STUDY ON SUSTAINABLE WASTE MANAGEMENT IN BHUTAN
A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY

PROJECT REPORT

ROYAL UNIVERSITY OF BHUTAN

Jigme Namgyel Engineering College

Department of Civil Engineering and Surveying

Dewathang

Samdrup Jongkhar : Bhutan

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“ Where we live must be clean, safe, organized, and beautiful, for national integrity, national pride, and for our bright future. This too is nation building.”

His Majesty, The King of Bhutan, April 2015

Abstract

Waste management has been and still is a persisting issue that has been gnawing the government over the decades, however several countries have become successful in reducing and managing the waste in best possible ways with strict adherence to the waste management policies and protocols. A developing country like Bhutan is tirelessly working in close collaboration with several stakeholders and community partners to educate and bring down the pollution and health hazards that could lead to several unprecedented complications for the country in future. Thus a study on waste management in Samdrup Jongkhar Municipality was carried out to foresee the ramifications from waste mismanagement within municipality and suggest sustainable approaches that can alleviate the persisting waste management issues at the grass root level. This study presents the scenario of the landfill and information that were collected from various sources to know about the situation of waste management and public attitudes towards the waste along with the interviews with the stakeholders. Similarly, waste generation forecasting along with the estimation of Green House Gas emission from the landfill site were carried out. Based on the data and inferences from this research, several recommendations were being passed to the Thromde as well to the community partners to collaboratively reduce and manage the waste. Thus, the recommendations and conclusions from this research can be reciprocated to other areas where managing waste at grass root level has become a nuisance.

Acknowledgement

We the project members would like to express our heartfelt gratitude to Mr. Phurba Tamang, the mentor for this project, who always encouraged and consistently guided us in this research. We would like to thank student team from Aalto University, Finland for showing their interest to collaboratively work on this pivotal issue and for being a great team and also for providing a deeper insights to this research. We would also like to thank Dewathang Primary School, Garpawong Middle Secondary School, Samdrup Jongkhar Initiative and Samdrup Jongkhar Thromde for their continuous support and for being our community partners.

We would also like to thank academics from Department of Civil Engineering and Surveying for providing valuable ideas and suggestions throughout the course of this project. A special word of thanks to all the households (staffs) and students whose patience, co-operation and effort provided us with necessary information to enable a better understanding on waste generation in the campus and not to forget the support and assistance that we received from the residents and locals from Samdrup Jongkhar Thromde. We are very much thankful to you all for providing us with all the relevant information and for your immediate responses to our queries.

Lastly, we would like to thank all the individuals who were directly or indirectly involved in our research and our institute Jigme Namgyel Engineering College for making us a part of PBL Project.

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Introduction

Many cities in developing Asian countries face serious problems in managing solid waste. The annual waste generation is increasing in proportion to the rise in population and urbanization and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes (Mufeed Sharholy, kafeel Ahmad, R.C.Vaishya, R.D.Gupta, 2007). According to World Bank's report, the world generates 2.01 billon tones of municipal solid waste annually, with at least 33% of that not managed in environmentally safe manner. An update to the previous report projects that it will push global waste to increase by 70% over the next 30 years-to a staggering 3.40 billion tons of waste generated annually.

Nedup Tshering, a retired civil servant an environmentalist who started a civil society organization based in Thimphu, Clean Bhutan, states that compared to other countries, waste in Bhutan is not a huge problem. However, it is growing rapidly, and within since 2014, when Tshering started his initiative, the waste produced by individual household has doubled from 250 grams per day to 500 grams per person.

The National Environment Commission's (NEC) report "Bhutan State of Environment, 2016" has pointed out that, with rapid socio-economic development, increasing population and urbanization, the country is seeing an increase in the amount of solid waste generated. More problematically the composition of that waste is shifting from biodegradable to non-biodegradable.

In Samdrup Jongkhar Thromde land-fill waste management is carried out through door-to-door collection with different collection schedules for core town, residential areas and Dewathang areas. The waste collected is currently dumped at the landfill (basically a dump yard) without any segregation though, certain amounts of recyclables such as pet bottles, metals etc... are collected by scrap dealers before the waste is dumped at the landfill.

The old landfill (dump yard) was constructed in the year 2012 with an expenditure of Nu. 6.1 million covering an area of 20,000 square feet. It is located at Matanga, at a distance of 3 km from Samdrup Jongkhar town. The daily waste generation is around 5 tons per day. The landfill was built to suffice the need of waste disposal for 10 years but within a span of 6 years, the landfill has already reached its brim.

1.1 Background

Landfill is the site for the disposal of waste materials by burying it, especially as a method of filling in and reclaiming excavated pits. As of today, Bhutan has over 25 open landfills of which the Samdrup Jongkhar Thromde's landfill is located in Matanga that is about 3 km from the town and is looked after by the Thromde administration. As per the waste inventory 2018, Samdrup Jongkhar Thromde generated 364.23MT in that year of which 56.95% of the total waste was dry and remaining 43.05% was wet waste.

The main objectives of this study is to learn and interpret the effect of solid waste mismanagement, to forecast waste generation within the Thromde, to calculate the approximate amount of Green House Gases emitted in the landfill and to propose a suitable well engineered landfill design to manage bio-degradable and non-degradable waste at the site. And also to recommend approaches to manage and reduce the waste at grass root level within the Thromde.

The approach for this study and the data collection protocols are reflected in the methodology.

Figure 1: Matanga Landfill (October,2019)

1.2 Aim

To study waste management approaches in Samdrup Jongkhar Thromde and to workout sustainable approaches to safely manage and reduce waste at sources and the Landfill.

1.3 Objectives

1. To study and interpret the effect of solid waste mismanagement at landfill.
2. To forecast the total amount of Solid Waste (dry and wet) generated within Thromde.
3. To deduce an approximate amount of Green House Gases emission from the landfill.
4. To perform feasibility study and propose a suitable engineered landfill design to manage bio-degradable and non-degradable waste at the site.
5. To recommend befitting approaches to reduce and manage the waste to our community partners and Jigme Namgyel Engineering College.

1.4 Expected outcomes

1. To understand solid waste mismanagement and related effects to the environment.
2. To know the GHG emission and calculate the amount of methane emitted from the landfill.
3. To derive feasible and sustainable waste management approaches.
4. Management of bio-degradable and non-degradable waste at the site by proposing suitable landfill design.

1.5 Problem Statement

1. The waste at sources are poorly managed with almost zero segregation.
2. The landfill waste contributes in emission of greenhouse gases such as carbon dioxide and methane.
3. The current landfill lacks facilities for treatment of the leachate as well as the management of bio-degradable and non-degradable waste.
4. Current landfill is overflowing with waste and the area needs to be augmented to control the waste coming in from the Thromde.

Literature Review

Rapid urbanization and population growth together with inadequate detailed and accurate data on quantity and composition of waste are exacerbating the problem of MSWM in many developing countries. The commonly practiced MSW management option in many other developing countries basically involves the collection of mixed waste materials and subsequent dumping at designated dump sites (K.A.Ayuba, L.A.Manaf, A.H. Sabrina, S.W.N.Azmin, 2013). It is not a practice to separate waste materials at the source or any point during its management in many developing countries (Patrick Aanlamenga Bowan, Sam Kayaga, Julie Fisher, 2020).

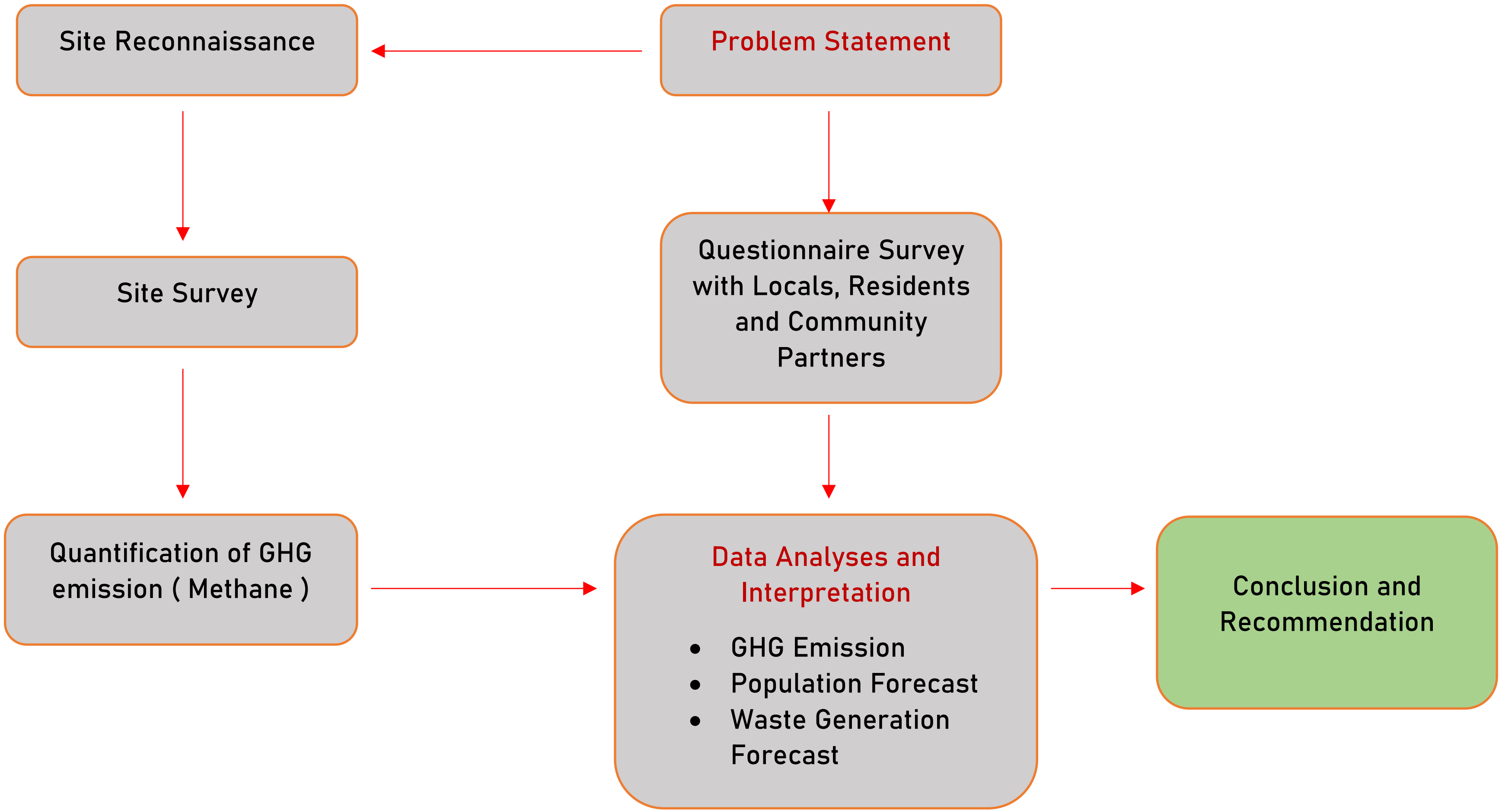
Solid waste management has become one of a major concern in environmental issues (Mazzanti & Zoboli, 2008). According to the most recent United Nations estimates elaborated by worldometer, the current world population is 7.7 billion as of September 2019 and it is estimated that almost half of this population lives in urban areas. Waste generation increase proportionally to this population number and income, creating the needs of effective management (Mazzanti & Zoboli, 2008). Urbanization and industrialization lead to new lifestyles and behavior which also affects waste composition from mainly organic to synthetic material that last longer ssuch as plastics and other packaging material (Idris et al., 2004). E-waste that barely existed before was generated as much as 20-50 metric tons a year (United Nations Environment Programme, 2006).

According to the recent draft report, Bhutan produces 861 MT of waste in a week. This brings the per capita waste generation to 0.17 kg a day (Kuensel, 2019). Thimphu's only land fill in Memelakha collects around 40.3 metric tons (MT) of waste daily and the dry waste segregation site in Babesa collects around 20-25 MT of waste daily (Business Bhutan, 2019). In Matanga landfill, MSW stream generally consist of bottles, plastics, paper, textile, metal, and glass. The waste inventory of Samdrup Jongkhar Thromde (2018) indicates that Throde generates about 364.23MT of solid waste (SW) per year, of which 56.95% is dry waste and 43.05% is wet waste made up of predominantly organic compostable, such as food, yard, and wood wastes.

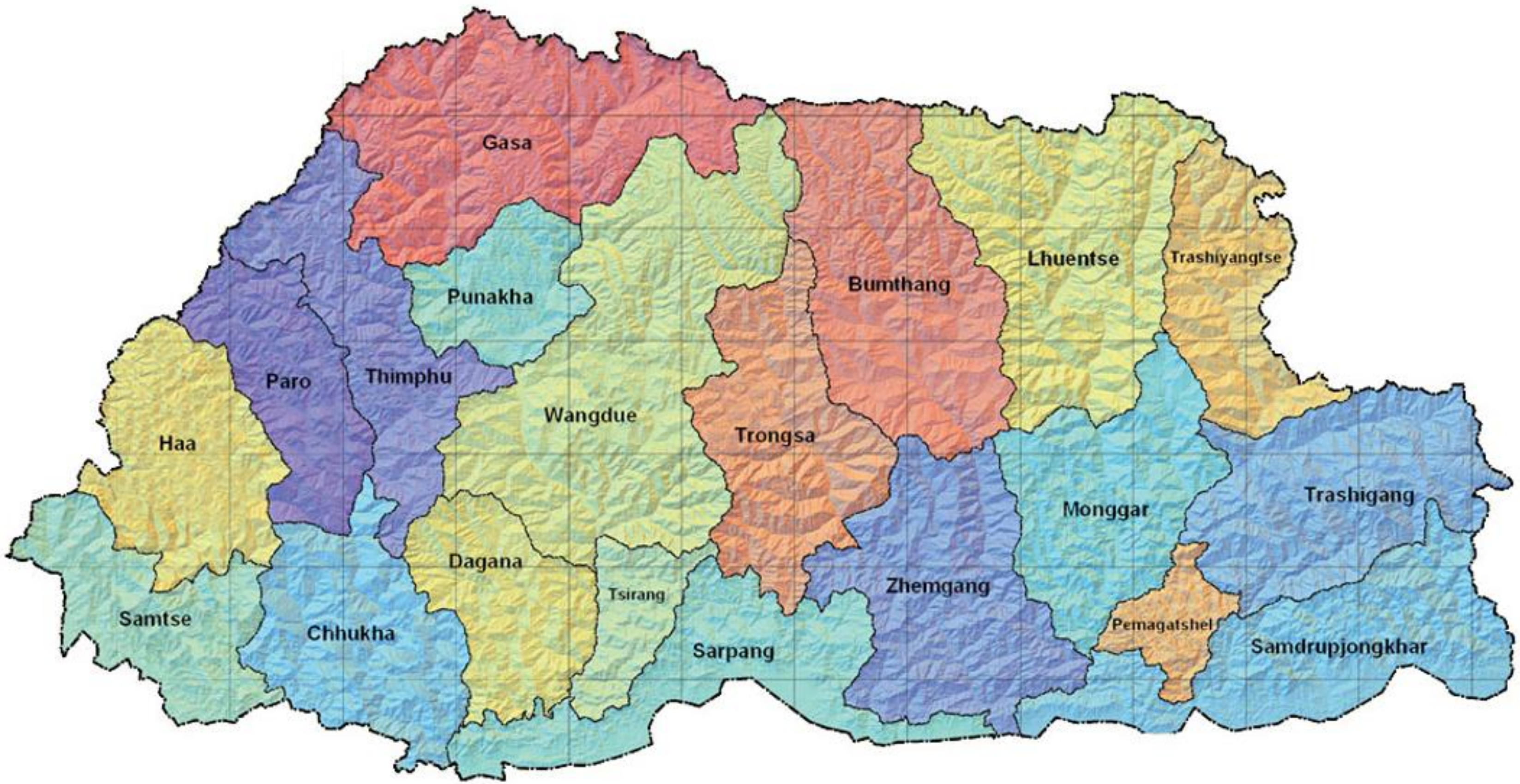
Adding moisture to the waste in a suitably designed and operated landfill should increase its degradation, leading to less risk and a move towards sustainability. Adding air along with moisture in a bioreactor system holds further promise as various laboratory, pilot- and field-scale projects have demonstrated. Aerobic conditions can lead to lower leachate treatment costs, reduced methane gas and less odor (Waste Management World, 2019). At solid waste disposal sites (SWDS) the degradable organic carbon in waste is decomposed by bacteria under anaerobic conditions into methane (CH_4) and other compounds. The methane emissions from SWDS are important contributors of global anthropogenic methane emissions (National Greenhouse Gas Inventories)

Waste collection, processing and final disposal still represent a problem in many low-middle income regions (Vaccari, V. Torretta, C. Collivignarelli, 2012) . This is due to waste management multi-factorial issues which involved technical, environmental, financial, socio cultural, institutional, legal frameworks and tourism, which are not fully considered in such emerging countries (V. Martinez-Sanchez, M.A. Kromann, T.F. Astrup, 2015). As a result, where public awareness and municipal solid waste (MSW) services miss, people burry or burn their own waste or an informal recycling sector start to operate within the area, like only feasible activity for poor households for receiving an income (. R.M. Atencio Pérez, J.A. Reyes-López, J.A. Guevara-García, 2013).

Methodology



Study Area



Source: https://www.vidiani.com

5.1 Study Area

3.1.1 About landfill

The land fill is located at Matanga which is approximately about 3km away from the Samdrup Jongkhar town. Initially it was constructed in the year 2012 with an expenditure of Nu. 6.1 million covering an area of 20,000 square feet. The landfill was built to suffice the need of waste disposal for 10 years but within a span of 6 years, the landfill had reached its brim. So, a new landfill was constructed adjacent to the current site but after using it for three months the new landfill started sinking and was even damaged away by a landslide. So, the thromde had no other option but to reuse the current landfill for dumping.

