibility, volume of the site and socio-economic effects and many others .Ranking of sites based on Site Sensitivity Index (SSI) developed by Central Pollution Control Board (CPCB), Ministry of Environment and Forest, Government of India. The calculated SSI for both the sites fall in the range of Site Sensitivity Index (300 to 750) indicating "Moderately Sensitive" conditions. Based on final Site Sensitivity Index (SSI) both Padaw and Karsada sites fall in moderate impact category.

Majumdar et al., (2017) The methods in this study paper were founded that the suitability of the three sites of Natagachi, Gangajoara and Kharamba as landfills as proposed by Kolkata Municipal Corporation has been checked by Landfill Site Sensitivity Index (LSSI) as well as Economic Viability Index (EVI). The study presented a multi-criteria Decision Making (MCDM) tool to evaluate and rank three available sites at Gangajoara, Natagachi and Kharamba, proposed for sanitary landfilling of municipal solid waste generated by Kolkata. The method in this paper included the landfill sitting, AHP, Landfill Site Suitability Index, Economical Viability Index. The results of LSSI and EVI analysis reveals that all the proposed sites are moderately suitable for landfilling that the total scores of three sites ranges between 300 to750. Natagachi is the best in terms of Site Sensitivity Index is 494.61 where Gangajoara is the best in terms of EVI is 467.5. Hence, taking importance to economy to a growing metropolis in a developing country like India, Gangajoara is the best choice as landfill site. Though case specific, the proposed MCDM tool will be very useful for landfill site selection for developing countries.

Kurian et al., (2005) This study paper presented an Integrated Risk Based Approach (IRBA) for developing a decision-making tool for dumpsite rehabilitation including sites with high health risk, maximum environmental impacts and sensitive public concerns. In this method risk indicative attributes were selected based on the literature, data obtained through observation of activities and investigations in and around a few dumpsites, consultation with experts on the contribution of the attributes to pollution, health risks and social impacts. The results of the Perungudi (PDG) and Kodungaiyur (KDG) dumpsites in Chennai, India presented that the sites scored a Risk Index of 569 and 579, respectively. The results indicated that PDG and KDG have moderate hazard potential and both need to be rehabilitated immediately. The hazard potential obtained for PDG and KDG following the method of Saxena and Bhardwaj (2003) was 505 and 491, respectively. The Risk Index of 569 and 579 obtained presently for PDG and KDG differs significantly as compared to those obtained employing the methodology suggested by Saxena and Bhardwaj (2003) for developing hazard potential. The variations can be attributed to the fact that 50% of the criteria used presently are different from those used by Saxena and Bhardwaj (2003). For instance, the high values of Risk Index are clear indication of the gravity of environmental risk presented by the dumpsite. Development of IRBA decision making tool is an attempt to provide guidance to Government and other implementing authorities for quick decision making for prioritizing actions related to dumpsite rehabilitation. Detailed investigations and regulatory approval may be required as per the respective national or local legislations. Further work to refine the approach with inputs from more experts in the region and validation by application to different dumpsites in Asia is in progress.

Paul et al., (2014) The paper is identified on landfill site selection for dumping of solid waste generated within Kolkata Municipal Corporation (KMC) area. The methods included GIS/remote sensing, Site Sensitivity Index technique developed by CPCB 2003 guidelines, Government of India and the Delphi technique. This paper attempts to locate the most suitable site for disposal of KMC area solid waste using the multicriterion decision analysis as stipulated in CPCB 2003 guidelines and the overlay analysis of geographic information system (GIS). In this paper total of four sites (Noara Bodura, Akandaberia village, Bodura-Khargachi , kalicharanpur village) are selected and as per the calculation of SSI of site 3 (Bodura-Khargachi) is the lowest and hence it is the most acceptable. However, site 4 (kalicharanpur village) is nearer to KMC area and land use land cover (LULC) data depict one-season Zaid cultivation, unlike the other sites where double/triple-crop plantation is practiced.

Banerjee A., (2021) The work of this research paper is focusing on the impact of municipal solid waste management and its disposal at Ghazipur landfill site (Delhi) and also a comparative analysis of the factors were done with the Boragaon waste dumping site in Guwahati. The impact of Ghazipur landfill site as well as Boragaon landfill site on the surrounding environment was studied and analysis of noise pollution, air pollution, soil quality and groundwater pollution was conducted including a socio-economic impact survey. In this study paper was observed that the impact of this municipal solid waste (MSW) on these sites to be negative on the surrounding environment which influences the nearby area greater than about 10km in diameter. People living adjacent to these areas are suffering the most in their day to day life. Both the sites adversely affect the residents of the surrounding area and in near future with the increase of quantity of MSW and it might be further result to a serious natural or environmental hazard.

Dar et al., (2019) This study was carried out to identify the optimal locations for a landfill site of Leh town of Ladakh. The methods included the suitability of the locations were evaluated in relation to socio-economic variables employing buffering, and weighted overlay analysis techniques in GIS environment. The criteria were assigned weights and ranks to arrive at decision making process. Also the work in paper is focusing on the identification of the problems, distance from the road network, distance from the agriculture area, distance from snow/glacier area, distance from air base /airport, study of the geology, slope etc. Seven potential sites were identified that can be considered for landfill. All of these sites have good road connectivity. Three of them have a relatively large size but being located on alluvial tracts are moderately suitable. In terms of slope and geology, only two sites can be considered. The methodology used in this study can not only be helpful in locating the appropriate sites for waste disposal but also other critical facilities in Leh town of Ladakh and can also be replicated in other towns in order to ensure sustainable environmental management. The methodology used in the present study can apply for other mountainous urban areas for managing the waste in a more scientific way. The outcome of this research work shall act as an input to government and other implementing agencies for quick decision making for prioritizing actions related to solid waste management.

Pandiyan et al., (2011) The paper work is analyzed the environmental assessment, field based study and economical assessment, economic viability related attributes of three landfill sites of Melakottaiyur, Pachaiyankuppam and Gummidipoondi Tamil Nadu, India were selected. The paper work is included the methods of landfill site selection, attributed score, decision-making, sensitivity index, Delphi approach, environmental assessment, economic sustainability of that particular sites. And the attributes are considered for decision-making and they were selected based on literature, observations with weightage assigned to each attribute following the pair wise comparison method. Sensitivity index on a scale of 0 to 1 is scored based on attribute measurement. The attributes were then grouped and ranked following Delphi approach. The sites are scored a Risk Index (RI) of 298.75, 369.05 and 408.25 respectively based on environmental assessment, field study. And the sites are scored Risk Index (RI) are 86.1, 94.3 and 131.5 respectively based on economical assessment, economic viability related attributes. In order to achieve economic sustainability of the landfill, economic viability related attributes has to be analyzed with high priority and weightage in economical assessment. Detailed investigations and regulatory approval may be required as per the respective national or local legislations. Further work to refine the approach with inputs from more experts in the region and validation by application to different landfill sites in Asia is in progress.

Wang et al., (2019) The paper prepared consequently, a satellite-based analysis method is identified and used to efficiently assess landslide susceptibility of landfill. The core steps include investigation of the topography and climate of the landfill site based on satellite data. Taking the rapid filling and water catchment are taken into account with GIS, which generate high excess pore pressures and eventually trigger the gentle landfill slope to failure. The results show that the satellite-based analysis method can obtain the key factors of the landfill landslide.

Eskandari et al., (2016) This study paper prepared for Any landfill siting without considering landslide susceptibility in such regions may impose additional environmental adversity.The paper proposed a practical method for selecting waste disposal site that accounts for landslide exposure. The proposed method was applied to a city which is highly proneness to landslide due to its geology, morphology, and climatic conditions. First, information on the previously occurred landslides of the region was collected. Based on this information, proper landslide causative factors were selected and their thematic maps were prepared.They had concluded that if any of these landslide prone sites are selected for landfilling, further environmental disaster would be terminated in the future.

Balteanu et al., (2010) The paper proposes a brief analysis of landslides in Romania, completed by a landslide susceptibility model.This synthetic method of landslide susceptibility assessment, applied to the whole country, is a useful tool to evaluate the distribution of landslide-prone areas, as well as to validate and to enhance some results obtained in previous studies based on field research and map interpretation.

Sayed et al., (2015) The work in this paper is focusing on the water quality analysis of Boragaon disposal site and its adjacent area of Guwahati, Assam, India. The study paper investigated the water quality in around the Boragaon disposal site by collecting through different sampling station like well, hand pump, and surface water for a period of one year. But the results identified that the water quality parameters were changing with time and locations but there is no fixed pattern is observed. Therefore the paper concluded that it is unable to predict whether these changes are due to leachate produced by waste disposal site or some other sources. Because of the dumpsite area is surrounded by industries, agricultural land, and one outlet of Bharalu River is flowing through the disposal site and connected to deepar beel. However the water bodies near to the dump site are showing some frequent changes in water quality parameters may be because of leachate formation or not, it cannot predicting from the present work of the research paper.

Hans gunter ramke (2018) The paper concluded independently from the typology of the top cover, the capped landfill surface and the surrounding area require to be equipped with systems for surface water collection. The paper proposed that drainage aimed to prevent the access of external water (watercources, groundwater, springs, hillside flow etc) to collect and divert runoff from landfill slopes and to drain and discharge the flow of percolated water preventing infiltration into the landfill body.

Keskin and Kezer (2022) This study presents slope stability analyses of MSW landfills. Numerical analyses were performed using finite element and limit equilibrium methods. The stability behavior of landfill slopes was analyzed for both unreinforced and geogrid-reinforced conditions in order to investigate the effects of shear strength parameters, the unit weight of soil waste, and material model parameters. It has been seen that the stability of landfill slopes can be increased significantly using geogrid materials. Slopes in landfills reinforced with geogrid reinforcements can be formed steeper, allowing more solid waste to be stored. Considering the high initial investment cost of MSW landfills, it has been concluded that storing more solid waste with the use of geogrids will provide significant economic gains. Based on the results, the optimum values of geogrid parameters were determined and suggested for maximum reinforcing effects in MSW landfill slopes.

Goswami et al., (2008) The work paper investigated the quality of solid waste treated soil collected from different locations and depth of the presently abandoned municipal solid waste dumping ground at Adabari in Guwahati city. The paper included the segments of study of solid waste, soil quality, solid waste dumping and impact on Soil quality. The study on the impact of msw solid waste disposal on soil properties identified that the experimental value for the physico-chemical parameters increased for the solid waste treated soil in comparison to the control soil. This leads to assess the changes in chemical characteristics and properties of solid waste treated soils. Continuous application of such wastes may pollute to the MSW treated soil. However most of the potential problems can be minimized by the proper selection of wastes, soils and judicious management processes. There should examine the composition of wastes and properties before municipal solid waste (MSW) application to land. If problems of pollution are minimized, then MSW can be considered as a valuable resource for use as a source of productivity. Optimized use of MSW can invariably improve the soil productivity without creating ecological hazards.

CHAPTER 3

METHODOLOGY

Following the "Guidelines for the selection of site for landfilling (2003)" given by the Central Pollution Control Board (CPCB, 2003). Site ranking of Boragaon dumpsite is performed based on the result of a survey of site.

1. Study area

2. Selection processes:

    1) Delphi method is adopted
    2) Site selection criteria is drawn up
    3) Data is obtained
    4) Weighted site ranking methodology is adopted

3. Factors to be considered:

    1) Accessibility Related Attributes
    2) Receptor Related Attributes
    3) Environment Related Attributes
    4) Socio-Economic Related Attributes
    5) Waste Management Related Attributes
    6) Climatologically Related Attributes
    7) Geological Related Attributes

3.1. Study area

The collection of information and data has systematically taken from Boragaon waste management office, Guwahati Municipal Corporation (GMC) officials were used and other sources include Pollution Control Board (CPCB) guidelines, 2003 etc. However we may say that the information and data collection for this study is based on the various sources and estimation of waste materials.. We have to go for the public consultant process before adopting the landfill sites which have a big issue. In order to ascertain various parameters considering the important for landfill site selection and the method of their analysis, a survey of available literature has been done. Delphi technique is also adopted. The table is indicating the guidelines prepared by CPCB (2003), Government of India taken into account the maximum number of attributes for evaluating the ranking of a site. Thus, Central Pollution Control Board CPCB (2003) approach based on site sensitivity index appears more detailed and the method of data analysis is also simpler. Hence we decided to evaluate and rank of Boragaon dumpsite of Guwahati city by using the Site Sensitivity Index methodology. Landfill with the consideration of all the factors or attributes from the site is found. Various parameters were taken into the consideration and table 4.1 summarizes the results of ranking of Boragaon dumpsite analysis.

The study area is the area within which field data is collected to identify all known environmental resources. The study area of Boragaon MSW landfill disposal site which is (26°6′46″ N Latitude and 91°40′38″ E Longitude) located adjacent to the Deepor beel in West Boragaon, on the south bank of river Brahmaputra of Kamrup district, Guwahati, Assam. Boragaon disposal site covers the area of approximately 108 bighas. The India’s largest river Brahmaputra passes in the northern side of the study area and Boragaon landfill site shares the boundaries with Ramsar site wetland Deepar beel. The distance from the main city of Guwahati to the Boragaon landfill site is about 9 km and about 1 km to 2 km from NH- 37. Boragaon landfill site was started in 2008 as an open landfill and nearby lakes or ground water, sources of water and soil quality becomes contaminated due to unsatisfactory manner dumping of waste materials. Site is considered to be a critical habitat due to a Ramsar site of Deepar Beel which is proximity to the site. Water quality is deteriorating at various locations of the Deepar Beel and the necessary steps are immediately required for sustaining the ecological balance of the wetland (Borah and Hazarika, 2022).It has been operating almost for 15 years and it can carry around 190-300 tons per day of the solid wastes. In the west and the south west there are the Rani Reserve Forest, Deepar Beel wetland and the alluvial tracts of the Brahmaputra plain area. andfill site as well as Boragaon landfill site on the surrounding environment was studied and it is observed that the impact of this municipal solid waste (MSW) on Boragaon sites to be negative on the surrounding environment and people living adjacent to these areas are suffering the most in their day to day life, both the sites adversely affect the residents of the surrounding area and in near future with the increase of quantity of MSW and it might be further result to a serious natural or environmental hazard (Banerjee A., (2021).The water bodies of Deepar beel near to the Boragaon dumpsite are showing some frequent changes in water quality parameters, may be because of leachate formation (Sayed et al.,2015).The concerned authorities responsible for the waste management are finding it very difficult to cop-up with the rapid rising wastes, increase in population growth, diversified activities as well as expansion of the city. Boragaon dumping site should be replaced so that waste are not find their way into the wetland (Deb et al., 2019). However the rag pickers contribute to the waste management system in the form of daily wages for their livelihood by collecting the recyclable materials such as paper, plastics, metals etc. Some photographs that has been collected from the Boragaon dumpsite and it has been shown below.

Figure 3.1: Boragaon dumpsite

(Source: Google earth)

Figure 3.2: Site visit at Boragaon dumpsite

Figure 3.3: Present scenario of Deepar beel from Boragaon dumpsite

3.2.1 Delphi method

3.2.1.1 Introduction

Delphi is a method for "eliciting and refining group judgments" and is one alternative idea or solution is generated by panel of experts who are individual, independent, isolated and anonymous. Delphi method is for facilitating structured group communication in order to gather a consensus of expert opinions in the face of complex problems, expensive sincere attempt, and uncertain outcomes. The principles of the method are that more minds are better than a single mind, and when used as a forecasting tool that structured group efforts lead to more accurate forecasts than unstructured. In order to generate even more creativity, a summary of the responses from the first round are given back during the subsequent rounds and additional responses elicited. The answers or summary or statements, move towards the agreement or consensus. The repeatation and controlled feedback process continues until a stopping point is reached (i.e., number of iterations, consensus, confirmed disagreement and stability of results).

Delphi technique can be used for achieving the following objectives:

a) The Delphi method is beneficial when the problem at hand can benefit from collective, subjective judgments or decisions and when group dynamics do not allow for effective communication (e.g., time differences, distance, and personality conflicts).

b) Physical group meetings may be too costly.

c) This is also true when using other futures methodologies that can benefit from the addition of a Delphi process to aggregate varied individual opinions (e.g., scenario planning, cross-impact analysis).

d) To determine or develop a range of possible program alternatives.

e) To explore or expose underlying assumptions or information leading to different judgments.

3.2.1.2 The method is used by the two characteristics which allow the number of rounds of information collection and feedback:

3.2.1.2.1. Investigator

a) The investigator (i.e., researcher, facilitator) is a key element of the Delphi method.

b) It is the responsibility of the investigator to understand the project at hand.

c) Recruit experts, know the effectiveness of the group size and composition, gather appropriate knowledge and opinions from the experts, facilitate their creative thinking as individuals and as a group, collect, compose, synthesize, and redistribute their varied responses and do this all in an effective, timely.

d) One investigator bias already widely recognized as a potential problem within the Delphi method comes from inserting his/her own preconceived opinions into the feedback process.

e) This increases transparency but leaves lengthy, detailed feedback.

3.2.1.2.2. Experts

a) There are several suggestions on how best to select a group of experts.

b) Although each situation and pool of experts from which to select will be unique.

c) Use experts with appropriate domain knowledge.

d) Use between 5 and 20 experts.

e) Continue Delphi polling until the responses show stability.

f) Three structured rounds are enough.

g) Obtain the final forecast by weighting all the experts' estimates equally and aggregate.

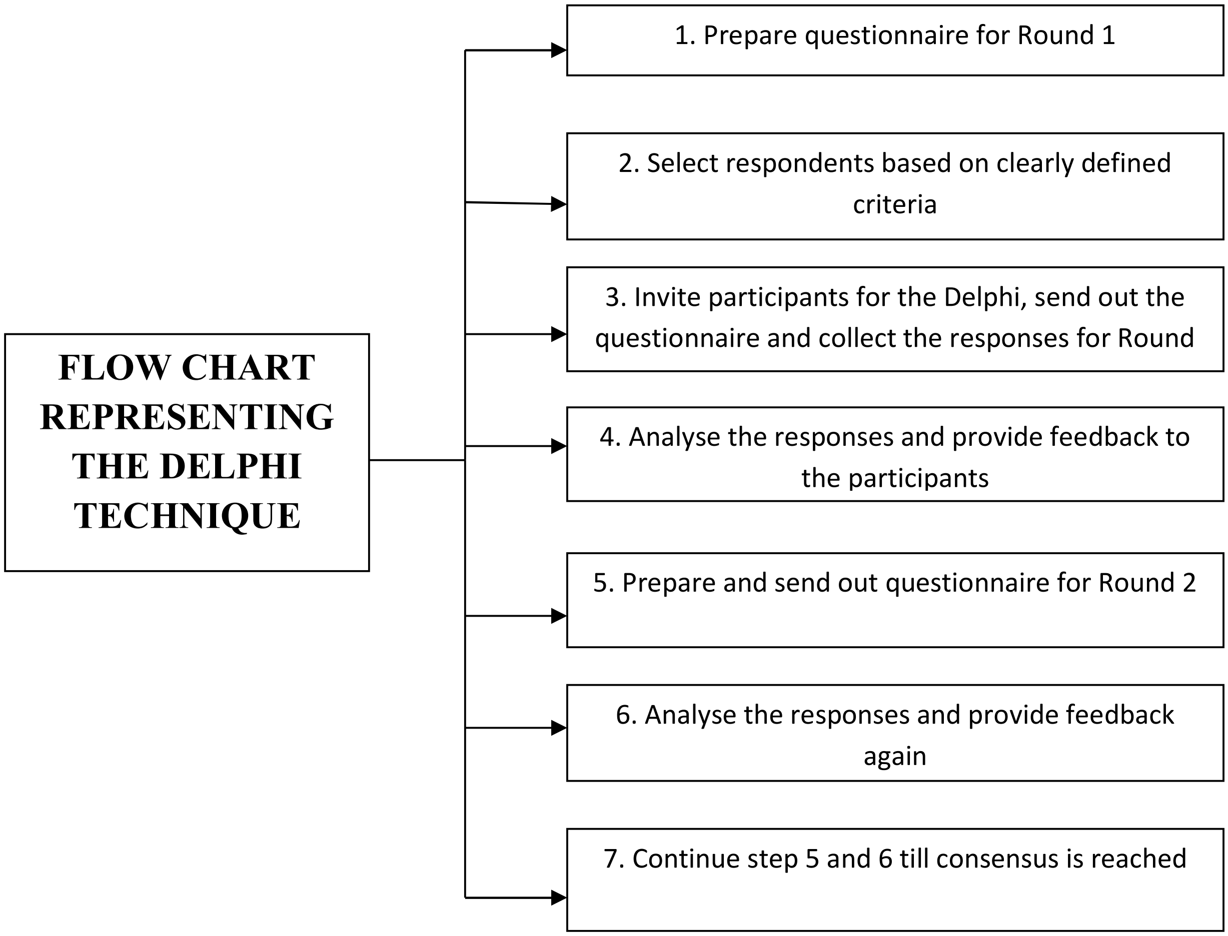


Figure 3.4: Flow chart of the Delphi technique

3.2.1.3 Round 1

In the first round, the Delphi process traditionally begins with an open-ended questionnaire.The open-ended questionnaire serves as the cornerstone of soliciting specific information about a content area from the Delphi subjects (Custer, Scarcella, & Stewart, 1999) .After receiving subjects' responses, investigators need to convert the collected information into a well-structured questionnaire.This questionnaire is used as the survey instrument for the second round of data collection.