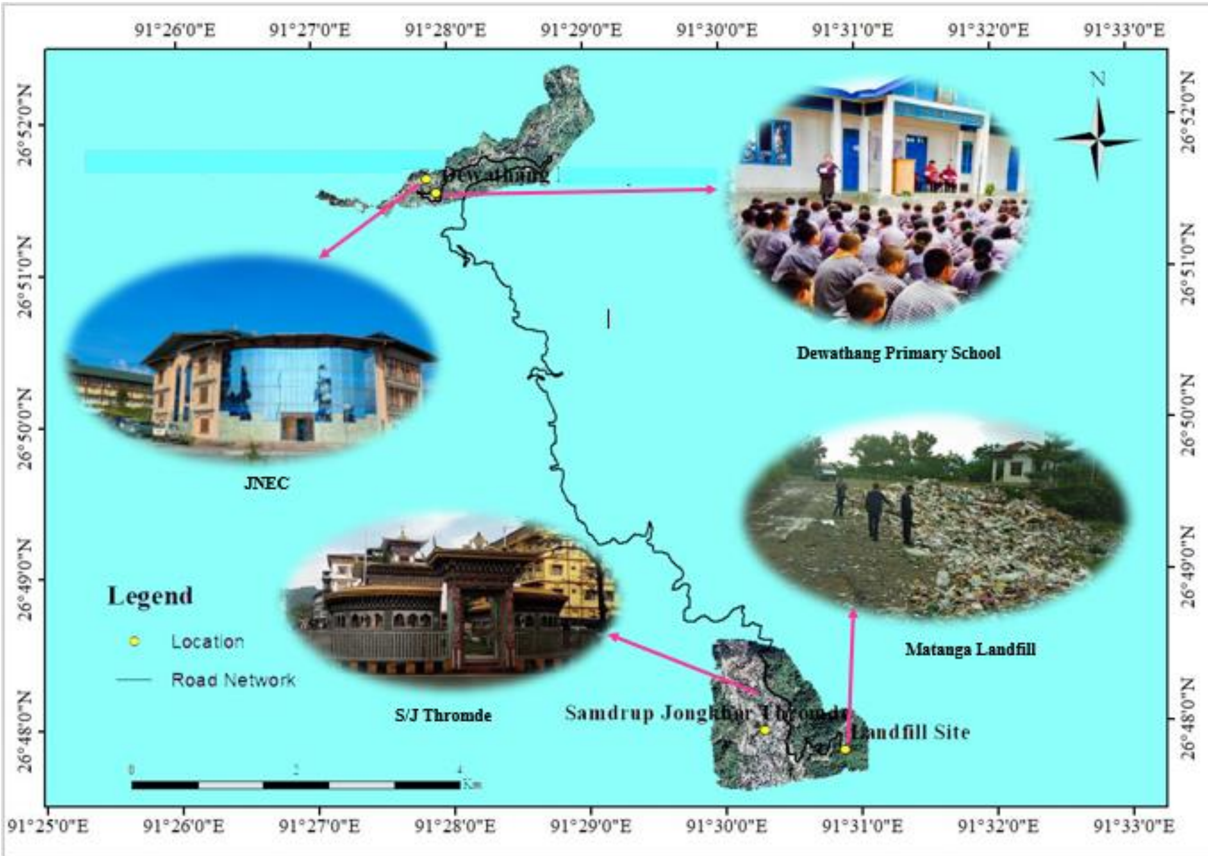


Figure 2: Study Area Map

5.1.1 Management of waste in landfill

There are two workers at the landfill. Their main job is to manage the solid waste and segregate the waste but the segregation is all about picking up of stones and woods amongst the dumped waste. Those waste which can be sold to scrap dealers are segregated and collected by locals from the border area of India.

They have a compost pit, for now they just collect biodegradable waste and dumped it there. Due to lack of expertise, the compost is poor managed and mentored by the administration. However, Thromde is planning to improve the compost and subsequently use the compost as manure.

Collection system

Waste collection is carried out door-to-door with different collection schedules for core town, residential areas and Dewathang areas. The Thromde send trucks to collect the waste every day in Samdrup Jongkhar town and twice a week in Dewathang.

Figure 3: Collection and disposal of waste.

5.1.2 Transportation

Thromde provides their own vehicles for the transportation of municipal solid waste and private vehicles are not used. These vehicles use good covering on the waste to prevent bad smell and flying of waste during transportation. Presently, Thromde uses two compactor trucks and a tractor for collection and transportation of the waste from collection point to the landfill site.

5.1.3 Types of waste dumped

The waste includes both the degradable and non-degradable waste and those which can be recycled such as plastic bottles, metals, cartoon boxes, etc., are segregated at the landfill by the workers.

The waste generated from the hospital are packed in a red and green plastics bags which is a degradable plastic bag. In red plastics, it includes such as used needle and syringes, chemical waste, pharmaceutical waste, etc., which are hazardous to health and green plastic bags contains such as papers, plastics, bottles, etc.

(a) (b)

Figure 4: Hospital Waste Segregated as Non-Hazardous (a) and Hazardous Waste (b)

Solid Waste: Solid waste is defined as, "any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations and from community activities." Example of solid wastes includes the following materials when discarded:

- Waste tires
- Seepage
- Scrap metal
- Latex paints
- Furniture and toys
- Garbage
- Appliances and vehicle parts
- Oil and anti-freeze
- Empty aerosol cans, paint cans and compressed gas cylinders
- Construction and demolition debris, asbestos

Waste Management

Mismanagement of solid waste is seriously spoiling the environmental conditions in developing countries. Negative environmental impacts from improper solid waste dumping can be easily observed everywhere in the developing countries. Similarly, in Samdrup Jongkhar, due to a lack of proper planning, the solid waste management scenario is very bad. To highlight the main causes of improper solid waste Samdrup Jongkhar landfill is taken as a case study. Improper solid waste landfill can be prone to different diseases in and around the study area. It was investigated during the research that due to growth in population, increments in solid waste generation, management deficiencies, lack of legislative implementation and funding, the solid waste management system of Samdrup Jongkhar is not working effectively. The major causes for the inefficient municipal solid waste management systems are the unintended invasion of the city, severe weather conditions, lack of social awareness/community involvement, improper resources including improper equipment and lack of funds. An inefficient municipal solid waste management system may create serious negative environmental impacts like infectious diseases, land and water pollution, obstruction of drains and loss of biodiversity.

4.1 Effects of solid waste mismanagements

4.1.1 Soil contamination:

Soil contamination is one of the main problems caused by improper waste removal and disposal. Some wastes that end up in landfills excrete hazardous chemicals that leak into the soil. Take the case of plastic bottles. When they eventually break down, they release DEHA (Diethyl hydroxylamine), a carcinogen that affects our reproduction systems, causes liver dysfunction, and weight loss. Soil contamination does not only affect plant growth, it is also unhealthy to humans and animals feeding on those plants.

It is therefore important that every household takes recycling to heart. Plastics, metals, paper, and electronic wastes can be recycled at your local recycling centres. If everyone takes time to segregate and sort their recyclable wastes and bring them to recycling centres, the bulk of waste can be removed from the landfills.

4.1.2 Air contamination:

Waste that contains hazardous chemicals, such as bleach and acids, needs to be disposed of properly. Some papers and plastics are burned in landfills, emitting gas and chemicals that hurt the ozone layer. Waste that releases dioxins are also dangerous and pose a health risk when they diffuse into the air that we breathe.

Finally, landfill gas produced by the decomposing wastes, can be hazardous and can harm nearby communities

4.1.3 Water contamination:

Hazardous wastes in the environment leech into the ground, and ultimately, into ground water. This water is used for many things, from watering the local fields to drinking. Toxic liquid chemicals from waste can also seep into water streams and bodies of water.

Untreated sewage can threaten marine life that comes into contact with the contaminated water. Contaminated water is also dangerous and harmful to humans who consume fish and other marine life.

4.1.4 Impact on environment and marine life:

Improper disposal of waste has many effects from visual effect and animals likewise suffer the effects of pollution caused by improperly disposed wastes and rubbish. Cigarette butts have been known to cause deaths in marine animals who consume them. Animals who consume grasses near contaminated areas or landfills are also at risk of poisoning due to the toxins that seep into the soil.

4.1.5 Disease-carrying pests:

Mosquitoes and rats are known to live and breed in sewage areas, and both are known to carry life-threatening diseases. Mosquitoes breed in cans and tires that collect water, and can carry diseases such as malaria and dengue. Rats find food and shelter in landfills and sewage, and they can carry diseases such as leptospirosis and salmonellosis. Moreover, moisture production from waste is a breeding ground for mould. It's bacteria that has the ability to spread and grow given the appropriate conditions, such as moisture production from appliances and food scraps.

4.1.6 Causes extreme climate changes:

Decomposing waste emits gases that rise to the atmosphere and trap heat. Greenhouse gases are one of the major culprits behind the extreme weather changes that the world is experiencing. From extremely strong storms and typhoons to smouldering heat, people are experiencing and suffering the negative effects of greenhouse gases.

4.2 The need to manage solid waste

Waste management is important because improperly stored refuse can cause health, safety, environment and economic problems. All living organisms create waste, but humans create far more waste than other species. To prevent damaging the ecosystems and maintain a high quality of life for the planet's inhabitants, humans must manage and store their waste efficiently and safely. Human beings have been practicing primitive waste management techniques for thousands of years. Early humans simply dug a hole and buried their refuse and trash. This was an effective technique for these early people because their population was relatively small, and they did not produce as much garbage as modern humans do. Burying the trash helps to prevent bugs and rodents from becoming a nuisance and spreading diseases.

At present, human cannot simply bury their trash. While primitive humans produced very little waste, and that which was produced would biodegrade quickly, modern humans produce large amounts of waste, much of which is not biodegradable. Additionally, many types of garbage may be damaging to the soil, ground water and surrounding habitat. To overcome this problem, modern well engineered landfill is being implemented in the developed countries around the world.

4.3 Waste Generation in Samdrup Jongkhar Thromde

4.3.1 Current Status of waste generation.

The Thromde survey consisting of residential area, core town and Dewathang has been conducted for the solid waste collection frequency from the public's opinion. From the core town and residential areas in Samdrup Jongkhar, the frequency of waste collection is daily whereas in Dewathang it is twice a week.

4.3.1 Data Collection

The method adopted for future prediction of Solid waste Management System comprises of four stages

1. First stage included the study of land use for the Thromde
2. Second stage followed with collection of inventory data in the form of maps and details from Thromde. In the present study, survey has been carried out in the month of March, 2020 in the Matanga and Samdrup Jongkhar Thromde. Subsequently, current scenario of solid waste system has been studied.
3. Third stage consists of analysis and calculation of solid waste generations and landfill site for future requirements.
4. In the fourth stage, proposal has been made for well-engineered landfill design to be used in Matanga and also in places that are major generator of the waste (example JNEC) in the Thromde.

4.3.2 Municipal Solid Waste (MSW) Generation

Samdrup Jongkhar Thromde is the forefront of various chemicals, steel and gypsum industries with small and medium scale. At present the solid waste is disposed in the conventional method of dumping in Matanga landfill that is located about 3km from the main town. However, Thromde do not have facilities of proper sanitary landfill site and currently one temporary site of 20,000 square feet over an existing landfill site is being used. The facilities of solid waste collection and disposal are managed by Thromde Municipality in and around the town area covering Dewathang (JNEC included).

Existing waste generation scenario according to waste inventory 2018 is as follows.

Table 1: Daily waste generation of S/Jongkhar Thromde

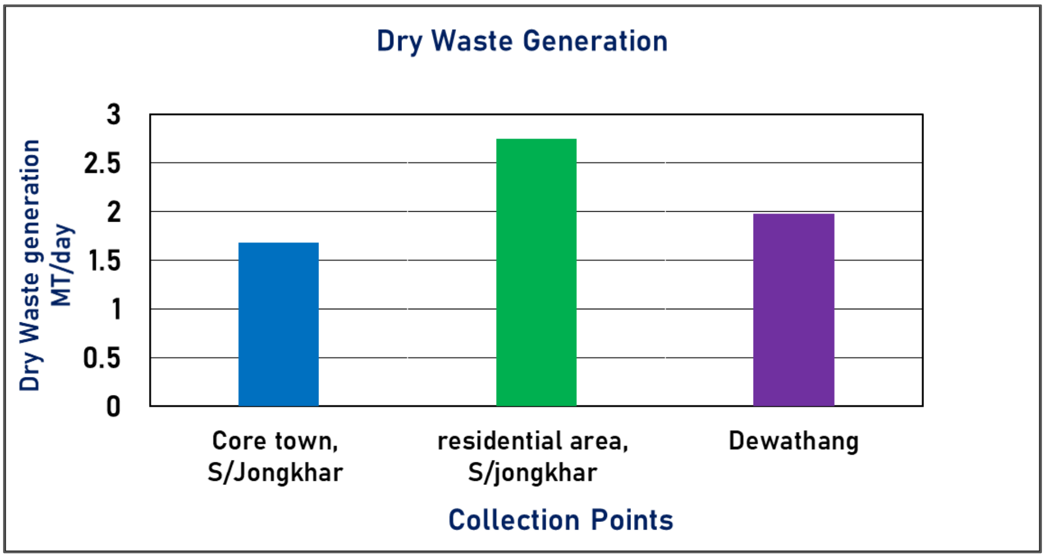
Daily wet waste generation	
1	S/Jongkhar = 4.34 MT/day
2	Dewathang = 0.44 MT/day
S/Jongkhar Thromde Daily wet waste generation = 4.78 MT/day	
Daily dry waste generation	
1	S/Jongkhar = 4.43 MT/day
2	Dewathang = 1.98 MT/day
S/Jongkhar Thromde Daily dry waste generation = 6.41MT/day	

Waste generation based on type of waste from different collection points are as follows.

1. Dry waste generation

Table 2: Daily Dry Waste Generation.

Place	MT/day
core town, S/Jongkhar	1.68
residential area, S/Jongkhar	2.75
Dewathang	1.98

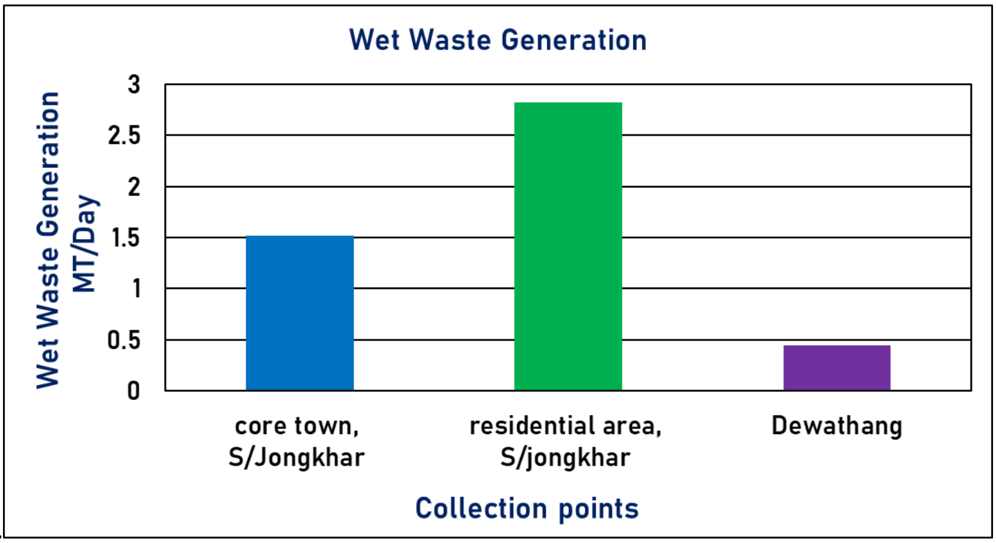


Graph 1: Dry Waste generation as per collection points

2. Wet waste generation

Table 3: Daily Wet Waste generation

Place	MT/day
core town, S/Jongkhar	1.52
Residential area, S/Jongkhar	2.82
Dewathang	0.44



Graph 2: Wet Waste generation as per collection points

4.3.3 Computation of Municipal Solid Waste Generation

In order to calculate the projected waste generation, we first need to forecast the population of Samdrup Jongkhar Thromde. To design a sustainable landfill, we need to know the population during that period so that the landfill can be used without being full before the designed period.

1. Population forecasting of Samdrup Jongkhar Thromde

Population in the year 2020 of Samdrup Jongkhar Thromde is 10545

According to UN World population Prospects (2019 revision) Bhutan's population growth rate as of 2020 is 1.12%

Population is projected using the Exponential formula given below

$$P_n = P_o \text{ x } e^{rt} \tag{1}$$

Where,

P_n= number of populations in n years

P_o= present population

r= Growth rate

t= time period

Population of Samdrup Jongkhar Thromde after one year

$$P_{2021} = P_{2020} \times e^{rt}$$

$$= 10545 \times e^{0.0112 \times 1}$$

=10,664

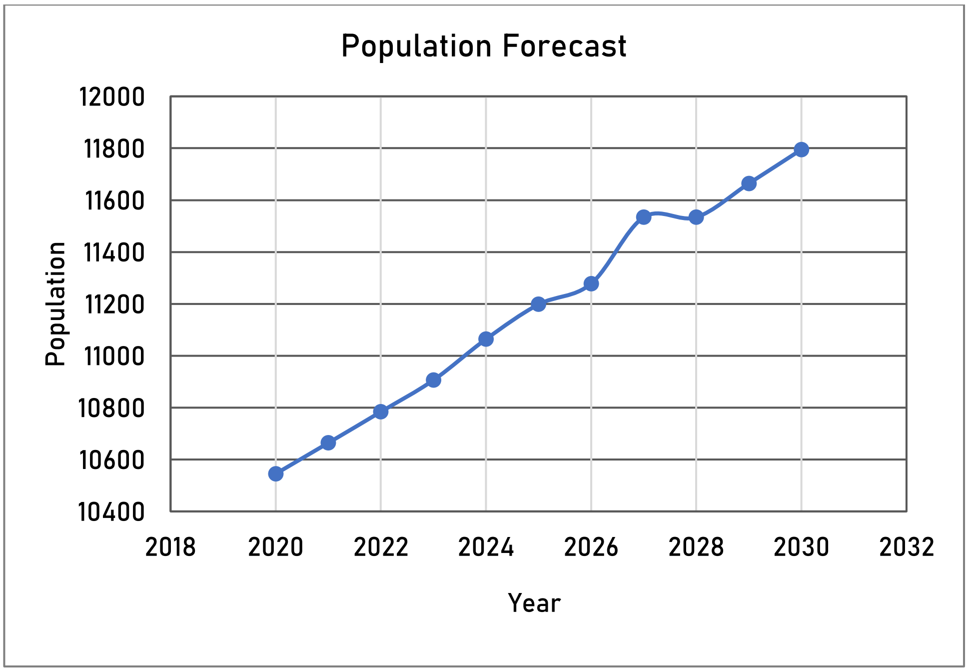
Population after 10 years

$$P_{2030} = 10545 \times e^{0.0112 \times 10}$$

= 11,795

Table 4. Population projection of Samdrup Jongkhar Thromde till year 2030

Year	Population	Year	Population
2020	10545	2026	11278
2021	10664	2027	11534
2022	10784	2028	11534
2023	10906	2029	11664
2024	11064	2030	11795
2025	11198		



Graph 3: Population of Samdrup Jongkhar Thromde 2020-2030

2. Waste Generation Forecasting

Waste generation was calculated using the population of the Thromde. However, the waste is separated as wet and dry.