3.2.1.4 Round 2

In the second round, each Delphi participant receives a second questionnaire and is asked to review the items summarized by the investigators based on the information provided in the first round. Accordingly, Delphi panelists may be required to rate or rank-order items to establish preliminary priorities among items As a result of round two, areas of disagreement and agreement are identified (Ludwig, 1994, p. 54-55). In some cases, Delphi panelists are asked to state the rationale concerning rating priorities among items (Jacobs, 1996). In this round, consensus begins forming and the actual outcomes can be presented among the participants' responses (Jacobs, 1996)

3.2.1.5 Round 3

In the third round, each Delphi panelist receives a questionnaire that includes the items and ratings summarized by the investigators in the previous round and are asked to revise his/her judgments or "to specify the reasons for remaining outside the consensus" (Pfeiffer, 1968, p. 152). This round gives Delphi panelists an opportunity to make further clarifications of both the information and their judgments of the relative importance of the items. However, compared to the previous round, only a slight increase in the degree of consensus can be expected (Weaver, 1971; Dalkey & Rourke, 1972; Anglin, 1991; Jacobs, 1996)

3.2.1.6 Round 4

In the fourth and often final round, the list of remaining items, their ratings, minority opinions, and items achieving consensus are distributed to the panellist. This round provides a final judge for participants to revise their judgments. It should be remembered that the number of Delphi iterations depends largely on the degree of consensus sought by the investigators

3.2.1.7 Summary

The Delphi technique provides those involved or interested in engaging in research, evaluation, fact-finding, issue exploration, or discovering what is actually known or not known about a specific topic to gather and analyze the needed data. Subject selection and the time frames for conducting and completing a Delphi study should be considered carefully prior to initiating the study. The Delphi technique has and will continue to be an important data collection methodology with a wide variety of judgements. Uses for people who want to gather information from those who are immersed and imbedded in the topic of interest and can provide real-time and real-world knowledge.

3.2.2 Selection of candidate sites for detailed investigation (CPCB, 2003)

3.2.2.1 Step I-Constraint mapping

Constraint mapping eliminates environmentally which have unsuitable physical and other environmental characteristic of sites and narrows down the number of sites for further consideration. According to the guidelines unsuitable areas or sites are excluded and sites can be selected based on the more desirable sites and detail evaluation must be done in order to determine the performance and economic ground of the sites. The constraints were related to roads, protected areas, residential areas, transportation routes, water bodies, airports, flood prone areas etc.

Restricted areas should be identified using map of appropriate scale and factors should be considered while selecting the landfill site. Hence, the preferred location must be fulfilled the some criterias are as follows:

a) Low population
b) Low alternate land use
c) Low groundwater contamination potential
d) Low permeable soils
e) Minimum rainfall
f) Not sensitive areas

.

Location criteria for sitting of landfill must be considered and factors should be considered while selecting the landfill site is mentioned in the tabular form in the following table 3.1.

Table 3.1: Location Criteria for lined landfill (CPCB, 2003)

S. No.	Place	Minimum Sitting Distance
1	Coastal regulation, wetland, critical habitat areas, sensitive eco-fragile areas, and flood plains as recorded for the last 100 years.	Sanitary landfill sites not permitted within these identified areas.
2	Rivers	100m
3	Pond, lake, water bodies	200m
4	Non-meandering water channel	30m
5	Highways, water supply wells	500m from center line
6	Power lines	700m
7	Habitation	500m
8	Earthquake zone	500m from fault line fracture
9	Flood prone area	Sanitary landfill site not permitted
10	Water table	The bottom liner of the landfill should be above 2m from the highest water table.
11	Airport	20km
12	Public park	500m
13	Flood plain	Protective Embankment

3.2.2.2 Step II-Identification of comparable potential sites

In this step the land use and infrastructure facilities (major highway access site of existing/former waste disposal facilities and land designated for industrial use), land area required are the major factors for the identification of comparable potential sites that provides the basis for highlighting promising site within the candidate areas remaining after step I analysis. The municipality must take an attention for the list of maximum numbers of possible sites imposed by the constraint mapping exercise depending on the restriction.

This may include positive features such as:

a) Easy access to a road system

b) Proximity to the urban area

c) Ease in land acquisition

d) Beneficial after use

The area required for landfilling can be computed by following methods:

The required site area will depend upon

a) The total quantity of waste materials and volume to be discharged at the site over its life time.
b) It also depend on the volume accommodated in the % of site covered depth and height of the landfilled waste.

Area of the site should be inclusive of the buffer between adjacent properties at the site boundary and the filling area:

a) Access road.

b) Soil stockpile area outside the fill surface.

c) On-Site structure and equipment-storage area.

d) Typically, the usable fill area ranges from 50% to 80% of sites gross area

3.2.2.3 Step III- Preliminary survey (walk over survey)

The step II sites selection are further examined to eliminate those areas that fail to meet additional environmental concerned at socio economic at the site and surrounding area by walk over survey. The step I and step II does not required firsthand knowledge, a formal examined/inspection of each sites requirement is necessary for the possible sites further elimination, a walk over survey identify and both favorable and unfavorable features of the sites. The preliminary survey may sometimes require confirmation by other authorities. The identification of sufficient constraint to reduce the number of possible sites is the main objective of the walk over survey.

This may be done by surveying the area and collecting data regarding:

a) Existing zones of development.

b) Areas of mineral deposition.

c) Freshwater and wetland.

d) Natural vegetation.

e) Exposed geology.

The data required from preliminary survey includes:

1. The site presently well drained or not.

2. There are established watercourses within or adjacent to the site or not.

3. There is evidence of ephemeral streams, springs or sinkholes or not and those are includes:

a) Knowledge of the geology of the area.

b) There should not any evidence of geological features on or near the site.

d) Site or the nearby well should not have high water table.

3.2.2.4 Step IV- Site investigation on preferred sites

Step IV is site investigation that is inspected by step III which includes detail survey of hydrogeology, water, climatology, soil etc. Subsurface exploration and a topographic survey should be carried out at the preferred site. These site investigations will be critical to the success of the sitting and design of the landfill. From the results of the site investigation program, the estimates of cost and capacity of the preferred sites may be firmed up and clearly preferred site identified.

3.2.3 Ranking of sites

The next step of site selection is mainly based on evaluation of each site involving comparison of candidates for more detailed impacts. After clearly examine/ scrutinizing the sites from step I to step III, the number of sites may be reduced and accordingly they are ranked to their environmental, social and community impacts.

3.2.4 Site scrutinisation

After conducting sitting phase for identifying comparable sites, final firm selection for one is arrived through site scrutinizing procedure. The procedure involves selection of attributes, attribute weightage and ranking.

3.2.4.1 Site scrutinizing procedure

The methodology for ranking of site alternatives comprises following steps:

a) Select attributes for evaluation of site alternatives.

b) Apportion of total score of 1000 between the assessment attributes based on their importance through pairwise comparison technique.

c) Develop Site Sensitivity Index using Delphi Technique.

d) Estimate weightage for each attribute for various candidate site alternatives using Site Sensitivity Index.

3.2.5 Selection through ranking of sites

3.2.5.1 Selection of attributes

As per the CPCB in 2003 guidelines, there are 32 factors or attributes taken into account for ranking a site. The selected 32 attributes based on the guidelines of CPCB (2003) are grouped into 7 categories such as Accessibility, Receptor, Environmental, Socio-economic, Waste management practices, Climatological and Geological related as shown in the following table 3.2.

3.2.5.2 Attribute weightage

The selected attributes are grouped into 7 categories. All 7 categories are given in weightage in a scale of 1000. A numerical value called weightage has been assigned to each category, in accordance with the relative magnitude of impact it assesses using a pairwise comparision technique. Based on Delphi, weightage is assigned among the 7 categories. The weightage to each attribute is assigned following the same procedure of pairwise comparision within the categories.

Table 3.2: Categories and Weightings (CPCB, 2003)

Category	Weightage
Accessibility Related	60
Receptor Related	250
Environment Related	305
Socio-Economic Related	110
Waste Management Related	85
Climatologically Related	40
Geological Related	150
Total	1000

3.2.5.3 Site sensitivity index

Site sensitivity index is scale indicating degree of sensitivity of individual attributes. This is the total score calculated for a site based on important attributes and sensitivity of the site. Delphi technique is also assigned in accordance with the relative magnitude of impact it may exerts using a pairwise comparison technique. A set of 32 attributes has been considered by CPCB (2003) for ranking of disposal site alternatives and accordingly for each of the attributes a four-level sensitivity index scale has been considered. This scale range of each attributes are as follows (0-0.25, 0.25-0.50, 0.50-0.75 and 0.75-1.0), zero (0) indicating no or very less potential hazard and one (1) indicating highest potential hazard. Once the site sensitivity index in between 0 to 1 which is coming the data from site, multiplied with the weightage for the site and add everything then we will get ranking of site score. We will get a score in between 0-1000. The ideal perfect site is 0 and most horrible site is 1000. These attributes have been decided on the basis of available literature relating to site selection and the experts views and factors contributing to the pollution pathways. Site ranking of existing landfill sites is performed based on the results of a survey of sites and ranked according to their environmental, social and community impact

Site Sensitivity Index based on all 32 attributes have been adopted from CPCB (2003) and it has been calculated using weightage and sensitivity index for a particular site

$$SSI = \sum_{i}^{n} wisi$$

SSI= Total attribute score or site sensitivity index.

wi = Weightage of i^{th} attribute

si = Sensitivity index of i^{th} attribute

n= No. of attributes for calculating

Sensitivity of a site is decided on following criteria (CPCB, 2003) as shown in the list of table 3.4

3.2.5.4 Estimation of weightage (Score)

Based on the actual measurements and the option of the experts, the corresponding site sensitive index will be given for each attribute. The value of the sensitivity index will be multiplied by the corresponding weightage of the attributes. This will result in weightage (score) for each of the attribute. Once the site sensitivity index in between 0 to 1 which the data is coming from site, multiplied with the weightage of each attributes and add everything then we will get ranking of site score. The results will be interpreted on the basis of the total score. Then the total score of the sites will be compared and will be ranked on the basis of less sensitivity.