A. Dry Waste generation

We are using the rapid method (Waste Management and Research, 1986) for estimating waste generation rate per capita. Formula for this method is given below.

$$\text{Waste generation rate} = \frac{\text{total amount of waste generated per day}}{\text{population present in the area}} \quad (2)$$

$$= \frac{6.41}{10545}$$

= 0.607kg/capita/day

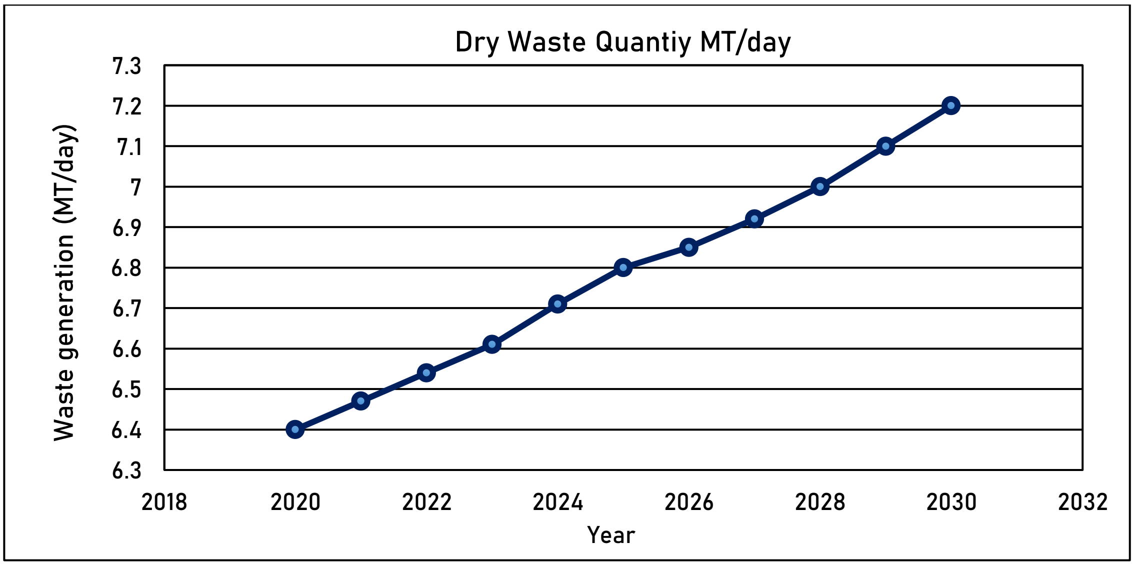
Total waste generation per day= Total population × waste generation rate

For the year 2030 waste generation per day will be about= 11,795×0.607

= 7.2 MT/day

Table 5: Projected Dry Waste Generation per day by the year 2030

Year	Population	Waste Generation Rate per Capita (Kg/c/day)	Waste Quantity MT/day
2020	10545	0.607	6.4
2021	10664	0.607	6.47
2022	10784	0.607	6.54
2023	10906	0.607	6.61
2024	11064	0.607	6.71
2025	11198	0.607	6.8
2026	11278	0.607	6.85
2027	11405	0.607	6.92
2028	11534	0.607	7
2029	11664	0.607	7.1
2030	11795	0.607	7.2



Graph 4: Dry Waste Projection till year 2030

B. Wet waste generation

$$\text{Waste generation rate} = \frac{\text{total amount of waste generated per day}}{\text{population present in the area}}$$

$$= \frac{4.78}{10545}$$

= 0.45kg/capita/day

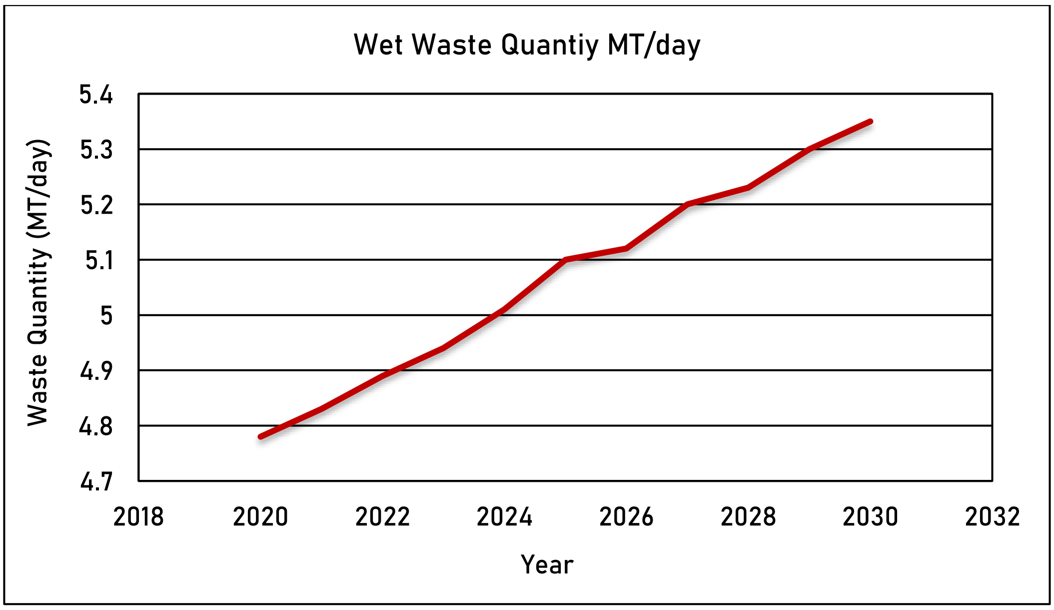
Total waste generation per day= Total population × waste generation rate

For the year 20230 waste generation per day will be about= 11795×0.45

= 5.35MT/day

Table 6: Daily Wet Waste Generation Projection till the year 2030.

Year	Population	Waste generation rate per capita (Kg/c/day)	Waste Quantity MT/day
2020	10545	0.453	4.78
2021	10664	0.453	4.83
2022	10784	0.453	4.89
2023	10906	0.453	4.94
2024	11064	0.453	5.01
2025	11198	0.453	5.1
2026	11278	0.453	5.12
2027	11405	0.453	5.2
2028	11534	0.453	5.23
2029	11664	0.453	5.3
2030	11795	0.453	5.35



Graph 5: Wet Waste Projection till year 2030

4.3.4 Analysis from Waste Projection

From the above data and graphs, it is observed that there is increase in daily wet waste generation from 4.78MT/day in 2018 to 5.35MT/day in 2030. And that of daily dry waste generation from 6.41MT/day in 2018 to 7.20MT/day in 2030.

Although the increase in daily waste generation is not that large, if we can manage the bio-degradable and non-degradable waste from the grassroot level by segregation and other means, there will be lesser effects on the environment as well as in and around the landfill. As per Thromde, Jigme Namgyel Engineering College is among the major waste generator of waste which means if we manage the waste at the grassroot level, the waste at the landfill site will be reduced.

As per the study, if we construct a compost pile for bio-degradable waste in JNEC itself then the waste quantity in the Matanga landfill will be reduced. For better waste segregation at sources, a garbage shed can be constructed within JNEC as well for areas where proper waste collection points have not been specified. Furthermore, an indoor composter for people of Dewathang can be proposed to curb the bio degradable waste.

If the waste generation is well taken care at the grass root level, it will be convenient for the Thromde in proper management of the waste.

4.4 JNEC - Biodegradable Waste Generation

JNEC generates highest amount waste per day. As per the calculations, biodegradable waste of 103 kg per day is generated by 286 students residing in self-catering hostels. The proposal and designing of compost pile in JNEC will be benefitting the student community. It has lots of advantages from visual effect to the reduction of waste going to the landfill.

4.4.1 Capacity of compost pile

The compost pile consists of three compartments and it aims to produce the manure at the end of three months. Each compartment of Compost pit was designed for the waste of $2m^3$ produced by the total population of 286 self-catering student in a month.

Therefore, from above data, the capacity of compartment of the compost brings to $2m^3$.

4.4.2 Calculation of capacity compost pile

Total number of self-catering blocks= 6 blocks and each block is of 3 storeys

Each storey has two kitchens with one bucket for degradable waste.

Therefore, total number of Buckets= 6 x 3x 2=36 buckets

Weekly every common room kitchen produces two buckets of biodegradable waste so, in a week total number biodegradable waste collected is 36x2= 72 buckets

Taking the average bucket capacity of 5.8 litres

There in a week amount of biodegradable waste produced=72x5.8=420L=420 kg/week

Daily biodegradable waste produced in Self-catering blocks= $\frac{420}{7}$ = 60 kg per day

Total biodegradable waste produced in a month = 60x30=1800 kg per month

Taking this quantity of biodegradable waste generation in Self-catering blocks, the compost pile is being designed.

4.4.3 Working of compost pile

The waste produced in the campus is put in the first compartment for whole month. The other two compartments are used to transfer the waste from the first compartment for the well mixing and to provide oxygen for better decomposition after first compartment is full. After second month it is transferred to third compartment and new waste is stored in first compartment simultaneously. After third the manure will be ready to use as fertilizer. This process will be continuous.

Figure 5: Recycling of Biodegradable waste (IMGBIN, n.d.)

4.4.4 Steps by step process of making rich organic fertilizer.

Foundation layer

Put the dry plants material such as small tree branches, maize stalks or sorghum stalks. Cut the plant material into small pieces. Spread the dry material evenly over the bottom of the trench to make a layer of 15-25cm. Sprinkle with water using a watering can or basin to ensure all material is moist but not wet.

Layer 1:

In this layer, put dry plant material such as grass, dry leaves mixed with top soil, manure and ashes. The layer should be about 20-25 cm thick (as thick as the palm of your hand). Mix the material with soil, manure and ashes and sprinkle water to make it moist.

Layer 2:

Make another layer of moist (green) material which is fresh or wilted such as weeds or grass cuttings, stems and vegetable leaves, tree branch leaves, damaged fruits, or vegetables or even kitchen waste. Do not sprinkle water in this layer. But you can spread it to remain even or flat.

Layer 3:

This layer should be composed of animal manure collected from fresh or dried cow dung, chicken waste, donkey manure and sheep or goat droppings. The animal manure can be mixed with soil, old compost and some ashes to make a layer that is 5 -10 cm thick. If the manure is not adequate, make a watery mixture and spread it over as a thin layer about 1-2cm thick.

Covering layer

The finished heap has to be protected from the sun or animals or anything that might interrupt with the mix. We can prepare wet mud mixed with grass or straw, or with wide pumpkin leaves, banana leaves or plastic polyethylene sheets. The cover should be sealed with only the ventilation stick (also called thermometer stick).

Turning the compost

After three months, you can open up the compost heap mixing all the layers while sprinkling water to make it moist but not wet.

Check the decomposition progress

Using the ventilation or temperature stick, you can keep on checking the decomposition process of your compost every week by pulling out the stick. If it has a white substance on it and has a bad smell, it means the decomposition is not going on well. You can turn the compost further and sprinkle some more water to make it moist.

Check if compost is ready

A mature compost heap is about the half the size of the original heap. Check to ensure the compost has a dark brown colour or black soil, which has a nice smell. All the original material should not be seen if the decomposition process went on well.

Working of Compost Pile

It is filled with fresh waste and carefully mixed green and brown waste thoroughly and kept

Compartment 1

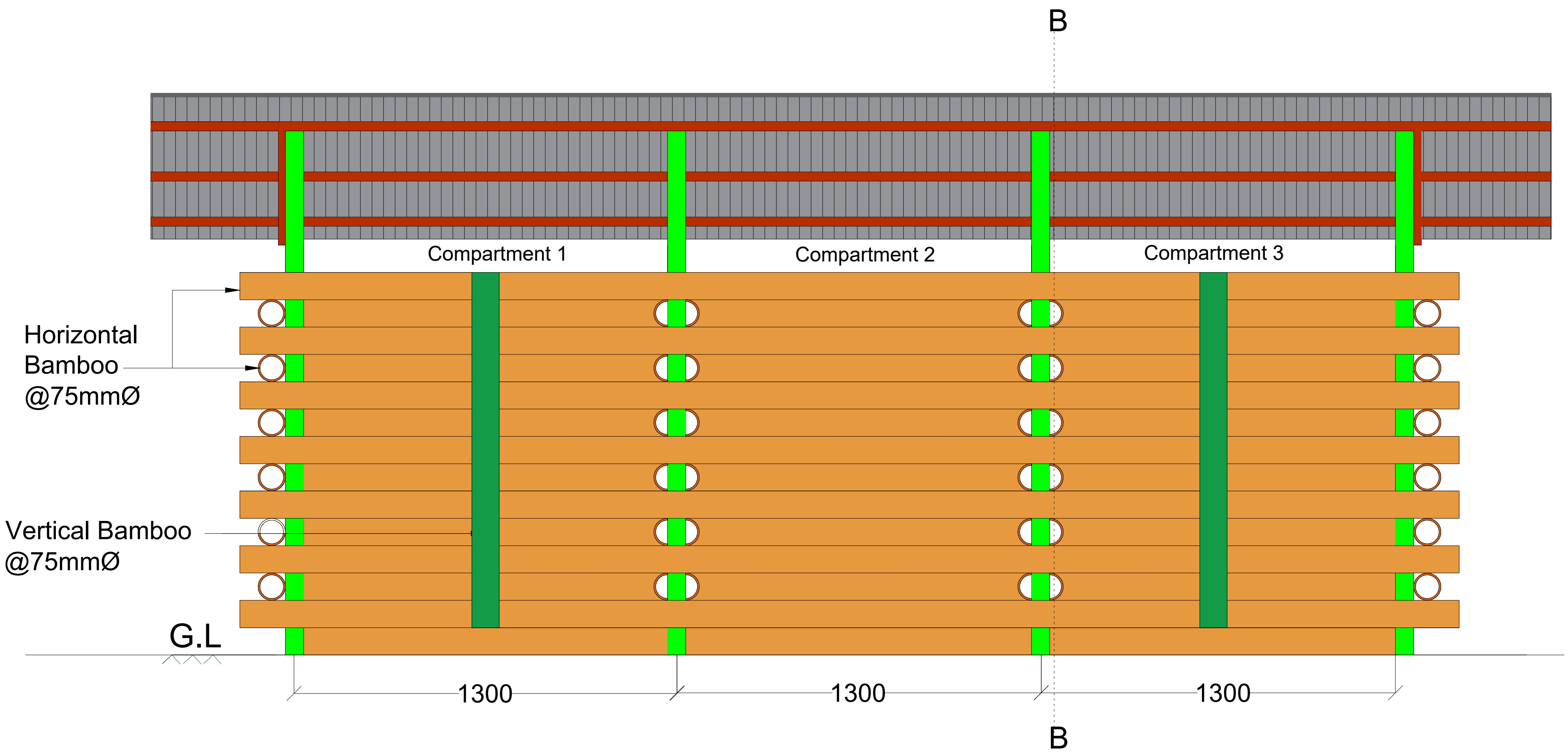
When first compartment is full, it is transferred in second chamber to accelerate composting by providing ventilation

Compartment 2

After another month the content of second compartment is shifted to third. At the end of third month compost is ready for the use.

Compartment 3

Manure can be used for flower gardening as well as for kitchen gardens.



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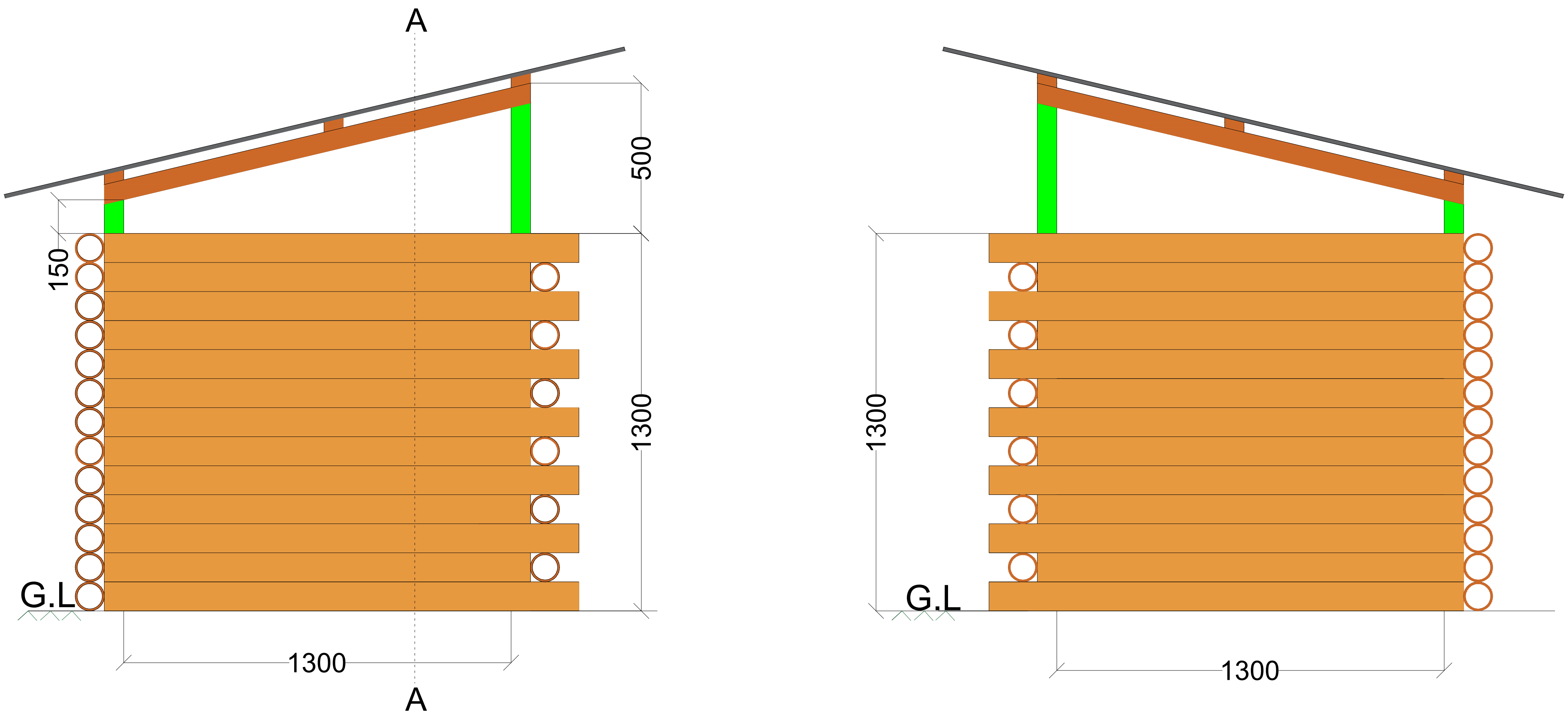
TITLE: FRONT ELEVATION	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			