A broad score is given to identify which site is acceptable. Hence we can conclude the ranking of site score based on as shown in the following table 3.3.

Table 3.3: Site Ranking Score (CPCB, 2003)

Serial No.	Total Score	Site Description
1	<300	Less sensitive to the impacts (Preferable)
2	300-750	Site Moderately Suitable
3	750-1000	Highly sensitive to the impacts. (Site is undesirable)

Table 3.4: Site Sensitivity Index (CPCB, 2003)

Attribute	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Accessibility Related (60)				
Type of Road	National Highway	State Highway	Local road	No road
Distance from collection point	<10km	10-20km	20-25km	>25km
Receptor Related (250)				
Population within 500 meters	0-100	100-250	250-1000	>1000
Distance to nearest drinking water source	>5000m	2500-5000m	1000-2500m	<1000m
Use of site by nearby residents	Not used	Occasional	Moderate	Regular
Distance to nearest building	>3000m	1500-3000m	500-1500m	<500m
Land use/ Zoning	Completely remote (zoning not applicable)	Agricultural	Commercial or industrial	Residential
Decrease in property value with respect to distance	>5000m	2500-5000m	1000-2500m	<1000m
Public utility facility within 2kms	Commercial and industrial area	National heritage	Hospital	Airport
Public acceptability	Fully accepted	Acceptance with suggestions	Acceptance with major changes	Non acceptance
Environmental Related (305)				
Critical environments	Not a critical environment	Pristine natural areas	Wetlands, flood plains, and preserved areas	Major habitat of endangered or threatened species
Distance to nearest surface water	>8000m	1500-8000m	500-1500m	<500m
Depth to ground water	>30m	15-30m	5-15m	<5m
Contamination	Air, water or food contamination	Biota - contamination	Soil contamination only	No contamination

Attribute	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Water quality	Highly polluted	Polluted	Portable	Confirming to standards
Air quality	Highly polluted	Polluted	Confirming to industrial standards	Confirming to residential standards
Soil quality	Highly contaminated	Contaminated	Average	No contamination
Socio-economic Related (110)				
Health	No problem	Moderate	High	Severe
Job opportunities	High	Moderate	Low	Very low
Odour	No odour	Moderate odour	High odour	Intensive foul odour
Vision	Site not seen	Site partly seen (25%)	Site partly seen (75%)	Site fully seen
Waste Management Practice Related (85)				
Waste quantity/day	<250 tons	250-1000 tons	1000-2000 tons	>2000 tons
Life of site	>20 years	10-20 years	2-10 years	<2 years
Climatologically Related (40)				
Precipitation effectiveness index	<31	31-127	63-127	>127
Climatic features contributing to Air pollution	No problem	Moderate	High	Severe
Geological Related (150)				
Soil permeability	<1*10-7 cm/sec	1*10-5 to 1*10-7 cm/sec	1*10-5 to 1*10-3 cm/sec	> 1*10-3 cm/sec
Depth to bedrock	>20m	10-20m	3-10m	<3m
Susceptibility to erosion & run-off	Not susceptible	Potential	Moderate	Severe
Physical characteristics of rock	Massive	Weathered		Highly weathered
Depth of soil layer	>5m	2-5m	1-2m	<1m
Slope pattern	<1%	1-2%	2-5%	>10%
Seismicity	Zone I	Zone II	Zone III	Zone IV & V

CHAPTER 4

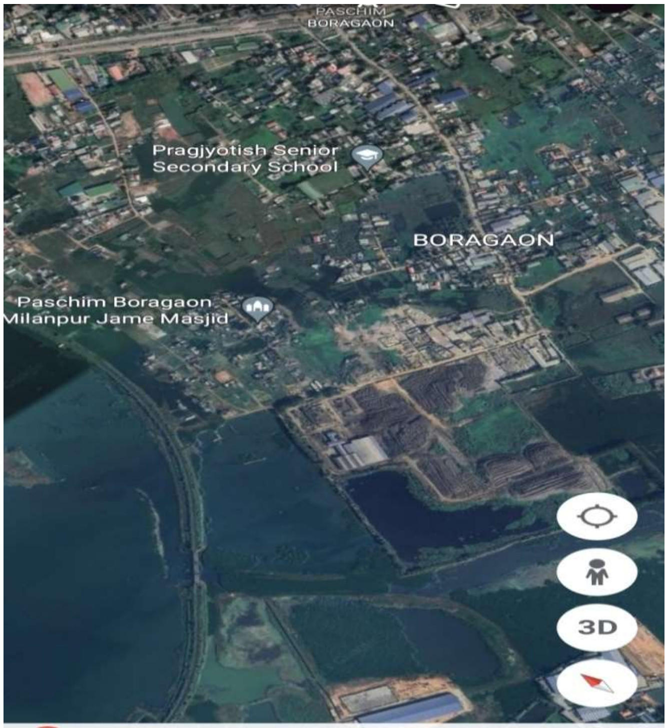
RESULTS AND DISCUSSION

4.1 However in the present case, Boragaon disposal site and its attributes are evaluated. Furthermore, an attempt has been made to describe the site wherever possible.

The study shows that Site Sensitivity Index (SSI) along with the analysis through Delphi technique is efficiently valuable decision making process that can help to locate the most suitable landfill site for municipal solid waste disposal. Site Sensitivity Index (SSI) depends on quality of available data similarly, site sensitivity index values of several environmental, geological, and hydro-geological attributes like depth of ground water table, availability of clay and other materials, background of pollution, background level of surface and ground water quality, precipitation etc. careful site investigation is needed from prospective sites. Thus, geographic databank of the study area needs to be built first, followed by site investigation studies as and when needed. Hence, once we have an idea of all the respective information with us, the site selection of prospective sites will be so much easier and can do the site ranking.

4.1.1 Accessibility related attributes

The Boragaon disposal site lies on the west side of the city at a distance of approximately 1 km to 2 km from the national highway 37 and a distance of approximately 9 km from the main city. The nearest locality lies with approximately 100 to 250 at a distance of approximately 500 m from the site.



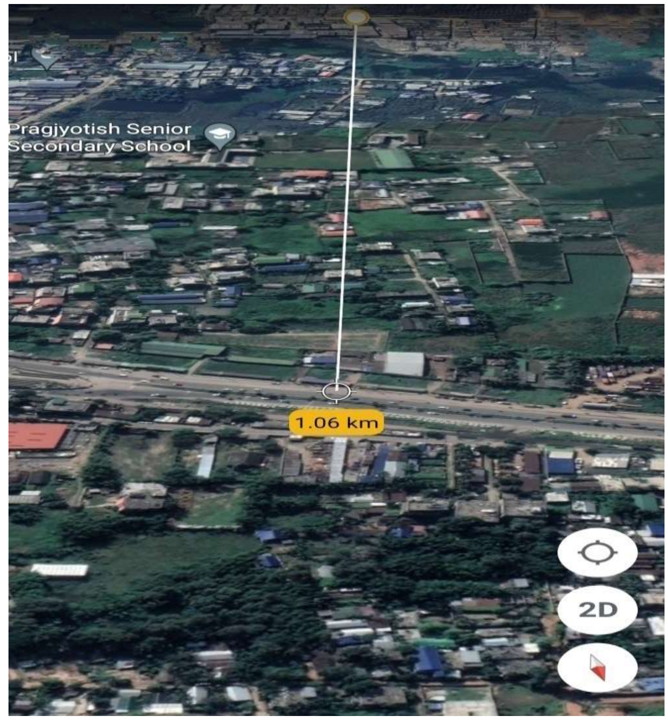


Figure 4.1: Boragaon dumpsite at a distance of approximately 1 km to 2 km from the highway.

(Source: Google earth)

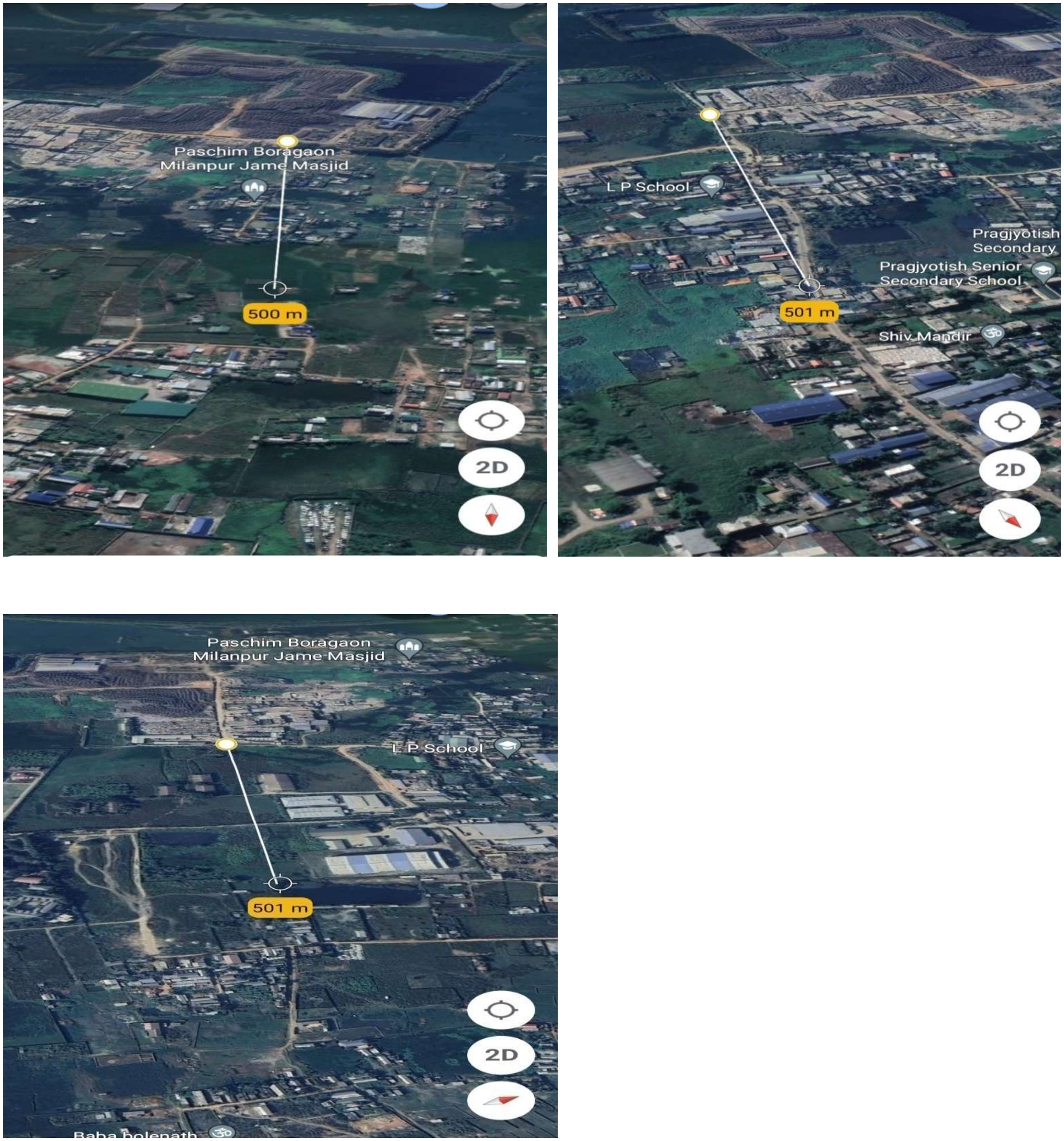


Figure 4.2: Locality at a distance of approximately 500 m

(Source: Google earth)

4.1.2 Receptor related attributes

The Boragaon disposal site is in the proximity to the city of population of 1,135,000 (2021 census). Since the residential localities are developing along the highway, the potential for moderate decrease in property value exist.

4.1.3 Environmental related attributes

The general elevation of the area is 53.33 meters above mean sea level. Boragaon disposal site represents a typical topographic plane area. This site is proximity to the wetland Deepor beel. The depth of water from ground level 3.5 m to 5 m. Baseline data for chemical analysis of the water samples from the surrounding water sources, groundwater and surface water, indicates that the somehow exceeds the permissible limit. Baseline data from soil analysis indicates that the soil is grayish brown clay some silt and sand with 25 % of sand and 75 % of silt and clay.

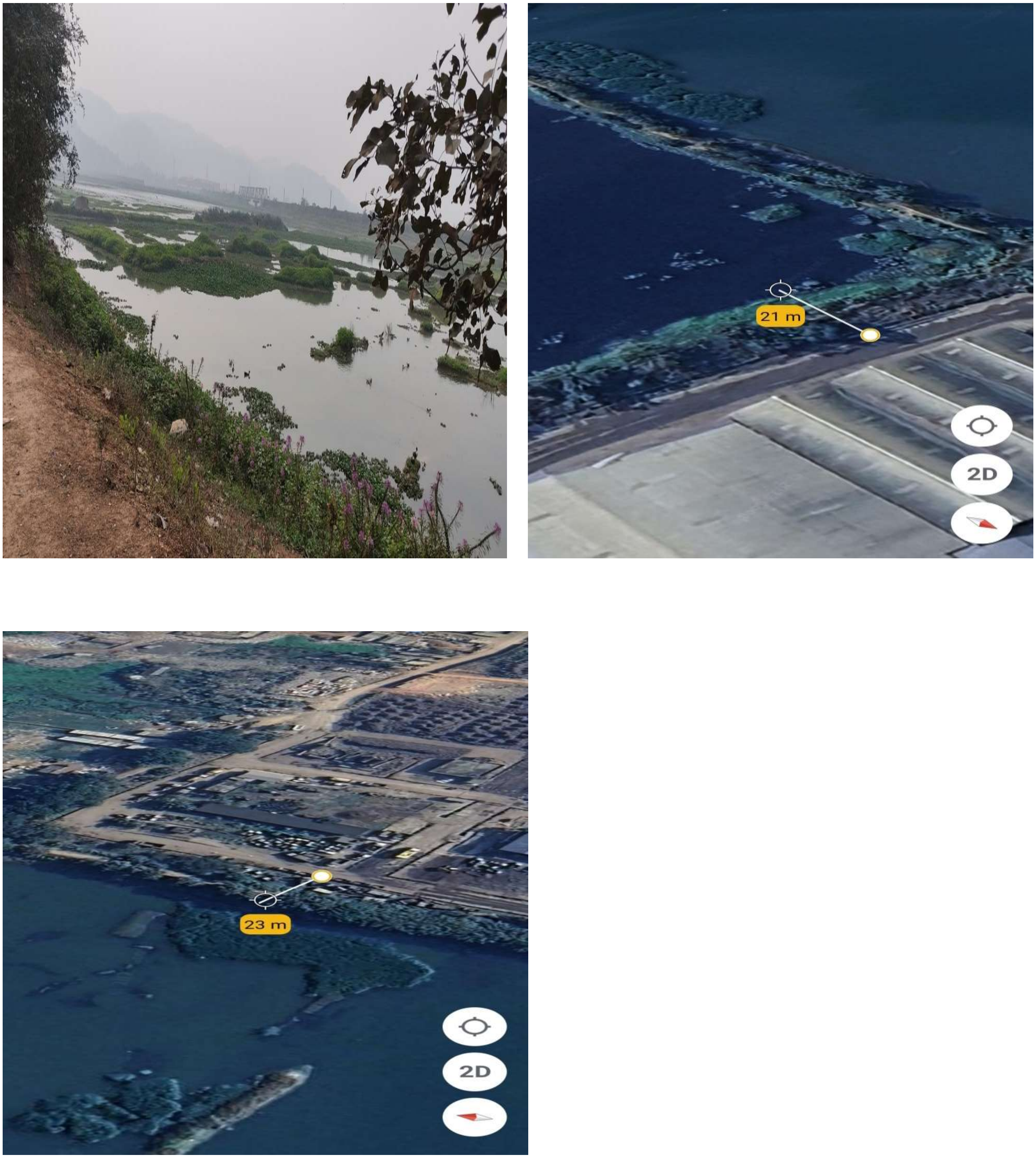


Figure 4.3: Deepor beel located approximately 20 m to 30 m from the dumpsite.

4.1.4 Socio-economic related attributes

As this site is close to the residents are affected by the odour, noise, aesthetics etc. due to landfilling operations. However, as human habitation in surrounding the area is mostly at a distance of approximately 190 m to 500 m from the site.

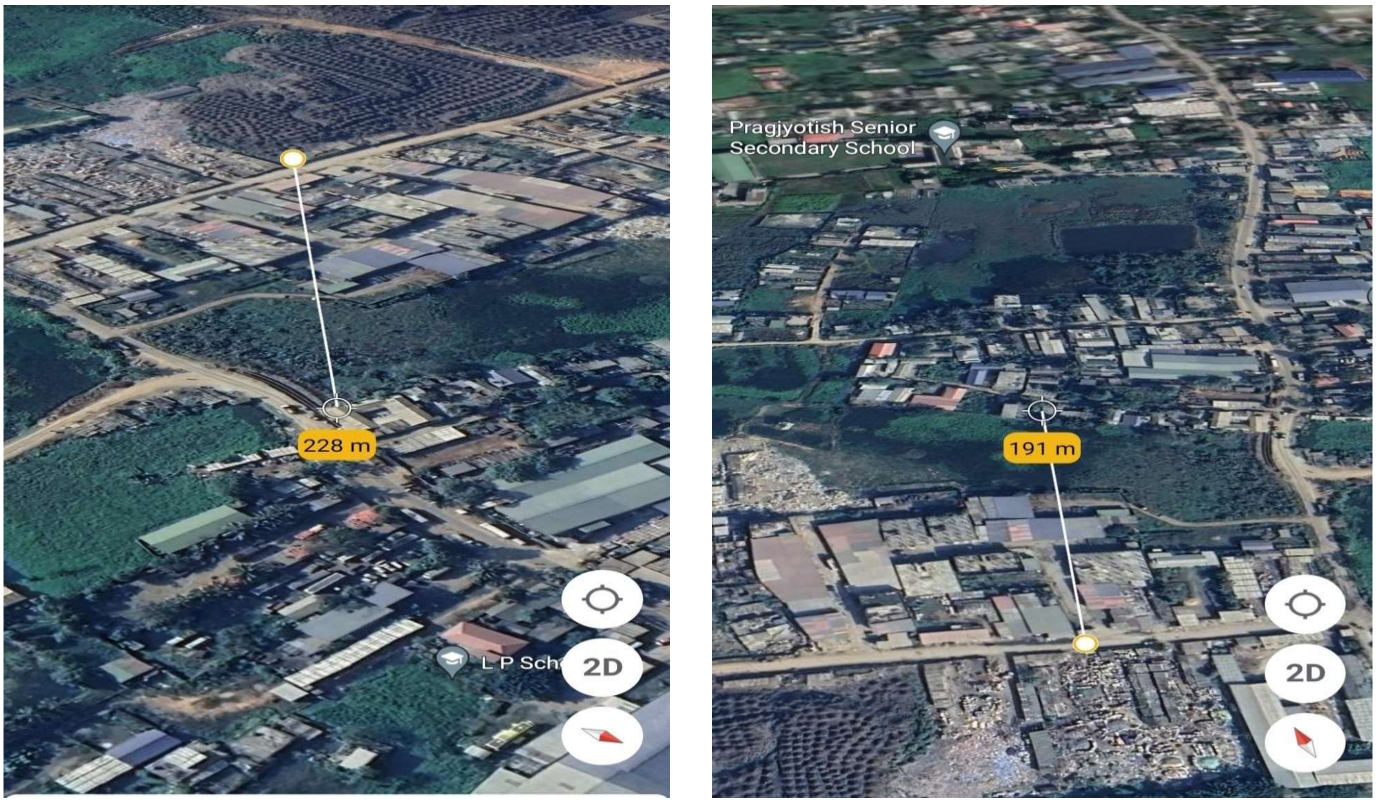


Figure 4.4: Human habitation at a distance of approximately 190 m to 500 m from the dumpsite.

4.1.5 Waste management practice related attributes

The Guwahati City has a population density of around 2695.43 per km^2 and it generates the waste around 550 tons per day it can carry around 190-300 tons per day of the solid wastes to the site. The area of the proposed site is approximately 108 bighas.

4.1.6 Climatological related attributes

About the site is average 1722 mm per year rainfall is recorded. The maximum average temperature is 32°c.

4.1.7 Geological related attributes

The depth to bedrock is 100 m. The soil permeability varies between in the range of $1x10^{-5}$ to $1x10^{-7}$ cm/sec. The site as per the seismic zoning, the stretch falls in the seismic zone v.

4.2 Site score calculation

On the basis of the data, site sensitivity index are calculated which are then multiplied by the weightages of each attribute. The total score for each category is then obtained by adding the score of each attributes. The site score calculation for Boragaon dumpsite is depicted in table 4.1 and 4.2.