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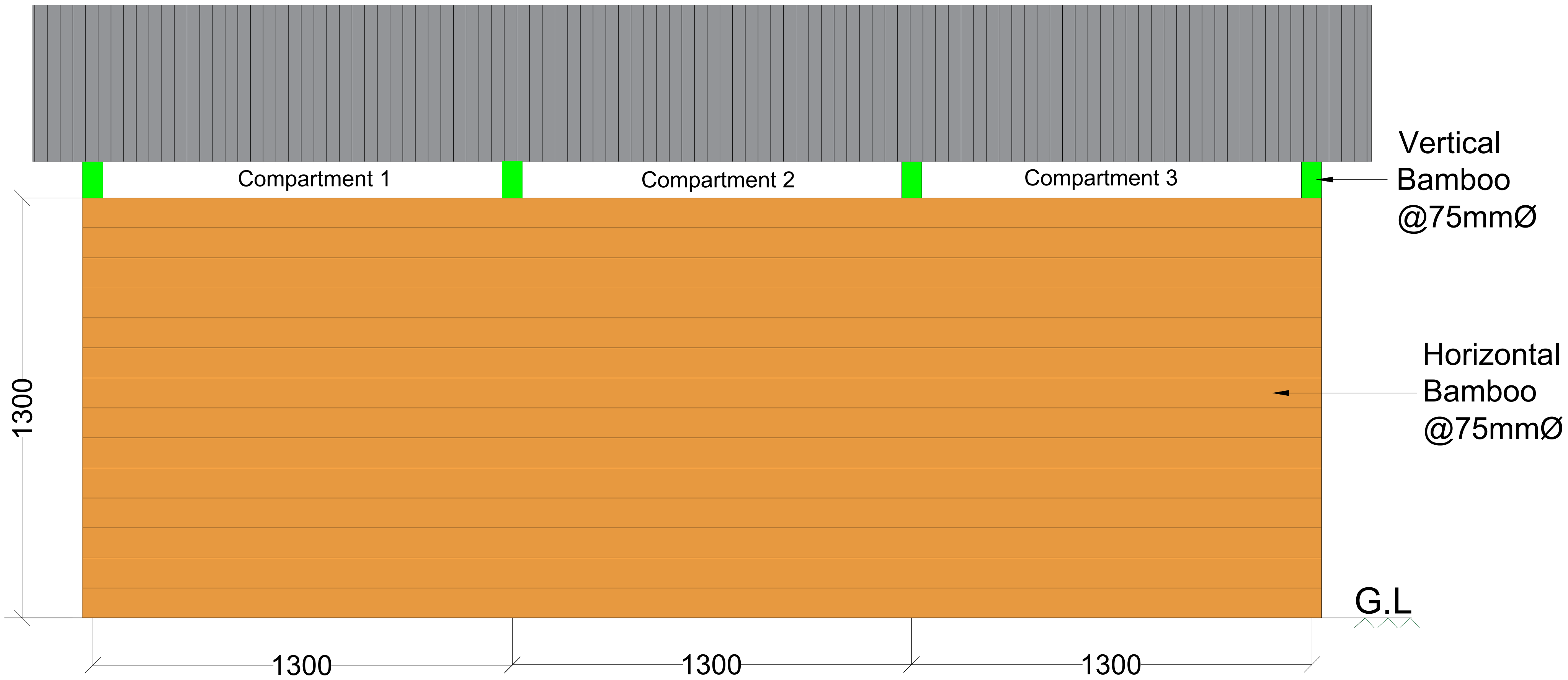
TITLE: SIDE ELEVATION	LOCATION: JNEC
GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING	
JIGME NAMGYEL ENGINEERING COLLEGE	



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TITLE: BACK ELEVATION	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
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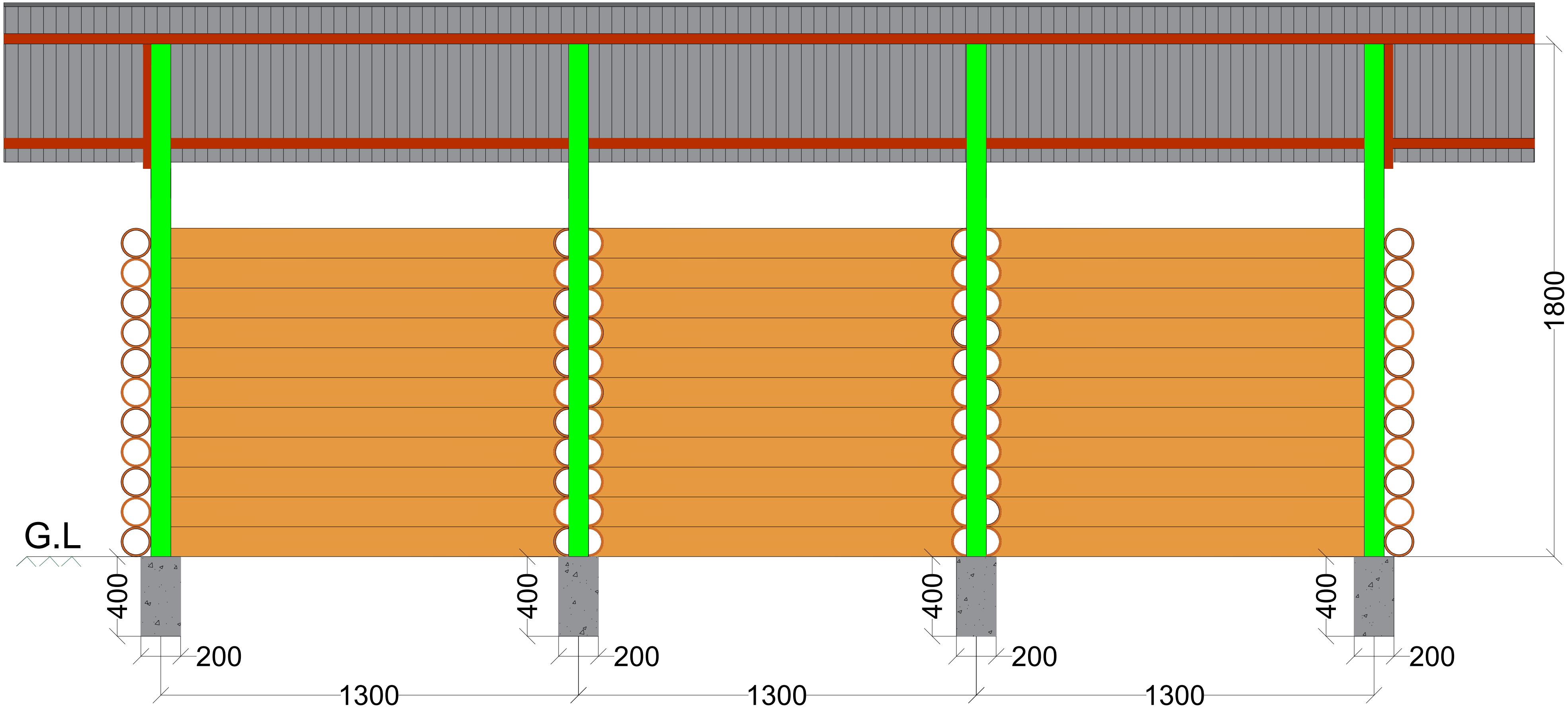

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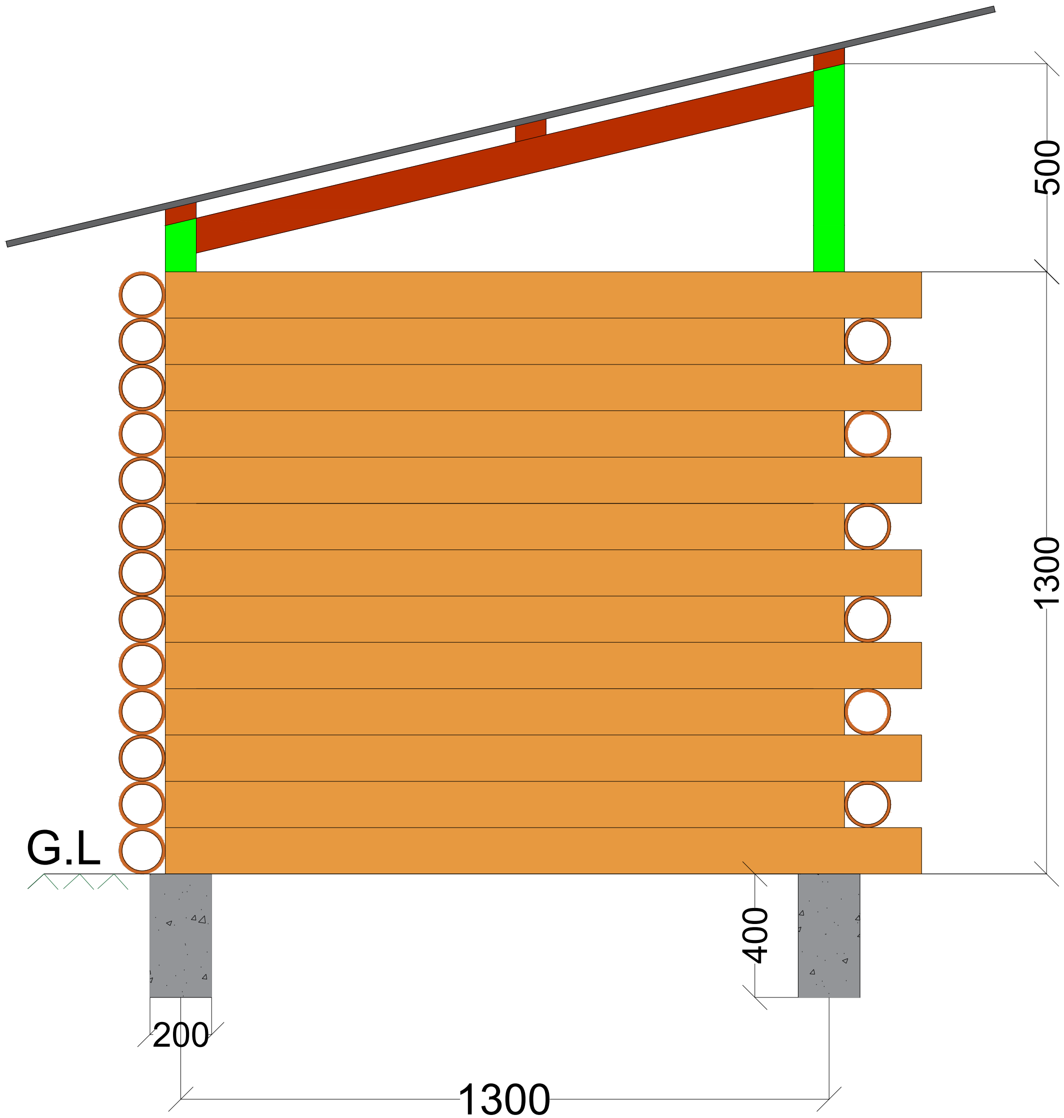
PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY

TITLE: SECTION A-A	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS

DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING

JIGME NAMGYEL ENGINEERING COLLEGE



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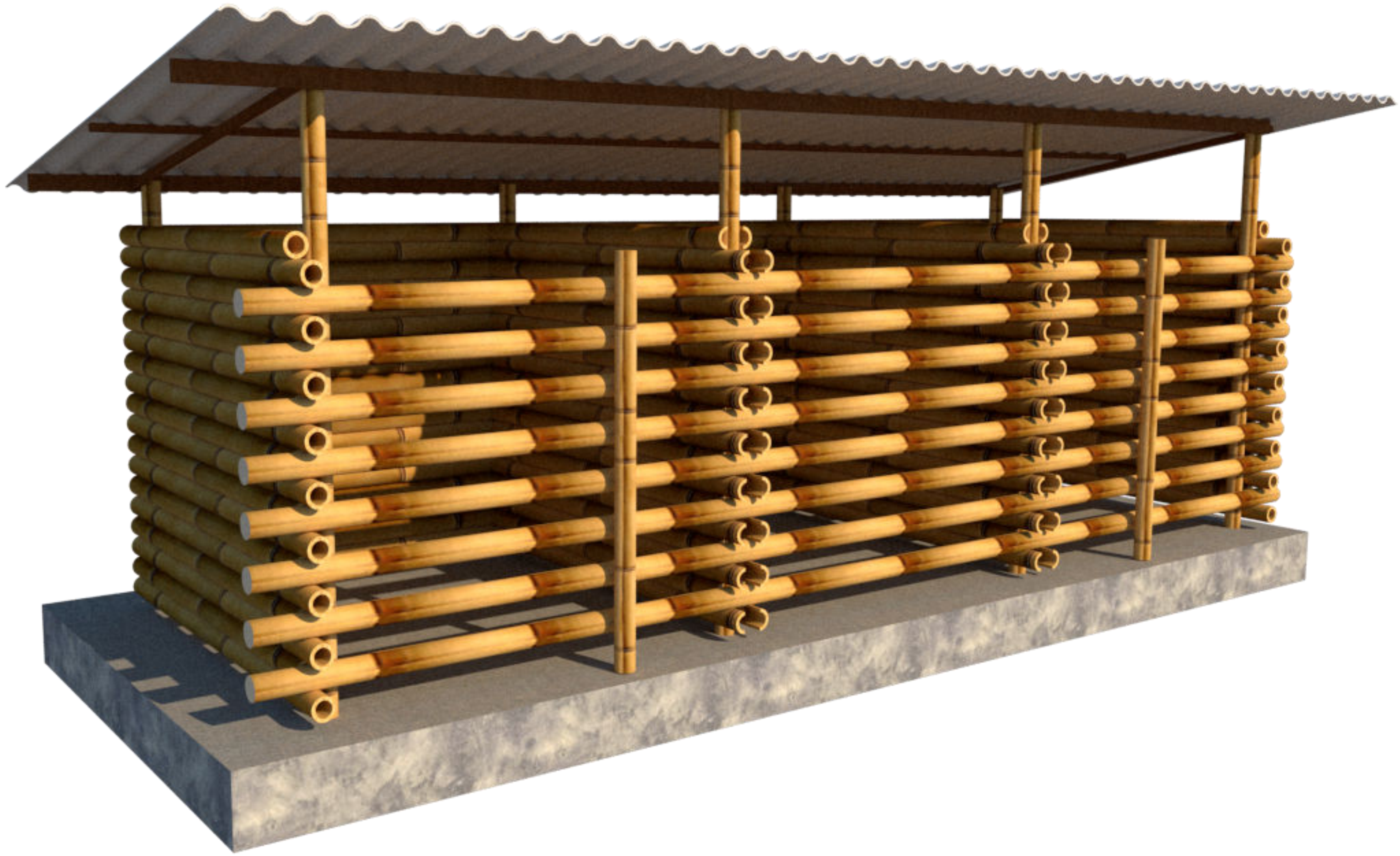
PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: SECTION B-B	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			



PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN: A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: ISOMETRIC VIEW	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			

4.5 Indoor Composter

Figure 6: Sample Design of Indoor Composter. (Things, n.d.)

Portable compost bins simply serve to temporarily confine a pile. When it is time to turn the pile or withdraw finished compost from the bottom, the bin is taken and set up in an adjacent location in the yard. The partially composted material from the top of the old pile is then forked over into the empty bin, leaving the finished compost at the bottom for removal and use.

Portable compost bins can be made from old wooden pallets lashed together or a roll of wire or snow fencing. This particular version is made from hardware cloth stretched at the bottom.

Transform all food waste (including cooked food, meat, fish and cheese) into a super healthy, nutrient rich compost with the help of this small and compact system in your kitchen or home - no smells, no flies.

Indoor composting is one of the most effective methods of recycling kitchen organic waste. It is carried out in an air tight container using Bokashi, leaves, sawdust, straw or shredded newspaper to exclude fruit flies and as a compost activator. Bokashi is a Japanese term meaning “Fermented Organic Matter”. It is a bran-based material that has been fermented with effective microorganisms (friendly bacteria) and dried for storage. Bokashi, a pleasant-smelling product, when added to your bucket aids the fermentation of organic matter. Bokashi is made using a combination of sawdust and bran (hard outer layers of cereal grain) that has been inoculated with the microorganisms. It takes about ten days to do its work, and in the end, it is left with nutrient rich liquid compost. The liquid produce is perfect for natural garden organic fertilization. (eco, n.d.)

The fermentation process does not produce adverse smells so you can keep the bucket under the sink or anywhere in the home. And once treated in the Kitchen Composter, the material can be safely dug into your garden or placed in your compost bin. It can hold more than 15 liters (4 gallons) of organic kitchen scraps

Instructions for Use:

Simply put your cooked and uncooked food scraps into the composter

Spray 2-3 sprays(bokashi) on top of the food waste at the end of the day

Press the material down using the compactor

Keep the lid shut at all times. This is an anaerobic composting system-the less air the better

Drain any excess liquid produced at the base of the composter as often as possible.

Once the bucket is filled to the capacity, transfer the waste to your garden, compost bin or planter for. further breakdown. In the garden dig a hole or trench and bury the compost. Wait two weeks before planting.

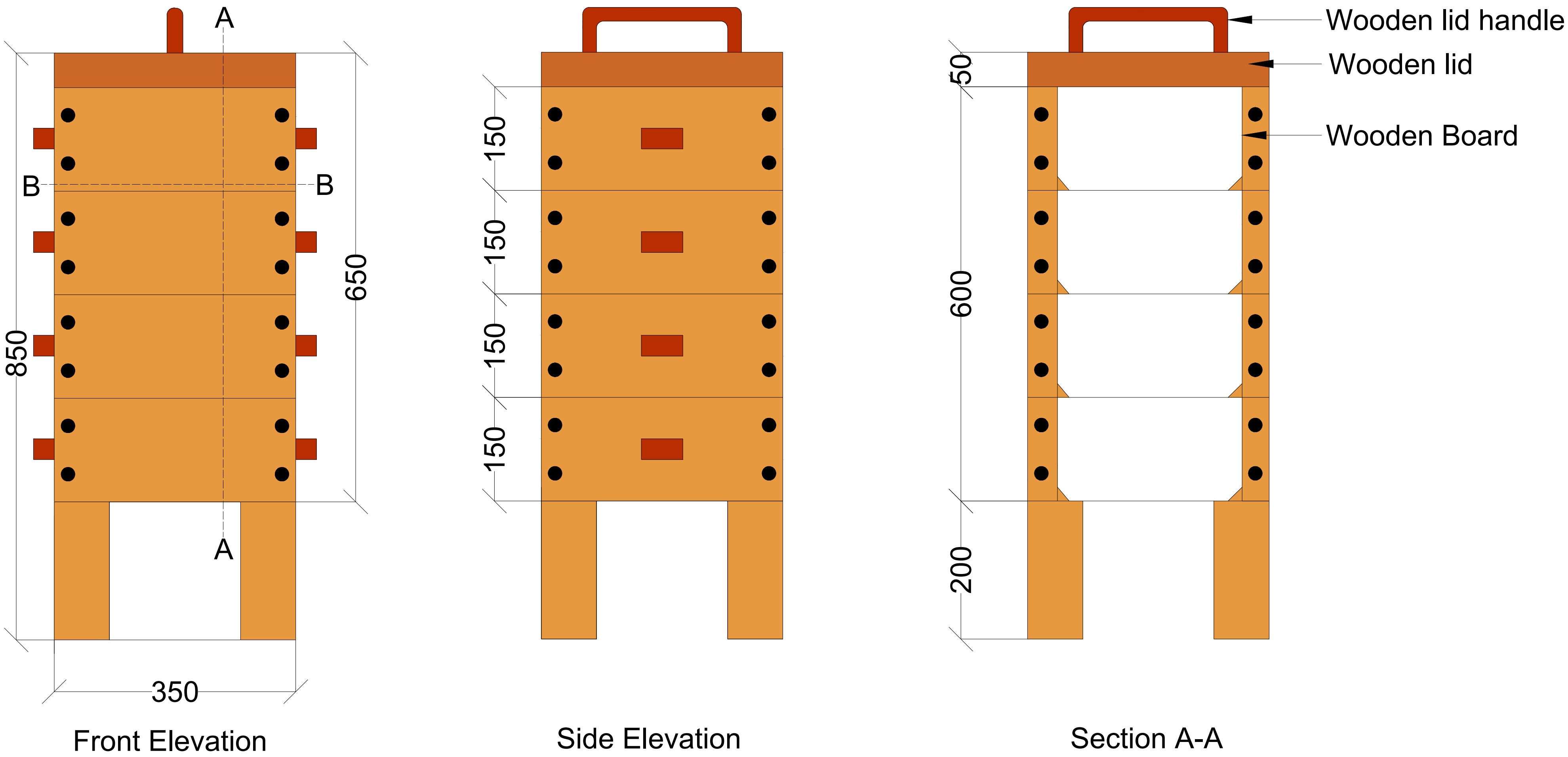
4.5.1 Benefits:

- 100% organic waste recycling. Cooked and uncooked food (including meat, fish, fruit and vegetables) may be safely composted in a home compost bin when done so using the Indoor Composter system.
- Small Shape; compact for the kitchen.
- No smells because friendly safe bacteria are used.
  - ✓ No fruit flies because the process does not require air.
  - ✓ Reduces greenhouse gas emissions.