4.3 Ranking of sites

The total score for existing Boragaon dumpsite is calculated on the basis of the ranking methodology table 3.3.The site with low score indicates that the site is less sensitive to impact. As far as the environmental related attributes such as contaminated land, polluted water, air and soil quality are concerned, the existing Boragaon dumpsite is moderately categorized dumping site.

Table: 4.1 Worksheet for present ranking of existing Boragaon dumpsite in the year 2023 (CPCB, 2003)

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
Accessibility (60)						
1	Type of Road	25	National Highway	0.0-0.25	0.125	3.125
2	Distance from collection point	35	20-25 km	0.5-0.75	0.625	21.875
Receptor Related (250)						
3	Population within 500 meters	50	100-250	0.25-0.5	0.498	24.9
4	Distance to nearest drinking water source	55	<1000m	0.75-1.0	0.875	48.125
5	Use of site by nearby residents	25	Not used	0.0-0.25	0.125	3.125
6	Distance to nearest building	15	<500m	0.75-1.0	0.967	14.505
7	Land use/ Zoning	35	Commercial or Industrial	0.5-0.75	0.675	23.625
8	Decrease in property value with respect to distance	15	<1000m	0.75-1.0	0.875	13.125
9	Public utility facility within 2kms	25	Commercial and Industrial	0.0-0.25	0.125	3.125
10	Public acceptability	30	Non acceptance	0.75-1.0	0.875	26.25
Environmental related (350)						
11	Critical environments	45	Major habitat of endangered or threatened species	0.75-1.0	0.830	37.35

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
12	Distance to nearest surface water	55	<500 m	0.75-1.0	0.81	44.55
13	Depth to ground water	65	<5m	0.75-1.0	0.973	63.245
14	Contamination	35	Air, water or food contamination	0.0-0.25	0.243	8.505
15	Water quality	40	Polluted	0.25-0.5	0.425	17
16	Air quality	35	Polluted	0.25-0.5	0.425	14.875
17	Soil quality	30	Contaminated	0.25-0.5	0.325	9.75
Socio-economic Related (110)						
18	Health	40	Moderate	0.25-0.5	0.325	13
19	Job opportunities	20	Low	0.5-0.75	0.734	14.68
20	Odour	30	High odour	0.5-0.75	0.748	22.4425
21	Vision	20	site partly seen 75%	0.5-0.75	0.675	13.5
Waste Management Practice Related (85)						
22	Waste quantity/day	45	<250 tones	0.0-0.25	0.145	11.27
23	Life of site	40	10-20years	0.25-0.5	0.325	13
Climatologically Related (40)						
24	Precipitation effectiveness index	25	31-127	0.25-0.5	0.325	8.125

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
25	Climatic features contributing to Air pollution	15	High	0.5-0.75	0.749	11.235
Geological Related (150)						
26	Soil permeability	35	$1x10^{-5}$ to $1x10^{-7}$ cm/sec	0.25-0.5	0.425	14.875
27	Depth to bedrock	20	>20m	0.0-0.25	0.125	2.5
28	Susceptibility to erosion & run-off	15	Moderate	0.5-0.75	0.675	11.22
29	Physical characteristics of rock	15	Nil	0	0.125	1.875
30	Depth of soil layer	30	>5m	0.0-0.25	0.125	3.75
31	Slope pattern	15	<1%	0.0-0.25	0.125	1.875
32	Seismicity	20	Zone V	0.75-1.0	0.978	19.56
Total Score		1000				539.96

Table 4.2: Worksheet for ranking of Boragaon site in the year 2008 (CPCB, 2003)

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
Accessibility (60)						
1	Type of Road	25	National Highway	0.0-0.25	0.125	3.125
2	Distance from collection point	35	20-25 km	0.5-0.75	0.625	21.875
Receptor Related (250)						
3	Population within 500 meters	50	0-100	0.0-0.25	0.100	5
4	Distance to nearest drinking water source	55	<1000m	0.75-1.0	0.875	48.125
5	Use of site by nearby residents	25	Not used	0.0-0.25	0.125	3.125
6	Distance to nearest building	15	500-1500 m	0.5-0.75	0.501	7.515
7	Land use/ Zoning	35	Completely remote (zoning is not applicable)	0.0-0.25	0.102	3.57
8	Decrease in property value with respect to distance	15	<1000m	0.75-1.0	0.875	13.125
9	Public utility facility within 2kms	25	Commercial and Industrial	0.0-0.25	0.125	3.125
10	Public acceptability	30	Non acceptance	0.75-1.0	0.875	26.25
Environmental related (350)						
11	Critical environments	45	Major habitat of endangered or threatened species	0.75-1.0	0.830	37.35

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
12	Distance to nearest surface water	55	< 500 m	0.75-1.0	0.81	44.55
13	Depth to ground water	65	<5m	0.75-1.0	0.973	63.245
14	Contamination	35	No contamination	0.75-1.0	0.712	24.92
15	Water quality	40	Portable	0.5-0.75	0.525	21
16	Air quality	35	Polluted	0.25-0.5	0.425	14.875
17	Soil quality	30	No contamination	0.75-1.0	0.751	21.45
Socio-economic Related (110)						
18	Health	40	No problem	0.0-0.25	0.102	4.08
19	Job opportunities	20	Moderate	0.25-0.5	0.261	5.22
20	Odour	30	High odour	0.5-0.75	0.675	20.25
21	Vision	20	site partly seen 25%	0.25-0.5	0.262	5.24
Waste Management Practice Related (85)						
22	Waste quantity/day	45	250-1000 tones	0.25-0.5	0.325	8.125
23	Life of site	40	10-20years	0.25-0.5	0.325	13
Climatologically Related (40)						
24	Precipitation effectiveness index	25	31-127	0.25-0.5	0.325	8.125

S. No	Attribute	Weightage	Attribute measurement	Sensitivity range	Site Sensitivity Index	Score
25	Climatic features contributing to Air pollution	15	Moderate	0.25-0.5	0.295	4.425
Geological Related (150)						
26	Soil permeability	35	$1x10^{-5}$ to $1x10^{-7}$ cm/sec	0.25-0.5	0.425	14.875
27	Depth to bedrock	20	>20m	0.0-0.25	0.125	2.5
28	Susceptibility to erosion & run-off	15	Moderate	0.5-0.75	0.748	11.22
29	Physical characteristics of rock	15	Nil	0	0.125	1.875
30	Depth of soil layer	30	>5m	0.0-0.25	0.125	3.75
31	Slope pattern	15	<1%	0.0-0.25	0.125	1.875
32	Seismicity	20	Zone V	0.75-1.0	0.978	19.56
Total Score		1000				453.495

4.4 Additional attributes for hilly regions

Apart from this site sensitivity index table of 32 attributes and specially for hilly regions we have added few other attributes. Choosing a site in hilly regions that cannot fully dependent on 32 attributes, few additional attributes are needed and we are trying to define those attributes that are needed for the site selection in hilly regions. Guidelines for Site Selection of Landfill in Hilly Regions (MSW Management Rules, 2016)

(a) Construction of landfill on the hill shall be avoided. A transfer station at a suitable enclosed location shall be setup to collect residual waste from the processing facility and inert waste.

A suitable land shall be identified in the plain areas down the hill within 25 kilometers for setting up sanitary landfill. The residual waste from the transfer station shall be disposed of at this sanitary landfill.

(b) In case of non-availability of such land, efforts shall be made to set up regional sanitary landfill for the inert and residual waste.

Few of additional attributes are listed below:

4.4.1 Landslide susceptibility
4.4.2 Drainage
4.4.3 Slope stability
4.4.4 Rainfall intensity
4.4.5 Downstream impact

4.4.1 Landslide susceptibility

Several cities across the world are located in mountainous and landslide prone areas. Any landfill siting without considering landslide susceptibility in such areas it may impose a additional environmental adversity. MSW disposal sites need more attention and control in hilly region to prevent the occurrence of landslide and consequently the mitigation of environmental, economic and social impacts. Landslide susceptibility is an appropriate tool to carry out this type of analysis so we recommend that the risk of natural disasters should be taken into consideration in the process of finding landfill areas, mainly because there is a tendency for extreme weather events to increase causing more flood and landslide events and consequently contributing to water scarcity and water degradation (Nascimento et al. 2017). Lack of proper management and monitor, many landfills experience high landslide risk, and typical case is the Guangming landfill landslide in Shenzhen, China on 20 December 2015 (Wang et al. 2019). Generally, a satellite-based analysis method is identified and used to efficiently assess landslide susceptibility of landfill. The steps include investigation of the topography and climate of the landfill site and dynamic evaluation based on satellite data.The results showing that the satellite based analysis method can obtained the key factors of the landfill landslide (Wang et.al 2019). Landslide susceptibility assessment is performed based on Landslide susceptibility mapping method in a range of phases. The initial phase is identified and evaluated the landslide-prone areas and constructing a landslide inventory map for future use (Yalcin et al. 2011). Landslide inventory maps can be prepared either by collecting historical information of individual landslide events or by using satellite imageries and aerial photographs coupled with field surveys by global position system (GPS) (Kayastha et al. 2013). If landslide susceptible areas are not considered in landfill site selection, the potential landfill sites would become more effective. It can be concluded that if any of these landslide prone sites are selected for landfilling, further environmental disaster would be terminated in the future (Eskandari et al. 2016).

One of the most important criteria that we have to considered in mountainous areas is landslide. The presence of cut or fill slopes during construction of the municipal solid wastes (MSW) landfill structure might cause slippage of existing soil or rocks. Therefore, the risk of landslides must be taken into consideration when we examined the new locations for a landfill (USEPA 2006).

The slope failures have been related to geological, topographical and climatic conditions thus, they can often facilitate the prediction of locations and conditions of future landslides (Yalcin et al. 2011). Selection of these parameters takes the nature of the study area and the data availability into account. Ultimately, landslide susceptibility map can be obtained by using any aggregation functions. This map is an important landfill site selection factor in mountainous regions. The low landslide susceptibility areas generally represent flat terrain surfaces with low slopes ranging between 0 to 20 degrees. Steep slopes are the most important factor that makes a landscape susceptible. Finally, the landslide susceptibility of the major sites are analysed with spatial multi criteria evaluation (SMCE) based on the available input factor maps: landslide points, slope angle, soil, geology drainage and land use.

From the literature it is observed that although landslide is an important landfill site selection factor due to natural condition of the study area, the landslide susceptibility map of the region was not available. Based on the concept given in Landslide susceptibility mapping and also literature review, six factors including slope, land cover, distance to streams, drainage density, distance to roads, and geology were assigned to prepare landslide susceptibility map of the study region.