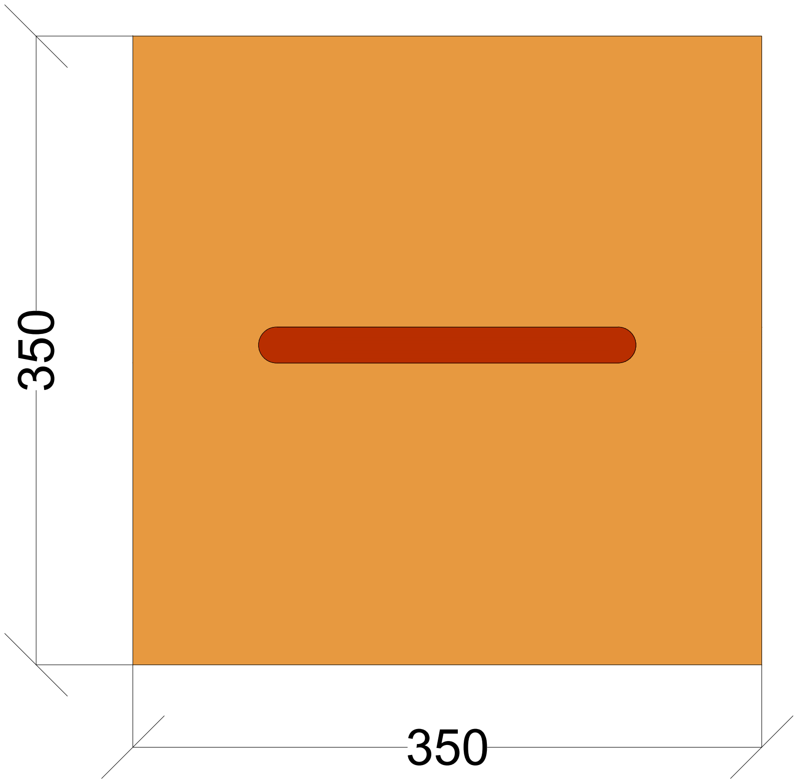
- ✓ Rebuilds the soil in your garden and decontaminates soil from harmful pathogens/pollutants.
- ✓ Releases a nutrient rich liquid that can be used as fertilizer. (Maze, n.d.)

4.5.2 List of Materials:

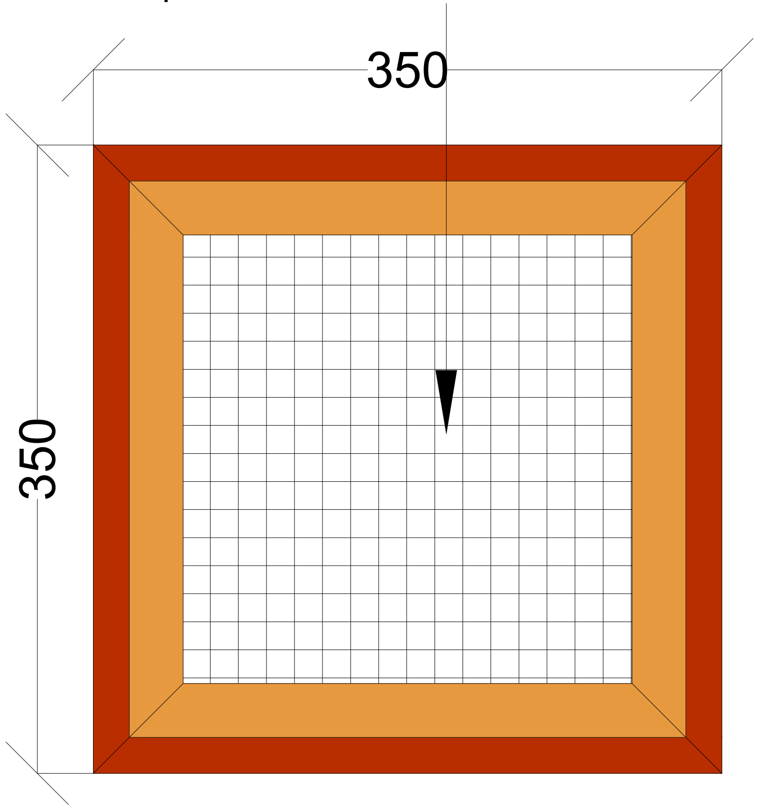
- ¼" mesh hardware cloth.
- Wooden Boards/ Plane wood.
- Wood Screws
- Waterproof wood glue.
- Penny galvanized nails.



PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: PORTABLE COMPOST	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			



Top Elevation



Section B-B

PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: PORTABLE COMPOST	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			

	PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN: A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
	TITLE: PORTABLE COMPOSE BIN	LOCATION: JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
	DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
	JIGME NAMGYEL ENGINEERING COLLEGE			

Landfill Green House Gases Emission

When solid waste (SW) is disposed in waste dumps and landfills, most of the organic material will be degraded over a longer or shorter period, ranging in a wide span from less than one year to 100 years or more. The majority of this process will be bio-degradation. Strongly depending on conditions in the site where the SW is disposed, this biodegradation will be aerobic or anaerobic. The main degradation products are carbon dioxide (CO_2), water and heat for the aerobic process and methane (CH_4) and carbon dioxide CO_2 for the anaerobic process. The CH_4 produced and released to the atmosphere contributes to global warming and the emissions need to be estimated and reported in national greenhouse gas inventories under the United Nations' Framework Convention of Climate Change (UNFCCC). The CO_2 produced originates from biogenic sources (example: food, garden, paper and wood waste) and the emissions need therefore not be considered in national inventories.

5.1 The impact of landfill gases

The environmental impact of gaseous emission from landfills, which are of global or regional significance, can be mainly grouped as contribution to the greenhouse effect and damage to the eco system. Apart from that, risk of explosion and odour problem due to some trace gases can also be identified as significant impacts. Gaseous pollutants have significant effects on plants, animals and entire eco systems. The lateral migration of gas through soil beyond landfill boundaries causes the displacement of oxygen from soil. This results in a decline in soil faunal populations and burrowing animals and causes vegetation dieback. Mainly the vegetation around the landfill and the newly planted vegetation on a closed landfill can be damaged due to the suppression of air around the roots by migrated landfill gas. The acidic gaseous constituents contribute to the phenomenon of acid rains and its secondary effects on the acidification of soils and ecosystems. Ammonia is a major acidic constituent which can be found in the landfill gas. It is a secondary acidifying agent following its atmospheric oxidation to nitric acid. It has effects on plants, causing a loss of stomatal control, a reduction in photosynthesis, enzyme, inhibition, changes in synthetic pathways and depressed growth and yield. (Nelen, 2012).

5.1.1 Type of waste that emits GHG

Organic Waste

When organic waste decomposes, carbon dioxide and methane gas is created. Methane is created when there is no air present while carbon dioxide is the natural product when anything rots in air. Both carbon dioxide and methane are greenhouse gases, which contribute to global warming and climate change.

Inorganic Waste

Inorganic waste does not contribute directly to greenhouse gas emissions, unless it is incinerated. However, it does represent greenhouse gases emitted previously during the manufacturing process. All manufactured goods use natural resources such as water, fuel, metal, timber in their production and this results in the emission of greenhouse gases, particularly carbon dioxide and other pollutants.

Thus, rubbish sent to a dumpsite or landfill represents a significant amount of greenhouse gases already emitted to the atmosphere and have contributed to climate change.

5.2 Deducing approximate amount of GHG emissions from Landfill

For the calculation of CH_4 emission the IPCC Guidelines describe two main methods:

(A): The default IPCC methodology that is based on the theoretical gas yield (a mass balance equation).

(B): Theoretical first order kinetic methodologies, through which the IPCC Guidelines introduces the "First order decay model" (FOD).

The second equation, i.e. Theoretical first order decay methodologies. The formulae are:

EQUATION 1 $Q = L_o x\ R\ x\ (e^{-kc} - e^{-kt})$

EQUATION 2 $Q_{T,x} = k\ x\ R_x x\ L_o x\ e^{-k(T-x)}$

EQUATION 3 $Q_T = \sum Q_{T,x}$ for x = initial year to T

Among the above three formula, the second equation is used depending on the data collected.

$$Q_{T,x} = k\ x\ R_x x\ L_o x\ e^{-k(T-x)}$$

Where,

$Q_{T,x}$: the amount of methane generated in year T by the waste R_x (Mg)

x: the year of waste input

R_x : the amount of waste disposed in year x (Mg)

T: current year

K= methane generation rate constant (This factor is depending on waste composition and site conditions, and describes the rate of the degradation process. A very wide range of values between 0.005 and 0.4 is given for k in the IPCC Guidelines.)

L_o = methane generation potential (A range between less than 100 m3/Mg SW and more than 200 m^3/Mg SW is presented in the IPCC Guidelines. No basis for this range is presented, no default values given or the conditions that influence the factor mentioned. However, this factor depends on the DOC and DOCF and the conditions at the SWDS as in the default method.

From the following data,

x= 2012

R_x = 364.23MT ($3.6423 x 10^{14}$Mg)

T= 2020

k= 0.05

L_o = 150 m^3/Mg (< 100 m^3/Mg or > 200 m^3/Mg)

$Q_{T,x}$ =0.05 x 3.6423x10^{14} x 150 x $e^{-0.05(2020-2012)}$

=1.831 x 10^{15} Mg = 1831MT

5.1.2 Result and Conclusion

The quantification of methane gases is estimated to be 1831 MT from the Matanga which has an area of almost 1858.06 m^2. Although comparing to other countries the methane emission from Matanga landfill (1831MT-2018) is comparatively less but we should also know that the landfill is not properly designed and have so many drawbacks which means we should know that methane emission can increase in future. Therefore, we all need to be aware of solid waste mismanagement and reconsider the designs of the landfill.

Landfill

6.1 Types of Landfill

There are currently three standard landfill types:

1. Municipal Solid Waste

In this type of landfill the municipal waste that are everyday used item that are discarded by the public. It includes both dry waste and the wet waste.

2. Industrial Waste Landfill

In this waste landfill the industrial wastes are disposed off. The waste materials include construction material such as concrete, bricks, asphalt, gypsum, etc. The reusable materials are bought by local people or business.

3. Hazardous Waste Landfills

This waste landfill is the closely regulated and structured landfills, specially designed to hold hazardous waste in a way that virtually eliminates the chance of it being released into the environment.

6.2 Leachate

A leachate is the liquid that drains or leaches out from a landfill. It is a mixture of organic degradation products, liquid waste and rain water. It has high organic carbon content, high concentrations of nitrogen and is usually slight acidic. The leachate varies widely in composition regarding the age of the landfill and the type of waste that it contains. It usually contains both suspended and dissolved materials.

No matter how hard landfill designers and operators try to avoid generating waste, through waste reduction, re-use, recycling, composting. Not to mention the many other methods of waste pre-treatment prior to landfilling. Landfilling will continue for many years yet, and thus leachate generation and its safe disposal without causing pollution, is a problem which is here to stay. Even if all the landfills could be closed, and the creation of new leachate from rainfall on open landfill phase surfaces, could be stopped today, there would still be need to manage leachate from both the present and old closed landfills. (Landfill Leachate Treatment Expert).

General characteristics of Landfill Leachate

The characterization of leachate varies with regard to its composition, volume and biodegradable matter present in the leachate. The leachate composition can vary depending on several factors; including the degree of compaction, waste composition, climate and moisture content (S.M.Ragbah, Ahmed M. Abd El Meguid, Hala A. Hagezi, 2013).

There are many factors affecting the quality of leachate, i.e., age, precipitation, seasonal weather variation, waste type and composition (depending on the standard of living of the surrounding population, structure of the tip). In particular, the composition of landfill leachates varies greatly depending on the age of the landfill. In young landfills, containing large amounts of biodegradable organic matter, a rapid anaerobic fermentation takes place, resulting in volatile fatty acids as the main fermentation products.

The early phase of a landfill's lifetime is called the acidogenic phase, and leads to the release of large quantities of free volatile fatty acids, as much as 95% of the organic content. As a landfill matures, the methanogenic phase occurs. Methanogenic microorganisms develop in the waste, and the volatile fatty acids are converted to biogas. The organic fraction in the leachate becomes dominated by refractory (non-biodegradable) compounds (Environmental Technologies, 2008). The characteristics of the landfill leachate can usually be represented by the basic such as:

1. Chemical Oxygen Demand (COD)
2. Biochemical Oxygen Demand (BOD)
3. The ratio of BOD/COD
4. pH
5. Suspended solids (SS)
6. Ammonium nitrogen (NH_3-N)

6.2.1 Impacts of Leachate

The dark liquid that drains out from the landfill contains organic and inorganic chemicals, heavy metals as well as pathogens; it can pollute the groundwater and therefore represents a health risk (Osterath, 2010). Its composition varies both from time to time and from site to site which makes it difficult to treat the liquid in right way. The leachate composition can vary depending on several factors, including the degree of compaction, climate and moisture content in the waste.

The leaching of waste, biodegradable waste, heavy metals, and other landfill waste, the soil and the ground water becomes contaminated. The main pollutants of landfills are organic residues acting on biochemical processes. In addition to large quantities of dissolved organic carbon leachate contains salts, ammonium, and specific organic compounds as well as the heavy metals and metalloids (Vodyanitskii, 2016).

Water soluble pollutants from municipal landfills can be divided into four groups according to (T.H. Christensen, P. KJeldsen, et al, 1994):

1. Water-soluble and oxidized by oxygen, organic substances including methane and volatile fatty acids.
2. Inorganic macro organisms components: Calcium, magnesium, sodium, potassium, iron, chlorine, sulphuric acid.
3. Heavy metals: cadmium, chromium, copper, lead, nickel, zinc.
4. Organic xenobiotics, falling from household and industrial chemicals.

Effects on soil

Soil contamination by leachate particularly by heavy metal content is most important considerations to be made throughout the industrialized world. The heavy metal pollution not only results in adverse effects on various parameters relating to plant quality and yields but also cause the changes in size, composition and activity of the micro-organisms community. Therefore, heavy metals are considered as one of the major sources of soil pollution (Jiwan Singh, Ajay S. Kalamdhad, 2011) .

Effects on Water

The leachate that drains out with content of various chemicals and heavy metals are highly persistent, toxic in trace amounts, and can potentially induce severe oxidative stress in aquatic organisms. Moreover, metals not being subjected to degradation it remains permanently in the environment (Woo S., Yum S., Park H.S., Lee T.K., Ryu J.C, 2009). Contamination of river with heavy metal content of leachate causes devastating effects on the ecological balance of the aquatic environment, and the diversity of the environment becomes limited with extent of the contamination. This contamination of the ground water and other sources of water near the landfill site will impose high health risk to the people living nearby and also the animals.

6.2.2 Leachate Treatment

Many different methods are currently in use to treat the landfill leachate. Most of these methods are adapted for waste water treatment processing and can be divided into two main categories: biological treatments and physical/chemical treatments (S.M.Ragbah, Ahmed M. Abd El Meguid, Hala A. Hagezi, 2013)

1. Aerobic Biological Treatment such as aerated lagoons and activated sludge.
2. Anaerobic Biological Treatments such as anaerobic lagoons, reactors.
3. Physiochemical treatments such as air stripping, pH adjustment, chemical precipitation, oxidation, and reduction.
4. Coagulation using lime, alum, ferric chloride and land treatment.
5. Advanced techniques such as carbon adsorption, ion exchange.

However, before treating the leachate, there are few factors that need to be considered (Ana Maria Schiopu, Maria Gavrilescu, 2010):

- Leachate composition, properties and volume.
- Need for leachate storage.
- Local water standards requirement for discharge.
- Technical value, ease of implementation, and cost of effectiveness of technologies.

Treatment Technology

1. Co-Treatment with Municipal Sewage

Leachate collected at the landfill can be treated by combining with municipal sewage at the sewage treatment plant. This method is used for its easy and low-cost operation (Renou, S., Givauda, J.G Poulain, S., Dirassouyan, F., Moulin, P, 2008). However, leachate co-treatment has limitations due to high contaminant load, organics with low biodegradability, and presence of heavy metals (Quasim, S.R, Chiang, W. , 1994), which may lead to reduction in the performance of the sewage treatment plant.

2. Leachate Recirculation

Leachate can be recycled by re-circulating it through the landfill to improve biodegradation and waste stabilization by controlling the moisture content (Renou, S., Givauda, J.G Poulain, S., Dirassouyan, F., Moulin, P, 2008). According to Environmental Protection Agency, 2017 the bioreactor landfill is an enhanced system with controlled leachate collection and injection, which is often supplemented with other liquids to maintain moisture content near field capacity to optimize decomposition.

Advantages of leachate recirculation or bioreactor landfill are increased decomposition rate, lower leachate treatment/disposal costs, and shortened post-closure maintenance period. Disadvantages include increased gas emissions and odors, physical instability of waste mass and surface seeps.

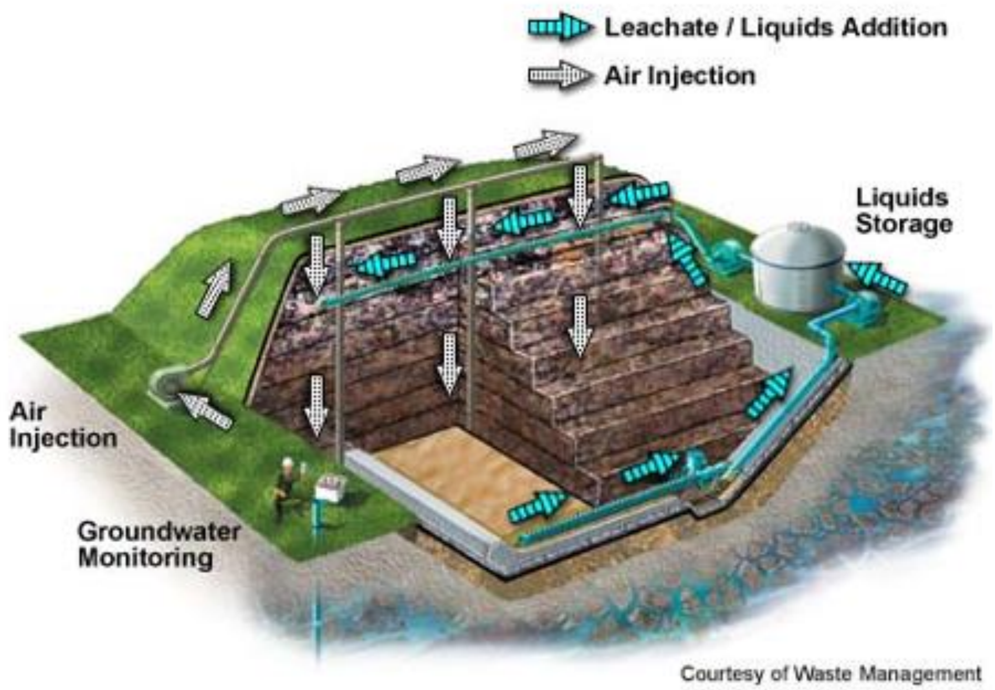


Figure 7: Re-circulation of leachate to landfill (Geo Engineer, 2017)

3. Constructed Wetlands

Another on-site treatment technique is constructed wetland, where leachate is reused as a fertilizer for energy (Justina, M.Z and Zupancic, M, 2009).

The advantages of this method are low construction and operational costs, low power consumption, and high contaminant removal efficiency (D. Bove., Merello, S., Frumento, D., Arni, S. A., Aliakbarain, B., Converti, A, 2015). The disadvantages are space requirement, generation of aerosols, applicability on low volumes only, and difficulty of control.

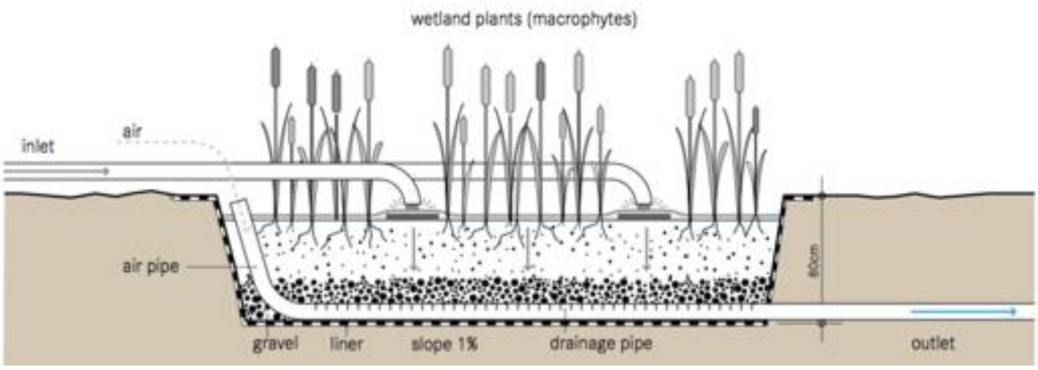


Figure 8: Constructed wetland (Geo Engineer, 2017)

4. Biological Processes

There are many types of biological processes used for leachate treatment, and most of them are applied for wastewater treatment processes (Metcalf & Eddy /Aecom, 2014). Biological treatment is used for its reliability, simplicity, high cost-effectiveness, and its efficiency in removing organic compounds.

5. Aerobic treatment processes

Aerobic treatment processes should allow treating biodegradable organics and nutrients. Unlike anaerobic processes, nitrification (oxidizing ammonium to nitrate) is available in the aerobic processes. The aerobic processes that are based on suspended growth (i.e., activated sludge) have been widely studied and adopted (Lin, S. H., Chang, C.C, 2000). The biological processes with attached growth (bio-film) have recently attracted significant interest: biological aerated filter (BAF), moving-bed bio-film reactor (MBBR) (Renou, S., Givauda, J.G Poulain, S., Dirassouyan, F., Moulin, P, 2008).

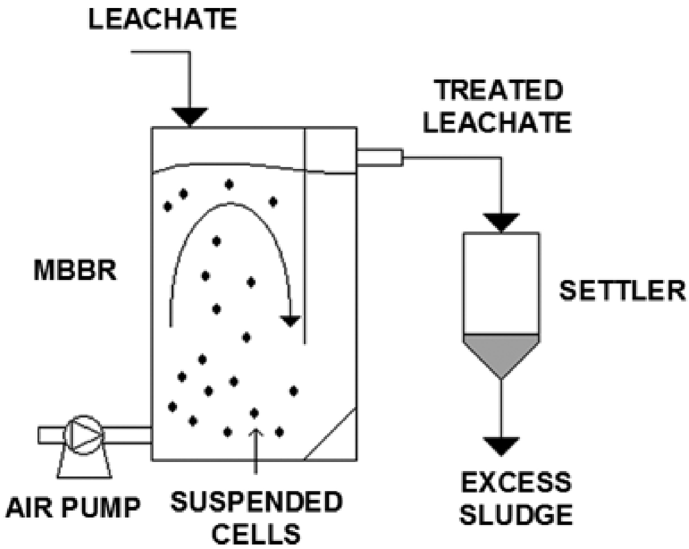


Figure 9: Schematic setup of an aerobic MBBR reactor with suspended cells (Bove et al., 2015)

6. Anaerobic treatment processes

Anaerobic treatment processes are commonly applied and these processes are suitable for dealing with high strength wastewater (Renou, S., Givauda, J.G Poulain, S., Dirassouyan, F., Moulin, P, 2008). Anaerobic digestion conserves energy and produces less sludge compared to aerobic processes with suspended growth. However, anaerobic digestion suffers from low reaction rates. In addition to anaerobic digestion, there are other processes such as up-flow anaerobic sludge blanket reactor and anaerobic filter. Oxidized ammonium and nitrate, can be denitrified to nitrogen gas in anaerobic condition, therefore, aerobic processes and anaerobic processes can be combined for completely treating nitrogen as nutrients.

Figure 10: A small scale anaerobic digester (Agri-Food and Biosciences Institute, 2016)

7. Flocculation-Coagulation

Flocculation is a treatment typically applied to remove non-settleable colloidal solids (such as surfactants, heavy metals, fatty acids and humid acids) using flocculants such as FeCl3 (Torreta, V., Ferronato, N., Katsoyiannis, I.A., Tolkou, A.K., Airoldi, M, 2017), which is more suitable for old and stable leachate. Flocculation is often used upstream of biological treatment or reverse osmosis, or downstream for the purpose of final cleaning. The main coagulants are aluminium sulphate, ferrous sulphate, ferric chloride and chlorine ferric sulphate. Flocculation is suitable for landfill leachate treatment due to its strength against low pH and high organics concentration in the leachate.

However, this treatment presents some disadvantages: consistent sludge volume is produced and an increase in the concentration of aluminium or iron in the liquid phase may be observed.

8. Separation through Membrane Filtration

Membrane separation process is a physical process that can be classified into micro-filtration (MF), ultra-filtration (UF), and nano-filtration (NF) based on the size of the membrane pores (Torreta, V., Ferronato, N., Katsoyiannis, I.A., Tolkou, A.K., Airoldi, M, 2017). Reverse osmosis (RO) is another filtration technology that is driven by inverse pressure across a semi-permeable membrane commonly applied for water desalination or drinking water plants. Membrane separation treatments, especially NF and RO, are very efficient in decreasing the COD, SS, and organics in landfill leachate. The disadvantages of membrane filtration are high pressure requirement leading to high energy consumption and membrane fouling which requires surface cleaning processes.

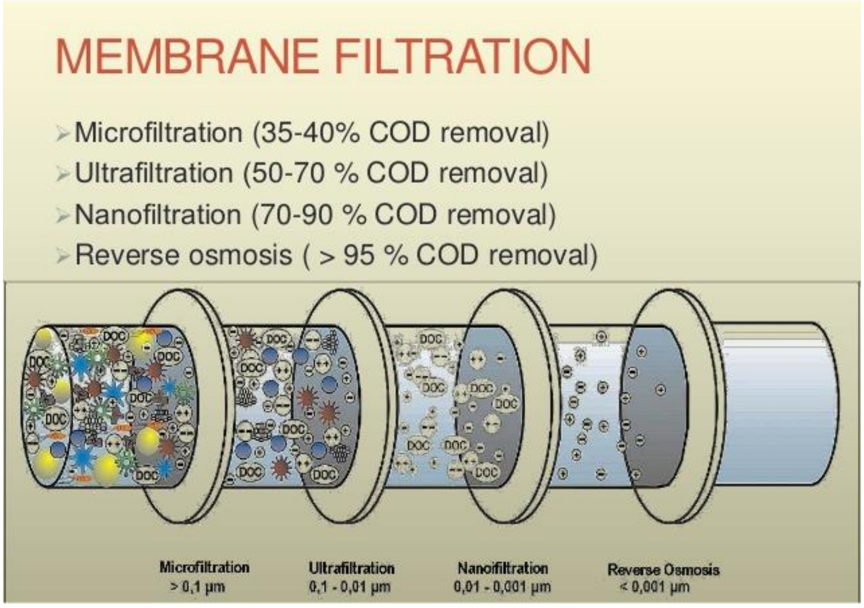


Figure 11: Membrane Filtration (Pravin)

Effectiveness of the treatment technology

1. Depending on the landfill age

Different parameters are needed when selecting leachate treatment method. One of the factors that influence the application of treatment method is the age of landfill. Leachate transfer and biological processes are effective during the young period of landfills, while the efficiency of different physicochemical processes varies. The table below shows the effectiveness of leachate treatment according to landfill age (Geo Engineer, 2017).

Table 7: Effectiveness of the treatment technology depending on the age of landfill.

Treatment Type	**Landfill Age**			**Target of Removal**	**Remark**
	Young (<5years)	Medium (5-10 years)	Old (>10 years)		
Co-Treatment with municipal sewage	Good	Fair	Poor	Suspended solids	Excess biomass and nutrients
Re-circulation	Good	Fair	Poor	Improve leachate quality	Least expensive and low efficiency
Aerobic Processes	Good	Fair	Poor	Suspended solids	Hamper by refractory compound and excess biomass
Anaerobic Processes	Good	Fair	Poor	Suspended solids	Hamper by refractory compound and biogas

Coagulation/Flocculation	Poor	Fair	Fair	Heavy metals and suspended solids.	High sludge production and subsequent disposal
Membrane Filtration: 1-Microfiltration	Poor	-	-	Suspended solids	used after metal precipitation.
2. Ultra-filtration	Poor	-	-	High molecular weight compound s	Costly and limited applicability due to membrane fouling
3. Nano filtration	Good	Good	Good	Sulfate salts, hardness ions	Costly and requires lower pressure.

2. Effectiveness of leachate treatment based on pollutant removal rates

Table 8: Leachate pollutant removal rate (Sustainability, 2016).

Technology	COD	BOD	Heavy Metals	Suspended solids	Turbidity
1. Biological Treatment by lagoons	40	64	-	-	-
2. Constructed Wetlands	50	59	-	-	-
3. Flocculation/Coagulation	79	-	-	90	93
4. Membrane process					
5. Aerobic process	43	-	24	-	-
6. Trickling Filters	80	94	-	-	-

6.3 Landfill and its Components

Solid waste management involves various steps, namely collection, transportation, processing and disposal. Land disposal is the most common method adopted and in most of the developed countries proper landfills exist along with proper construction and maintenance. But in our country, the waste is disposed of in open dumps, which not only leads to severe environmental degradation but also results in loss of natural resources. (Yedla, 2005)

The basic criteria for the landfill design involve the safe disposal of waste. With the rise in waste generation as also availability of proved technology for gas recovery in the developing countries, a new and a modified approach to the design of landfill system with gas recovery has been developed. Unlike developed countries, Bhutan has no landfills but only open dumps. As uncontrolled landfills have shown potential of polluting various parts of the environment, regulations have been imposed on landfill location, site design and their preparation and maintenance. A certain degree of engineering was made mandatory for landfills. Landfill location was based on many factors. Land availability for longer dumping periods and availability of cover material are some of the important guiding parameters in landfill site selection.

Leachate Collection Pool

Leachate can be defined as a liquid that passes through a landfill and has extracted dissolved and suspended matter from it. Leachate results from precipitation entering the landfill from moisture that exists in the waste when it is composed. Leachate generated in municipal landfill contains large amounts of organic and inorganic contaminants. leachate is characterized by high values of COD, pH, ammonia nitrogen and heavy metals, as well as strong color and bad odor. At the same time, the characteristics of the leachate also vary with regard to its composition and volume, and biodegradable matter present in the leachate against time. All these factors make leachate treatment difficult and complicated. (Safaa M.RaghabAhmed M.Abd El MeguidHala A.Hegazi, 2013)

Leachate is liquid generated from rainfall and the natural decomposition of waste that is filtered through the landfill to a leachate collection system. The leachate collection system's job is to direct the leachate to collection pool so it can be properly removed from the landfill. (Austin community landfill, n.d.)

Soak pit

A soak pit, also known as a soak away or leach pit, is a covered, porous-walled chamber that allows water to slowly soak into the ground. Pre-settled effluent (liquid waste or sewage discharge into a river or the sea) from a collection and storage/treatment or (semi-) centralized treatment technology is discharged to the underground chamber from which it infiltrates into the surrounding soil.

If there is no intention or no need to reuse wastewater, soak pits can offer a cost-efficient opportunity for a partial treatment of wastewater from a primary treatment and a relatively safe way of discharging it to the environment and therewith recharging groundwater bodies. As wastewater (greywater or blackwater after primary treatment) percolates through the soil from the soak pit, small particles are filtered out by the soil matrix and organics are digested by microorganisms. The wastewater effluent is absorbed by soil particles and moves both horizontally and vertically through the soil pores.

Sub-soil layers should therefore be water permeable in order to avoid fast saturation. High daily volumes of discharged effluents should be avoided (HEEB et al. 2008). Thus, soak pits are best suited for soil with good absorptive properties; clay, hard packed or rocky soil is not appropriate. Soak pits are used the same way as leach fields, but require less space as well as less operation and maintenance. But they generally can also receive less influent and the groundwater pollution may be higher than with leach fields. (Sustainable Sanitation and water management toolbox, 2019)

Advantages

1. Can be built and repaired with locally available materials
2. Technique simple to apply for all users
3. Small land area is required
4. Low capital costs; low operating costs
5. Recharging groundwater bodies

Disadvantages

1. Primary treatment is required to prevent clogging
2. May negatively affect soil and groundwater properties
3. Applicable only were soil conditions allow infiltration, the groundwater table is at least 1.5 m below the soak pit, there is no risk for flooding and any water well is in a distance of at least 30 m
4. Difficult to realize in cold climate
5. Should be avoided for high daily volumes of discharged effluents.

Slow Sand Filtration:

The leachate that drains out from the landfill can also be pre-treated by using normal sand filtration tank. Due to the presence of various chemical components in the leachate, it is very difficult to remove all the impurities and make it suitable to drink. However, by the following simple filtration scheme, certain impurities can be removed from leachate and it reduces the soil or water pollution.

Sand filtration is used for removal of suspended particles as well as floating and sinkable particles. Particles are removed by way of absorption or physical encapsulation. The two sand filter functions are surface filtration and depth filtration. Surface filtration involves particles above the filter bed. These particles jointly form a limp, which is able to collect new particles in a very effective manner. Depth filtration generally involves smaller particles that are more difficult to collect, and which are bound to the sand particles by adsorption.

Slow sand filters produce high-quality water without the use of chemical aids. Passing flocculated water through a rapid gravity sand filter strains out the floc and the particles trapped within it, reducing numbers of bacteria and removing most of the solids.

The filters provide excellent turbidity removal and provide the community with a safe and low maintenance treatment system. (Robert A. LeCraw, n.d.)

Advantages of slow sand filters are:

1. Effective treatment for turbidity, bacteria, and greater than 4 log removal of cysts.
2. No pre-treatment chemicals.
3. No backwashing.
4. No automation required.
5. A failure to clean the filter will result in loss of production but no loss of quality.

Disadvantages of conventional slow sand filters are:

1. Raw water turbidity must generally be low.
2. Raw water must not have high algae counts.
3. Color removal is fair to poor.
4. Unpredictable filter run times necessitate lengthy pilot studies.
5. Need for a conservative design in the event of high algae results in very large filters.

However, chemicals need to be added to improve the yield of sand filters. The heavily polluted water that is created after being used to rinse the sand filter needs to be treated and disposed properly (emis, 2010). It is less effective when it has high turbidity and algae contamination, so pre-treatment is required. It also has lower rate of filtration.

Mechanism in Filters: The phenomenon of filtration is generally on the basis of the following four actions:

1. Mechanical Straining: this is responsible for removing suspended matter that are too large to pass through the intersection between the sand grains.
2. Sedimentation and Adsorption: this accounts for the removal of colloids, suspended and bacterial particles. The sand grains acts as minute sedimentation basins by which particles adhere to the grains because of physical attraction and forms the gelatinous coating.
3. Biological metabolism: The surface layer gets coated with zoogloeal film in which bacterial activities are highest thereby converting them by a complex biochemical action into simple and harmless compounds.
4. Electrolytic Action: A certain amount of dissolved and suspended natter in water is ionized which possess electrical charges of opposite polarity. These neutralize each other and while doing so, the chemical character of water also changes.

Materials

Filter sand: The selected filter sand should be free from clay, loam, vegetable or organic matter. It should be uniform and of proper size. If the sand is too fine, it tends to quickly clog causing a greater loss of head in the filter and if it is too coarse, it will permit suspended solids and bacteria to pass through the voids between the sand grains.

Filter gravel: The gravel supports the sand bed while in some case it helps to distribute the wash water evenly through the sand. The gravel used should be hard, rounded and durable.

Sizes

Gravel that pass through sieve 12mm. And discard rocks that are more than 12mm.

Coarse sand between sieves 1-6mm.

Fine sand <1mm

Operation

A sand filter makes use of sand to filter water. The basic principle of the process is very simple. The leachate flows through a layer of sand, where it not only gets physically filtered but biologically treated. This removes both sediments and pathogen.

When the leachate to be treated is made to pass through sand filter, it slowly sinks through the sand of the filter, leaving the dirt particles from the water behind in the fine pores of the sand. This filter technology is better suited for pre-treatment of the leachate and other treatment can be proceeding after the sand filtration. In most cases, for filtration process, sand with a diameter of 0.8mm to 1.25mm (Royal Brinkman) however, the sand filtration being installed for treating leachate, two layers of sand are being used. Coarse sand 1mm-6mm and in the fine sand layer, less that 1mm sand particles are used. Filtration rate ranges from 100-200 liters/hour in the case of slow sand filters (Duggal, 1966).

Effectiveness

Sand filtration is used primarily for suspended matter. The yield in this case varies between 50 and 99.99% depending on whether support aids such as coagulants/flocculants are used (emis, 2010). In addition to suspended matter, COD, BOD, organically bound nitrogen and phosphate, and un-dissolved metals are removed from waste water. The following data shows the rate of removal of impurities by slow sand filtration (Adams, 2006):

Table 9: Typical pollutant removal efficiency of slow sand filter

Sl.no	Pollutant	Percent Removal
1	Biochemical Oxygen Demand (BOD)	70
2	Total suspended solids (TSS)	70
3	Total Organic Carbon (TOC)	48
4	Total Nitrogen (TN)	21
5	Iron (Fe)	45
6	Lead (Pb)	45
7	Zinc (Zn)	45

Difference between slow and rapid sand filtration.