4.4.2 Drainage

A functioning landfill drainage system looks like water trickling through the surface unit it reaches the bottom level of the landfill. Next, instead of seeping into the groundwater, it is blocked by a liner and flows into your drainage system. Finally the water is efficiently evacuated to a location to be treated. Seems simple, but there are a number of potential hazards that can pollute the surrounding area. When a drainage system is not working properly, whether it is simply draining too slowly or cant drain at all, one problem is landfill surface runoff. Particularly when landfills are filled primarily with nonbiodegradable materials like plastics, water flows freely off of the surface and into local rivers. One study conducted in 2000 in India found that landfill surface runoff was one of the main contributors of river pollution in Delhi and by extension, the rest of the country.

In hilly regions drainage facility is installed to reduce the amount of leachate generated from landfill sites. Drainage system should be constructed surrounding the landfill site to prevent outside rainwater from flowing through the landfill site into the low lying areas of hilly regions. Drainage facility provides us as a vital role of the overall drainage network in the sanitary landfill system to reduce leachate volume generation through removal of rainwater.

One of the most critical pieces of infrastructure for any landfill is the liner that serves as a barrier between the ground and a mountain of waste. Without a liner waste will contaminate the groundwater and when erosion inevitably occurs, will flow away from the landfill begin to contaminate the area. A liner is essentially just a containment method. The problem is that without proper drainage and soil gas venting the liner will become stressed, damaged and completely non functional. The drainage system forms a geocomposite drainage layer that has only capacity to remove water before it can cause damage.

In hilly regions, the drainage system of landfills that are highly clog-resistant is essential. The rain falls very fastly on the hills and as the slopes of hills are quite steep, the water reaches the downstream areas very quickly as well as the contaminated water from landfill enters quickly into the low lying areas and can impact the low lying areas and might be created hazardous problems. The contaminated water and rain water thus collected should be disposed off in a proper way through the well planned and designed drainage system in hilly regions. In hilly regions due to improper drainage system causes the weaking of the pavement and it also causes problems of slope stability. It is therefore necessary to control flow by adopting the suitable method of the drainage system. For carrying the surface water the side drains are provided on the hilly regions landfill and there are limitations in the formation of drainage system that could utilize the space of side drains. There are requirements that add highly to the significance of drainage in the case of hilly regions such as side drains, catch water drains, and measures for improving slope stability. In hilly areas due to heavy rains may lead to subsidence the landfill. They occur when there is a movement of soil, rocks, debris down the mountain slope

Hilly areas have a high rainfall level (Amien, 2011). Drainage management of landfill is important when the water flow is regulated so that the flow goes to a lower area. The surface drainage discharge is one of the indicators that influence drainage systems management (Valipour, 2012). Drainage management is a science that studies flood control in areas. In hilly regions, landfill drainage is one of important parameters in the design of landfill. The design and construction of landfill drainage must consider land use, slope and large rainfall (Mursito & Amien, 2011). Water flow is set to control puddles and floods. Floods are avoided in the Waste Landfill. Contaminated water of landfill is expected to enter the water channel to the river while in the low lying areas. Drainage planning stage starts from measuring the landfill site plan, precipitation modeling, designing flood discharge, drainage channel design and channel dimensions (Amien, 2011). Precipitation model is required to obtain large rainfall falling to the low lying ground. Some of the models mentioned above will generate a statistical value that corresponds to the actual condition in the field. After obtaining rainfall, the next step was to estimate runoff discharge that flows around the landfill. Runoff debit is calculated using the rational method. This method has the function of estimating the design flood discharge. Flood design in question is the peak flood discharge included in the non-hydrograph design (Yanto, Warman, & Hatta, 2014). The next step is to design the flow and dimensions of the drainage channel. The channel dimensions are closely related to channel slope and runoff discharge. The channel is expected to accommodate peak flood discharge and safely channel runoff water to a lower place (Amien, 2011). Precipitation Analysis If the observation points in the area are not evenly distributed, then the method of calculating the average rainfall is done by calculating the area of influence of each observation point (Arora & Singh, 1989; Yeshoda, Meenambal, & Manikandan, 2015). Leachate control within a landfill involves the following steps: (a) prevention of migration of leachate from landfill sides and landfill base to the subsoil by a suitable liner system; and (b) drainage of leachate collected at the base of a landfill to the sides of the landfill and removal of the leachate from within the landfill. Liner systems comprise of a combination of leachate drainage and collection layer. A system of perforated pipes are provided within the drainage layer.

4.4.3 Slope stability

The stability analysis typically performed for a waste slope considers either a deep-seated potential failure mode within the waste mass structure or along discrete bottom liner system interfaces. It is a static or dynamic analytical or empirical method to evaluate the stability of earth and rock-fill dams, embankments, excavated slopes and natural slopes in soils and rock. Slope stability is defined as the condition of inclined soil or rock mass slopes to withstand or undergo movement from external stress or forces. Analysis are generally aimed at understanding the causes of an occurred slope failure, or the factors that can potentially trigger a slope movement, resulting in a landslide as well as at preventing the initiation of such movement, slowing it down or arresting it through mitigation countermeasures. The stability of a slope is essentially controlled by the ratio between the available shear strength and the acting shear stress which can be expressed in terms of safety factor. A slope can be globally stable if the safety factor, computed along any potential sliding surface running from top of the slope to its toe is always larger than 1.Stable slopes that require attention, monitoring and engineering intervention (slope stabilization) to increase the safety factor and reduce the probability of a slope movement.

In hilly regions it is usually not possible to find flat ground for landfilling. Hence, Slope landfills and valley landfills have to be adopted in such hilly regions. In hilly regions, landfills were placed along the the sides of existing hill slope, within a valley, on a sloping ground (Seed et al.1990). Control of inflowing water from hillside slopes is a critical factor in design of such landfills in hilly regions. In such locations, there are several major failure cases in the construction of landfills (Seed et al.1990), (Koerner and Soong, 2000) and Blight, 2007). Limiting equilibrium methods that are common in geotechnical engineering practice are used in most landfill slope stability analysis. There are many causes for landfill slope failures (over building of waste slopes, freeze/thaw conditions, weakened foundations, poorly installed geosynthetics and so on) but in almost every case, running water and the erosion it causes played a part. To design a landfill in hilly region for slope stability, examine the elements that influence stability. Failure along weak geosyntehtic interfaces of liner system is also one of the most important factors. In an engineered landfill stability of the sloped liner can be increased by increasing microscopic roughness of geomembrane (Mahanta et al. 2017). In an engineered landfill on slopping ground of hilly regions, stability analyses against slippage along the sloped liner system plays an important role in overall stability for the whole landfill and this is critical due to weak geosynthetic interface between the geomembrane (GM) and the compacted clay liner (Seed et al.1990). Foundation soils must be capable of supporting the landfills infrastructure. Landfill failures occur when foundation soils beneath or adjacent to the landfill yield because of the applied forces or loads. The applied load corresponds to the material or composition weight above the foundation soils, e.g. the liner system and waste mass. The susceptibility of foundation soils to failure under the applied load or forces can be determined by routine soil borings and laboratory testing, which measures the shear soil strength. Shear strength refers to the ability of the material to resist structural damage when a force is applied to it, and can be used in stability analysis. Landfill liner system construction is important to slope stability for an engineered landfill on sloping ground of hilly regions. An earthen berm can be constructed at the base of a landfill slope movement in an adjacent cell or undeveloped area. Some slope failures have occurred when the berm was removed during new cell construction and when the berm was not large enough to provide sufficient resistance to lateral slope movement. Failures may have occurred at under construction, operating and closed landfills. Widely known failures have been due to uncontrolled dumps and led to significant loss of life too. From the literature it has been observed that slope stability in hilly regions, calculations become difficult due to the heterogeneous structure of MSW landfills and leachate, and therefore, slope geometries are formed by choosing low slope angles for safe designs. Numerical analyses were prepared using finite element and limit equilibrium methods. The stability behavior of landfill slopes can be analysed for both unreinforced and geogrid-reinforced conditions in order to investigate the effects of shear strength parameters, the unit weight of the soil waste and the safety factor of the slope can be increased by upto approximately two times (Keskin et al. 2022). Slopes in landfills reinforced with geogrid reinforcements can be formed steeper, allowing more solid waste to be stored and that storing more solid waste with the use of geogrids will provide significant economic gains and based on the results, the optimum values of geogrid parameters were determined and suggested for maximum reinforcing effects in MSW landfill slopes (Keskin et al. 2022).

4.4.4 Rainfall intensity

Short-term precipitation is expressed in hourly intensity formulas. This intensity is called rainfall intensity (mm / hour). The amount of rainfall intensity varies. This is caused by the length of rainfall or the frequency of occurrence (Utama et al. 2022). Rainfall intensity is defined as the ratio of the total amount of rain or rainfall depth falling during a given period to the duration of the period. As the rainfall intensity increases, the surface and underground runoff increases and the runoff difference becomes more substantial with increases in rainfall. Compared with moderate rainfall events, heavy rainfall and storm rainfall events own a greater destructive power to destroy the landfill structure due to soil and cause larger erosion module in hilly areas. The slope of the land causes water to move faster in the downwards. If a stream or river is flowing down, a mountain it will move more quickly the landfill component as it is flowing across a flat areas. Moving water also has the ability to move along small pieces of rock and soil. Sometimes it rains a lot at one time and heavy leachate formed when rain water filters through wastes placed in landfill. It rains so hard that the rain cannot soak into the ground. Instead, it runs over the land. Gravity causes the water to flow downhill slope. As the runoff flows, it may pick up loose material. These materials may include bits of soil and sand or any other structure. It is carried away by this running water across the surface of the land. The quick speed of water causes a lot of erosion. The rain falls very heavily on the hills and as the slopes of hills are quite steep, the water reaches the downstream areas very quickly as well as the contaminated water from landfill enters quickly into the low lying areas and can impact the low lying areas which pose a great risk to environment as well as on human health to the nearby areas. Increased frequency of heavy rain is predicted to affect the chemical stabilization of bottom of landfill, as rainwater seeps into and interacts with landfill components (Linh et al. 2020). High leachate levels seriously affect slope stability in landfills (Yang et al. 2020). Heavy rainfall and degradation of waste are the main causes of high leachate levels. High leachate levels exist downstream of the landfill slope and dissipate slowly. In order to stabilize landfills for safety we suggest the use of drainage measures (Yang et al. 2020). The main risks come from higher rainfall intensity in short intervals causing erosion, flooding and landslide (Wille, 2018).