Rapid sand filtration provides rapid removal of relatively large suspended particles. It is a purely physical treatment as the water flows through several layers of coarse-grained sand and gravel; only relatively larger particles are help back. It is different from slow sand filtration, not simply a matter of rate of filtration but underlying concept of the treatment process. Slow sand filtration is essentially a biological process whereas rapid sand filtration is a physical process (Sustainable Sanitation and Water Management).

Although removal of sediments is an important part of purification, the underlying aspect is the biological filtration which is comparatively lower in the case of rapid sand filters.

6.4 Parts of a Landfill:
The main components of a permitted landfill are;

- **Bottom liner system** - separates trash and subsequent leachate from groundwater
- **Cells (old and new)** - where the trash is stored within the landfill
- **Storm water drainage system** - collects rain water that falls on the landfill
- **Leachate collection system** - collects water that has percolated through the landfill itself and contains contaminating substances (**leachate**)
- **Methane collection system** - collects methane gas that is formed during the breakdown of trash.
- **Covering or cap** - seals off the top of the landfill.

Bottom liner: The bottom liner separates and prevents the buried waste from coming in contact with underlying natural soils and groundwater. The bottom liners are generally constructed using some type of durable, puncture-resistant synthetic plastic HDPE (High Density Polyethylene) ranging from 30 to 100 mils thick. HDPE are recommended for landfill use due to their resistance to most chemical. (Meegoda, 2016) The plastic liners may also be designed with a combination of compacted clay soils, along with synthetic plastic. Thickness of a liner always depends on the type of material selected. Thicker layers are used to better handle the construction related issues.

Cells (old and new): This is the area in a landfill that has been constructed and approved for disposal of waste. These cells range in size (depending upon total tons of waste received each day at the landfill) from a few acres to as large as 20+ acres. This is where the waste coming into the landfill for disposal that day is prepared by placing the material in layers or lifts where the waste is then compacted by heavy landfill compaction machinery. (Disposal, n.d.)

Leachate Collection System: As the water percolates through the trash, it picks up contaminants (organic and inorganic chemicals, metals, biological waste products of decomposition). This water with the dissolved contaminants is called **leachate** and is typically acidic. To collect leachate, perforated pipes run throughout the landfill. These pipes then drain into a leachate pipe, which carries leachate to a leachate collection pond. The leachate in the pond is tested for acceptable levels of various chemicals (biological and chemical oxygen demands, organic chemicals, pH, calcium, magnesium, iron, sulfate and chloride) and allowed to settle. After testing, the leachate must be treated like any other sewage/wastewater; the treatment may occur on-site or off-site. Some landfills recirculate the leachate and later treat it. This method reduces the volume of leachate from the landfill, but increases the concentrations of contaminants in the leachate.

Storm water drainage: It is important to keep the landfill as dry as possible to reduce the amount of leachate. This can be done in two ways:

1. **Exclude liquids from the solid waste.** Solid waste must be tested for liquids before entering the landfill. This is done by passing samples of the waste through standard paint filters. If no liquid comes through the sample after 10 minutes, then the trash is accepted into the landfill.
2. **Keep rainwater out of the landfill.** To exclude rainwater, the landfill has a storm drainage system. Plastic drainage pipes and storm liners collect water from areas of the landfill and channel it to drainage ditches surrounding the landfill's base.

The ditches are either concrete or gravel-lined and carry water in collection ponds to the side of the landfill. In the collection ponds, suspended soil particles are allowed to settle and the water is tested for leachate chemicals. Once settling has occurred and the water has passed tests, it is then pumped or allowed to flow off-site. (Freuderich, n.d.)

Methane collection system: Bacteria in the landfill break down the trash in the absence of oxygen. This process produces landfill gas, which is approximately 50 percent methane. Since methane gas has the potential to burn or explode, it has to be removed from the landfill. To do this, a series of pipes are embedded within the landfill to collect the methane gas. This gas, once collected, can be either naturally vented or control- burned.

Cover (or cap): Waste that is placed in a cell is required to be covered daily with either six inches of compacted soil or an alternative daily cover. Covering (or capping) is performed in order to isolate the waste from exposure to the air, pests (such as birds, rats and mice) and to control odors. When a section of the landfill is finished or filled to capacity, it is permanently covered with a combination of a layer of polyethylene plastic, compacted soil and a layer of topsoil that will support growth of vegetation to prevent erosion.

6.5 Need of Well-Engineered landfill design

Landfill has been defined as “the engineered deposit of waste onto and into land in such a way that pollution or harm to the environment is prevented and, through restoration, land provided which may be used for another purpose”. A sustainable landfill is one in which the waste materials are safely assimilated into the surrounding environment, whether or not they have been treated by biological, thermal or other processes, and which manages gas related problems so as to minimize the environmental impacts.

6.5.1 Present Scenario

The waste collected from the Thromde and Dewathang is currently dumped at the landfill (basically an open dump yard) without any segregation of wet and dry wastes, certain amounts of recyclables such as pet bottles, metals etc... are collected by scrap dealers before the waste is dumped at the landfill.

The old landfill was constructed in the year 2012 with an expenditure of Nu. 6.1 million covering an area of 20,000 square feet. It is located at Matanga, at a distance of 3 km from the town. The daily waste generation is around 5 tons per day. The landfill was built to suffice the need of waste disposal for 10 years but within a span of 6 years, the landfill had reached its brim.

The two scenarios are being presented:

6.5.2 Scene 1: Existing Landfill

The existing landfill does not have an engineered lining system or measures to control environmental pollutants such as leachate and landfill gas. There is no phasing of the landfill, which results in large expanses of waste left uncovered, leading to the inherent problems of scavenging, odour, litter, excessive leachate production and uncontrolled gas escape. The landfill currently has no leachate collection system in place and precipitation readily enters the waste and leachate emerges, escaping at a series of levels and flows out of the waste and downhill into the stream at the base of the site which subsequently joins the river. There is no gas extraction system in the current landfill and therefore gas is allowed to vent directly to the atmosphere. There are no proper segregations of the wastes.

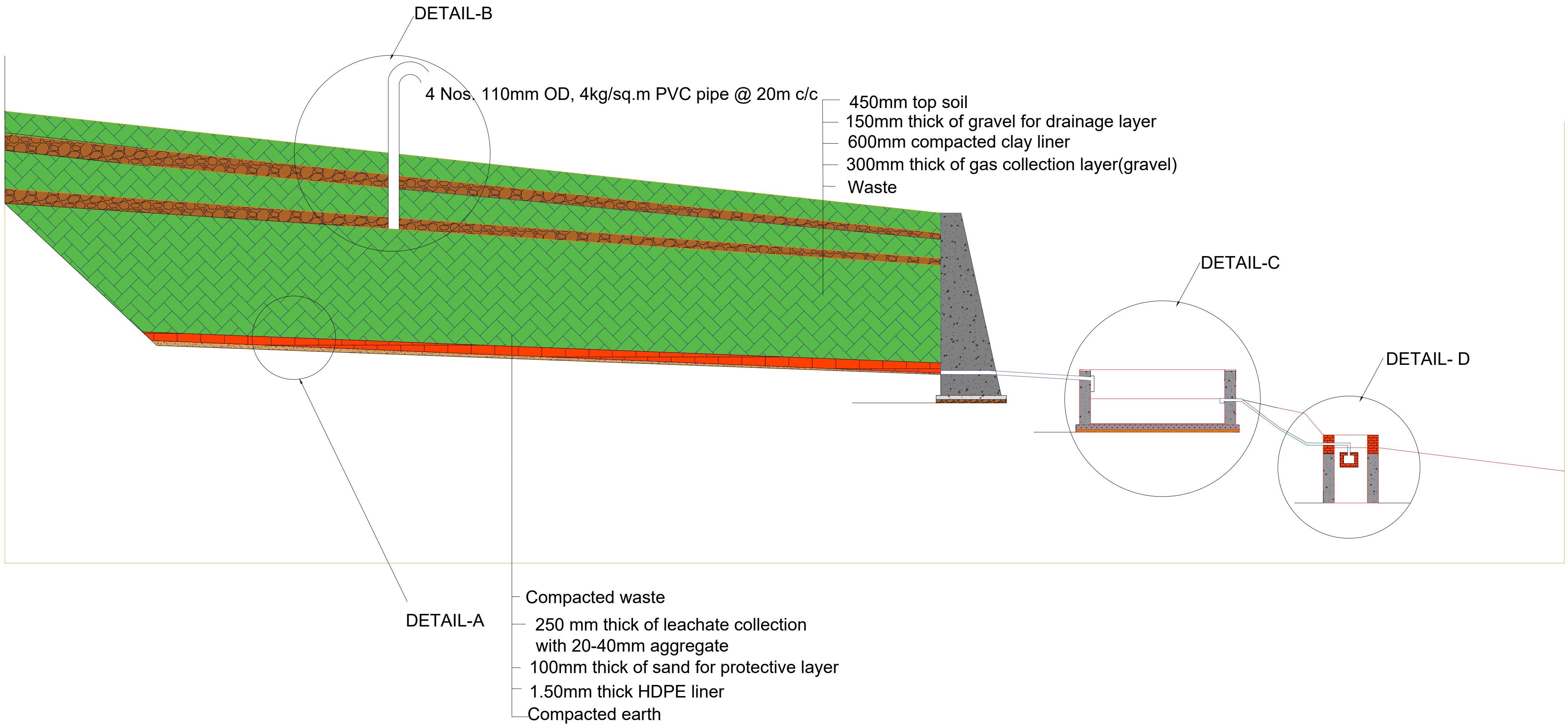
There are no initial costs incurred in this landfill but the environmental consequences are very high as the leachate may pollute the soil and ground water and the emissions could pollute the air.

Figure 12: Matanga Landfill (March,2020)

6.5.3 Scene 2: Engineered Landfill (Proposed landfill system)

This method satisfies the requirements of an engineered landfill but does not have the gas recovery system. The waste is dumped on the land which has the protective liner system and closed using the cover system. The waste undergoes anaerobic degradation and releases landfill gas to the atmosphere. The quantity of release of landfill gases depends on the quantity of degradable organic content present in the waste. Since there is no gas recovery system installed these gases are emitted into the atmosphere. Some of these gases like methane are greenhouse gases and lead to global warming. There is also a release to the hydrosphere in the form of leachate which is controlled by the liner system and the leachate collection and treatment systems.

The engineering landfill system includes bottom liner and capping system design, leachate management, and co-generation, development of landfill operation procedures and manuals, and maintenance plans, cost analyses, and cost recovery. The leachate system may need to be supplemented by leachate extraction wells to control and manage the emerging leachate.



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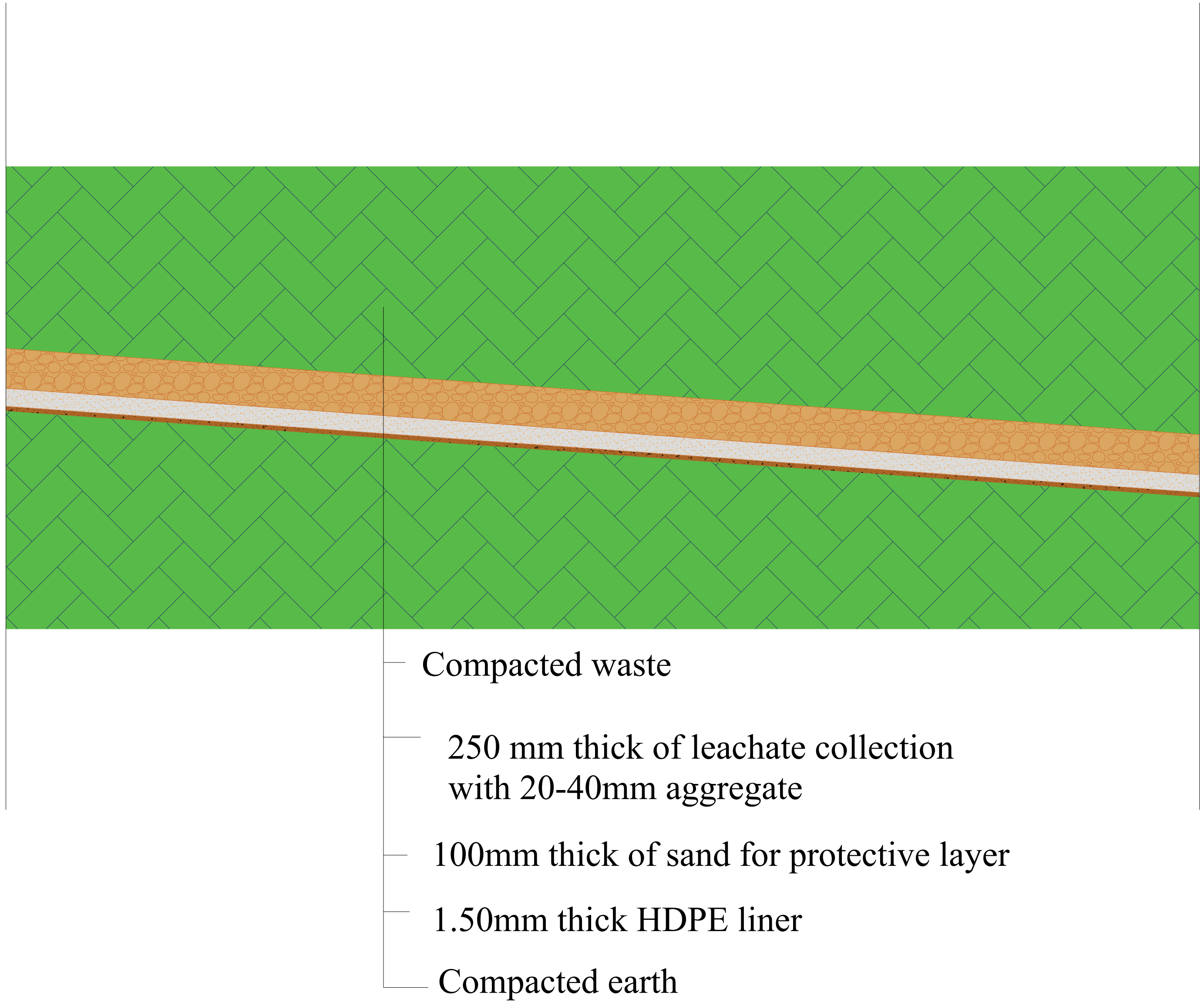
TITLE: L- SECTION SHOWING THE EXISTING GROUND PROFILE- F F	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS

DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING

JIGME NAMGYEL ENGINEERING COLLEGE



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DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
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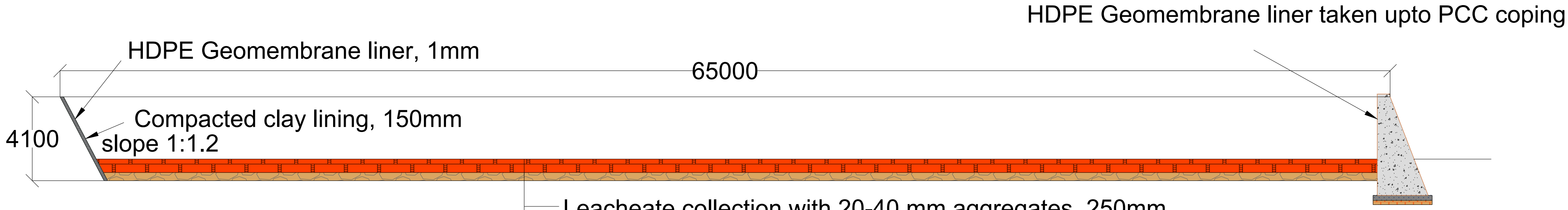
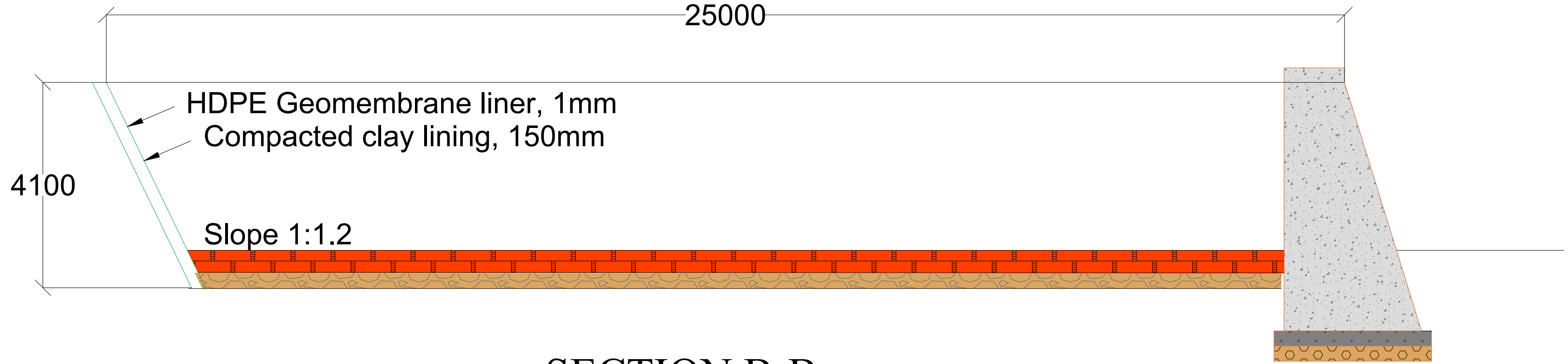