4.4.5 Downstream impact

Landslides and flooding are common in India in hilly regions. They are particularly frequent during the pre-monsoon or monsoon season when heavy rains lead to subsidence of earth and rocks. They occur when there is a movement of soil, rocks and debris down the mountain slope. In hilly areas continuous landslide, flooding and soil erosion may collapse the landfill into the direction of downstream areas. In hilly regions, the drainage system of landfills that are highly clog-resistant is essential. The rain falls very heavily on the hills and as the slopes of hills are quite steep, the water reaches the downstream areas very quickly as well as the contaminated water from landfill enters quickly into the low lying areas and can impact the low lying areas which pose a great risk to environment as well as on human health to the nearby areas. The rapid transfer of rapidly flow over the surface can have a significant and damaging impact on downstream receptor system. For example where a small upstream area discharges into a large river system, the actual impact may be small but because the maximum value occurs ahead of the peal in the receiving river. It may pass downstreams without detriment and in such cases it may be detrimental to provide storage attenuation if this leads to the peak flows occurring at around the same time. The downstrems system can also prevent the exceedance from freely discharging increasing the risk of upstream flooding. It is important to understand the interaction between the upstream system conveying the flow, and the downstream receptor. If contaminated water enters into the water bodies such as river, lake, stream and groundwater will decrease the water quality subsequently disrupt the natural ecosystems. Landfill leachate can contaminate nearby surface water and ground water by discharging different pollutants such as salts, organic matter, heavy metals and xenobiotic organic compound.

The inadequate treatment or disposal of waste in mountains not only creates risks for ecosystems and human health in mountain regions, but also for downstream areas. There should be such options available to prevent and manage waste in mountain environments, in ways that protect mountain ecosystems and people, and prevent problems from migrating downstream. In mountains, steep slopes, terrain instability, seismic activity and adverse weather conditions add another level of complexity and risk to waste management.Some of the largest waste dumps are found in mountain regions. Poorly managed waste in mountain regions has the potential to move downwards. More intense rainfall and flooding events have the potential to increase the risks of storage failure and weaken existing waste infrastructure. Large amounts of waste and some of which can be hazardous with the potential to have large downstream impacts.

4.5 Results and discussion

Having the lowest Site Sensitivity Index score, it will be the lesser impact on the environmental quality due to the disposal site and hence it is the less sensitive and most acceptable. As per CPCB 2003 guidelines, the site of low score is better and higher score is most probably undesirable. The ideal perfect Site Sensitivity Index of sites is zero and the most horrible site is 1000. Out of the total score of 1000, the sites with less than 300 (<300) are preferable, having score of 300-750 will be moderate impact and greater than 750 (>750) are undesirable it is highly sensitive to the impacts. Site ranking of existing landfill sites is performed based on the results of a survey of sites and the total score of the sites are ranked on the basis of less sensitivity

The site which is scores the best in terms of acceptability should be adopted. We have to go for the public consultant process before adopting the landfill sites which have a big issue because local people about the landfill and the public acceptance is very important and then we will get a regulatory approval. The site sensitivity of any particular landfill site is depending on the data which is coming from the sites. The Guwahati City has a population density of around 2695.43 per km^2 and it generates the waste around 550 tons per day it can carry around 190-300 tons per day of the solid wastes to the site**.** Boragaon dumpsite is situated in huge populated area like Guwahati city of Assam so there will not get the available land for landfill site. Boragaon dumpsite is the only one disposal site of Guwahati city. As per the Topographical, Geological and Climatological survey covering the entire area of Boragaon dumpsite, site is collected with the consideration of all the factors and reachable distance. We can see the Boragaon dumpsite is the flat low line area is located near to the surface water body wetland Ramsar site of Deepor Beel. As per the calculation of table, Site Sensitivity Index (SSI) score of the Boragaon dumpsite in the year 2023 is 539.96, it falls under the "moderate impact" category and hence moderately acceptable dumpsite. As per the calculation of table, Site Sensitivity Index (SSI) score of the Boragaon dumpsite in the year 2008 is 453.495.The methodology and approach adopted in this study can be employed in urban areas and high populated areas or elsewhere. In case of hilly regions apart from the 32 attributes, some additional attributes should be needed such as landslide susceptibility, slope stability, drainage, rainfall intensity, downstream impact etc. few of additional attributes are identified for the site selection in hilly regions.

CHAPTER 5

CONCLUSION AND SCOPE FOR THE FUTURE STUDY

5.1 Conclusion

An attempt has been made to study related to the impact on environment, using site ranking method and from the results it can be concluded that,

1. The present ranking score of existing Boragaon dumpsite in the year is 539.96 which indicate us that the land having the value of 539.96 is categorized under the moderately affecting environmental land and there is no high significant impact on the environmental quality which is neither adversely affected nor lowly affected.

2. The ranking score of Boragaon site before siting the dumpsite is being approximately 453.495 in the year 2008 on the basis of CPCB, 2003 guidelines.

3. This clearly shows us that the Boragaon site in the year 2008 is found to be limited and it is preferable for siting the dumping site.

4. But as per my own perception the calculation of CPCB guidelines may not be completely correct and this might not give us final solution to it as it is not possible to placed a dumpsite in that site because the site is surrounded by a huge water body called Deepor Beel, which is a well-known of Ramsar site in the North-Eastern region of India which is located at a distance of approximately less than 500 m.

5. As the Boragaon dumpsite is present in the vicinity of a huge water body Deepor Beel, due to the ecological importance of the Deepor Beel, the waste dumpsite at Boragaon poses a huge environmental concern that needs to be addressed and managed effectively.

6. The weightage value of critical environments is taken as 45 only out of 1000 (4.5%) that is having less importance as per the guidelines, so in my point of view the weightage value of critical environments should take the value of above 4.5% or more it must be given more importance for the site selection of landfill..

7. This site need further physical verification in terms of present land use because the dumping ground at Boragaon is not a proper landfill site as it does not conform to all specification and guidelines due to the improper segregation of the garbage being dumped from the entire city and also non availability of leachate collection facility so it is needed for proper management practices.

8. Boragaon dumpsite is the only one disposal site in the entire Guwahati city which polluting thc habitat surroundings and the natural wetlands, therefore taking the present scenario in hand, if we could provide a leachate collection facility with proper specifications then it would might become helpful in proper management and mitigating their effects.

9. So on the other hand if we shift the dumpsite to a remote area with a proper engineered landfill practices, it might play a important in management of waste.

10. It must be aims to reduce the MSW generation rate and increase the collection efficiency and improve the recovery of recyclables.

5.2 Scope for future study

The guidelines are designed to provide a framework for the development of policy and procedure to protect health of community and environment quality arising out of disposal of municipal solid waste and to assist the appropriate agency in the siting for disposal of MSW in suitable location. The study of the proper attributes and the risk associated with it should be studied with almost care and precision. The various factors that can be included in the scope for future study as listed below:

1. The findings of the present study are to predict the environmental and social impacts itself that can be reduce the adverse impacts and minimize health risk.
2. The methodology of ranking the site and approach adopted in this study can be employed in urban areas, high populated areas and hilly areas.
4. Identify the need for proper management practices to reduce the effects and possible solutions to manage the waste generation.
5. The outcome of this work will act an input for quick decision making prioritizing actions related to the solid waste management.

References

1. Banerjee, A. (2021). Impact of Municipal Solid Waste Landfill on Surrounding Environment: A Case Study. In Proceedings of the Indian Geotechnical Conference 2019 (pp. 249-260). Springer, Singapore.

2. Banerjee, A., Dimri, A.P., & Kumar, K. (2020). “Rainfall over the Himalayan foot-hill region: present and future”. Journal of Earth System Science 129 (2020):1-16.

3. Balteanu, Dan, Viorel Chendes, V., Sima,M., & Enciu, P. (2010). A country-wide spatial assessment of landslide susceptibility in Romania.Geomorphology, 124 (3-4), 102-112.

4. *C*PCB, 2003. Guidelines for the selection of site for landfilling. Central Pollution Control Board, New Delhi, India.

5. Chakraborty, A., Goswami, A., Deb, A., Das, D., &Mahanta, J. (1772). Management of waste generated in Guwahati City and the incorporation of geocells at the landfill site. City, 2025(22.15), 0-8.

6. Dar, S. N., Wani, M. A., Shah, S. A., &Skinder, S. (2019). Identification of suitable landfill site based on GIS in Leh, Ladakh Region. GeoJournal, 84(6), 1499-1513.

7. Eskandari, M., Homaee, M., & Falamaki, A. (2016). Landfill site selection for municipal solid wastes in mountainous areas with landslide susceptibility. Environmental Science and Pollution Research 23 (2016):12423-12434.

8. Hazarika, R., &Saikia, A. (2020). Landfill site suitability analysis using AHP for solid waste management in the Guwahati Metropolitan Area, India. Arabian Journal of Geosciences, 13(21), 1-14.

9. Keskin, M. S., & Kezer, S. (2022). Stability of MSW landfill slopes reinforced with geogrids. Applied Sciences, 12(22), 11866.

10. Kurian, J., Esakku, S., Nagendran, R., &Visvanathan, C. (2005, October). A decision making tool for dumpsite rehabilitation in developing countries. In Proceedings of Sardinia.

11. Majumdar, A., Hazra, T., & Dutta, A. (2017). Landfill site selection by AHP based multi-criteria decision making tool: a case study in Kolkata, India. Journal of The Institution of Engineers (India): Series A, 98(3), 277-283.

12. Ohri, A., & Singh, P. K. (2009, November). Landfill site selection using site sensitivity index a case study of Varanasi city in India. In Proceedings of 1st International Conference on Solid Waste Management. KhudiramAnushilan Kendra (KAK) & Netaji Indoor Stadium (NIS), Kolkata, India (p. 31).

13. Paul, K., Dutta, A., & Krishna, A. P. (2014). A comprehensive study on landfill site selection for Kolkata City, India. Journal of the Air & Waste Management Association, 64(7), 846-861.

14. Pandiyan, P., Murugesan, A., Vidhyadevi, T., Dineshkirupha, S., Pulikesi, M., &Sivanesan, S. (2011). A decision making tool for hazardous waste landfill site selection. American Journal of Environmental Sciences, 7(2), 119.

15. Ramke, H. G. (2018). Collection of surface runoff and drainage of landfill top cover systems. Solid Waste Landfilling: Concepts, Processes, Technology, 373.

16. Sayed, A., Singh, R. K., & Ajay, K. S. (2015). Water quality analysis of Disposal site and its adjacent area of Guwahati, Assam, India. International Research Journal of Environment Sciences, 4(5), 12-17.

17. Wang, H., Zhang, J., & Lin, H. (2020). Satellite based analysis of landfill landslide: the case of the 2015 Shenzhen landslide. International Journal of Geotechnical Engineering, 16 (3), 293-300.