SECTION A-A



SECTION B-B

PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY	
TITLE: SECTION A-A AND SECTION B-B	LOCATION: Samdrup Jongkhar · GUIDE: Mr. Phurba Tamang · SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING	
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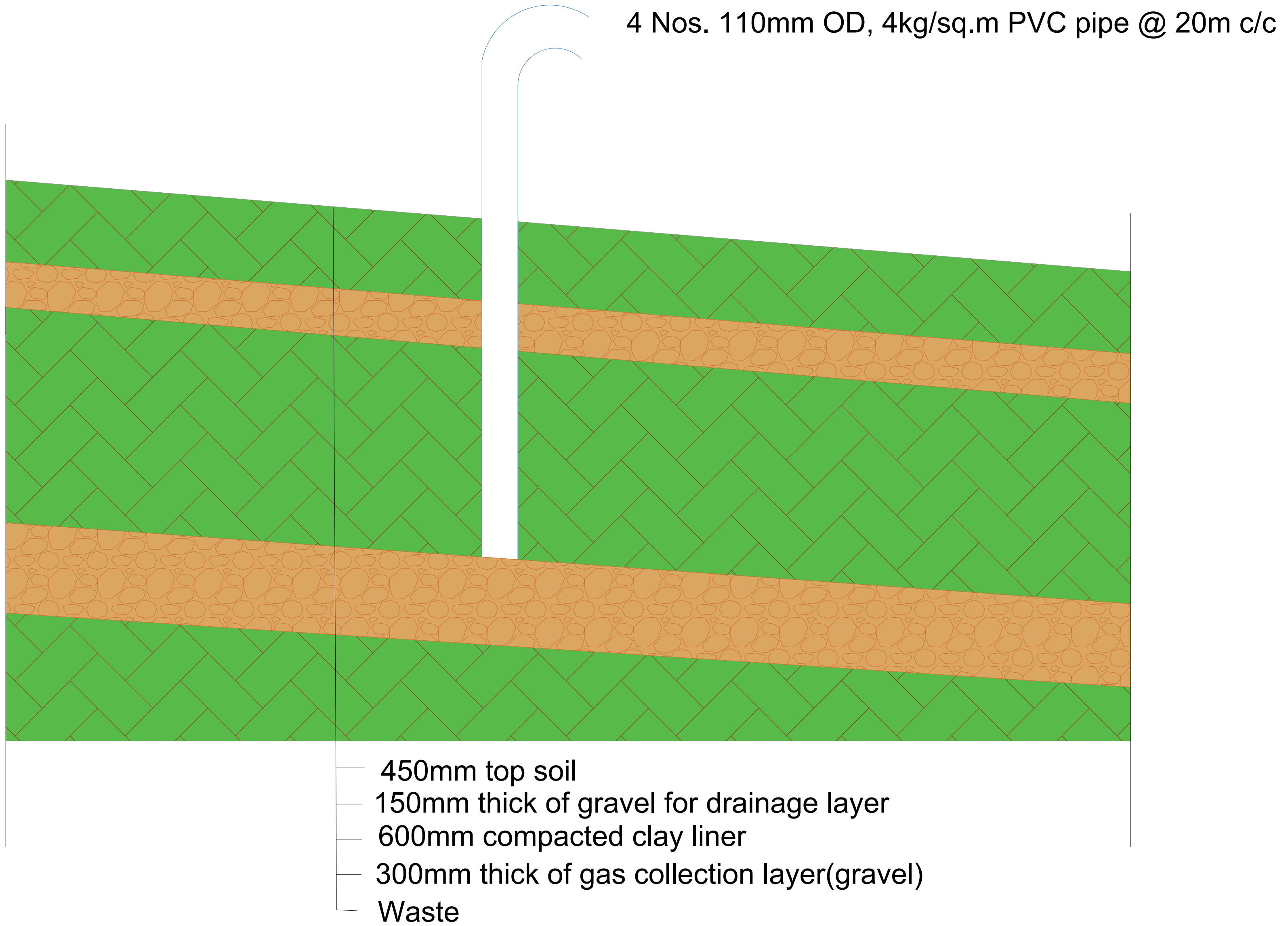
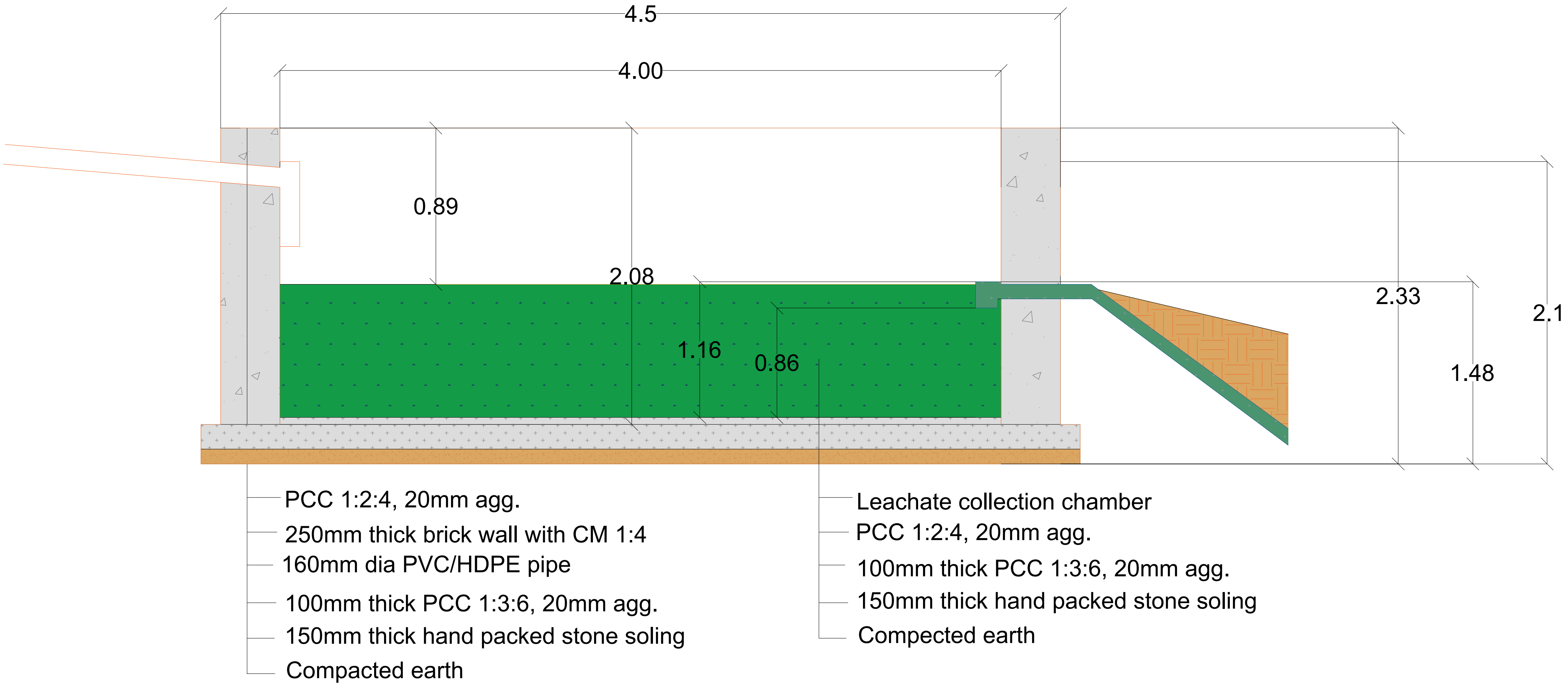


PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: DETAIL B	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			



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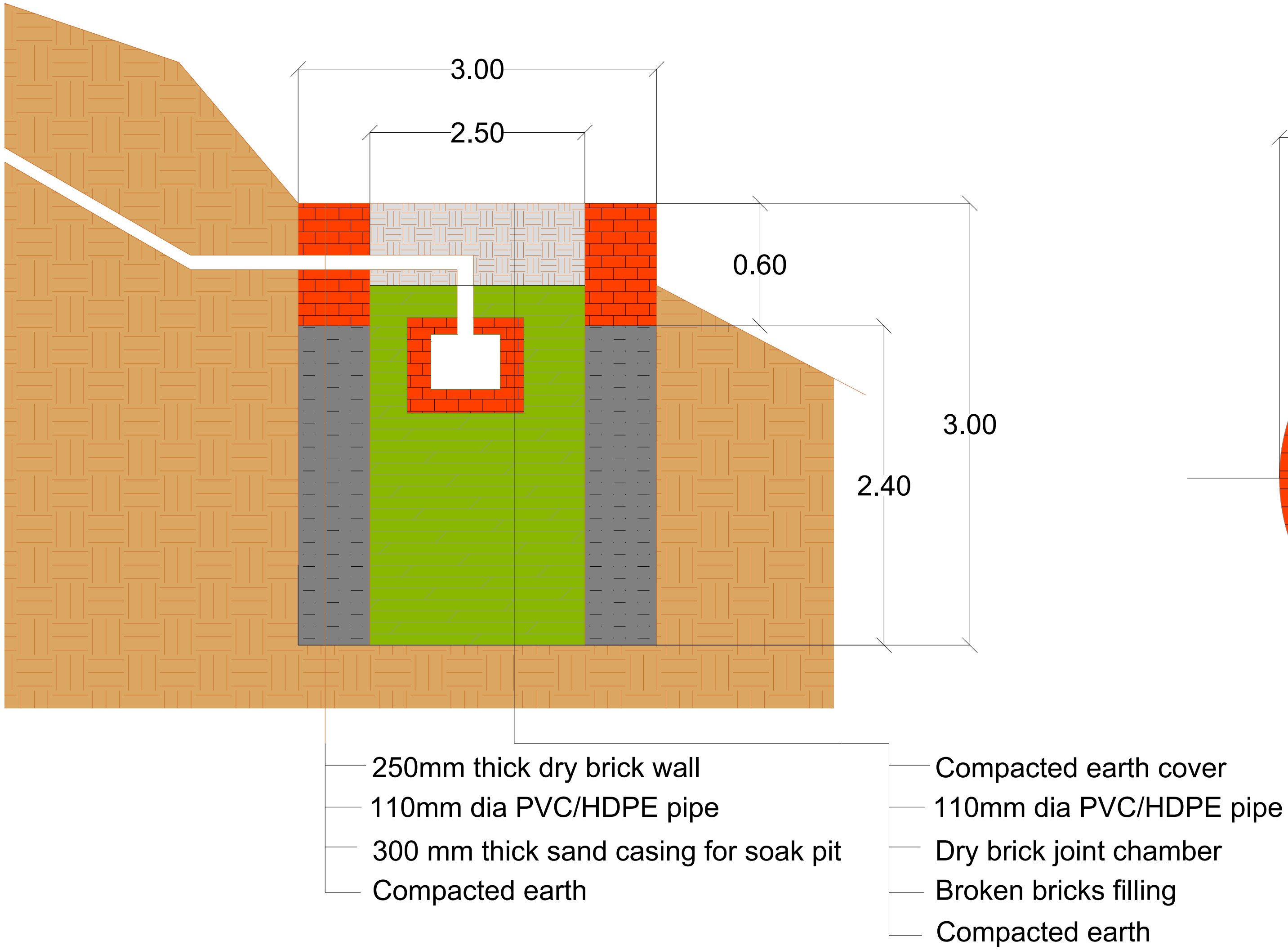

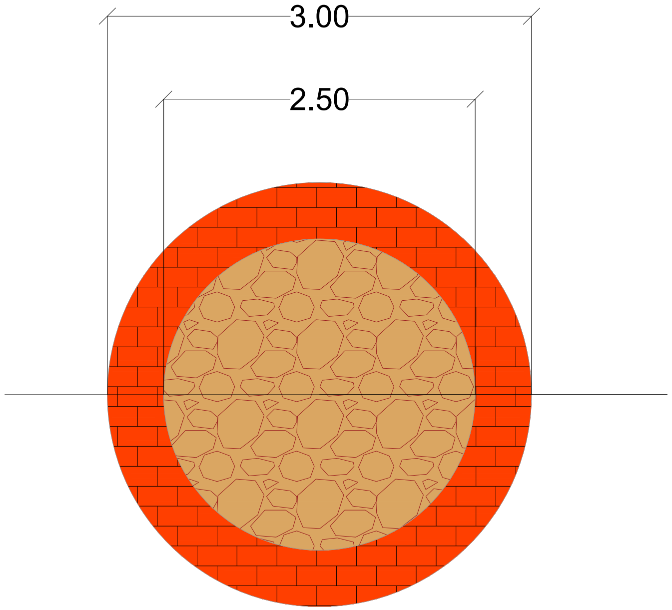

PLAN

	PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
	TITLE: SECTIONAL VIEW - DETAIL D	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS
	DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
	JIGME NAMGYEL ENGINEERING COLLEGE			

H (mm)	W (mm)	b (mm)	S (mm)
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1500	1130	600	1190
2000	1300	600	1360
2500	1490	600	1550
3000	1670	600	1730
3500	1850	600	1910
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4500	2200	600	2260
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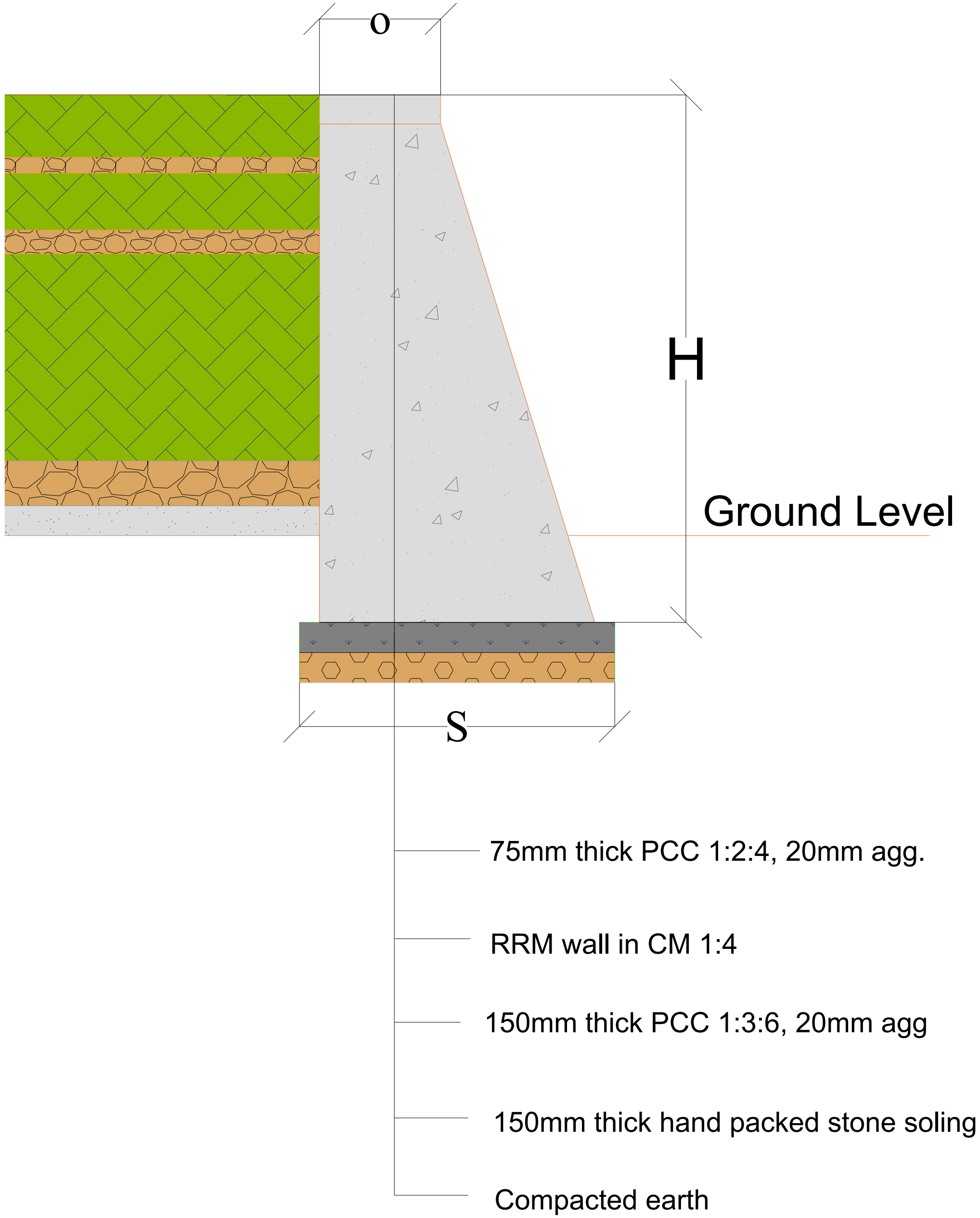
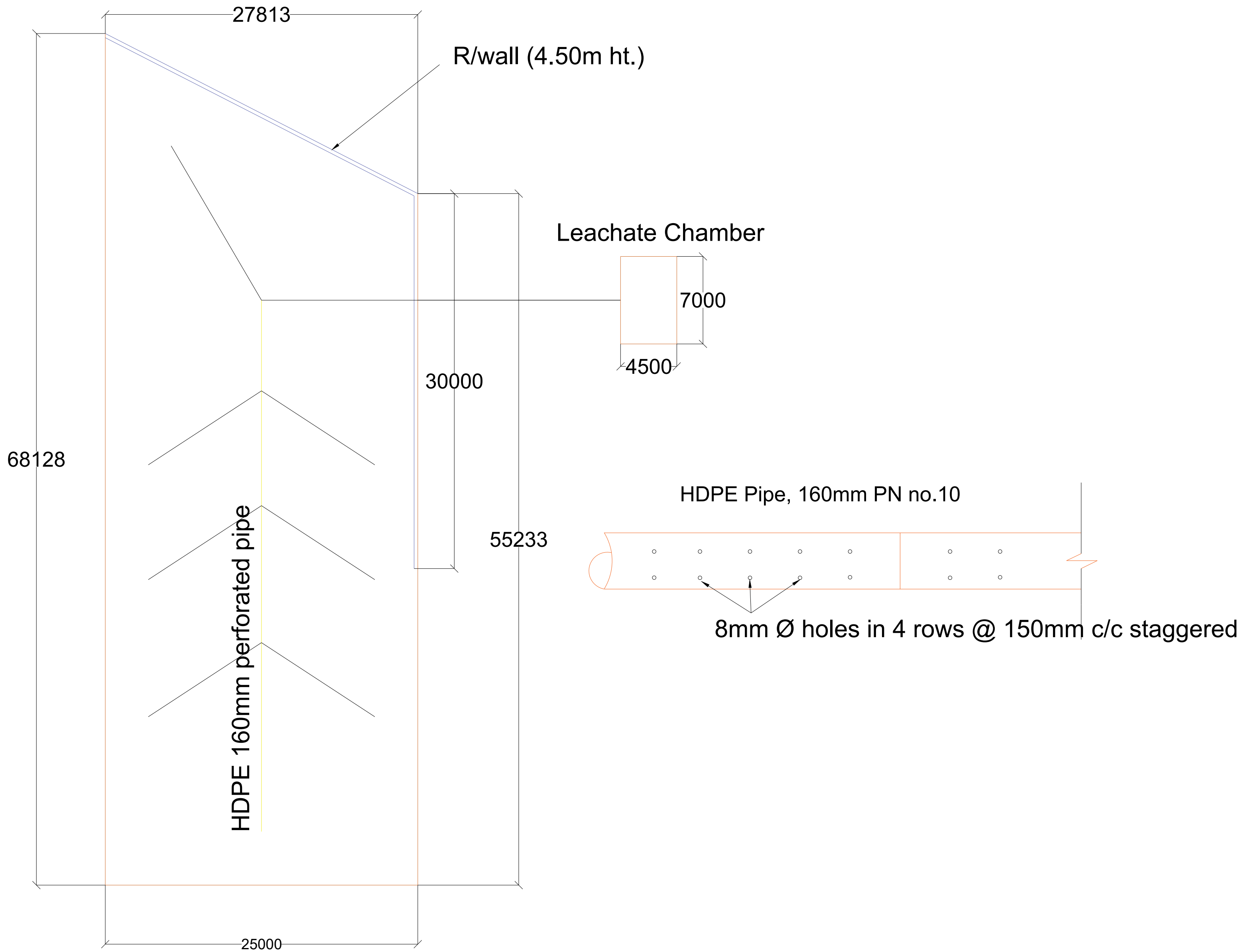


PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY

TITLE: RETAINING WALL	LOCATION: Samdrup Jongkhar	GUIDE: Mr. Phurba Tamang	SCALE: NTS

DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING

JIGME NAMGYEL ENGINEERING COLLEGE



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DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
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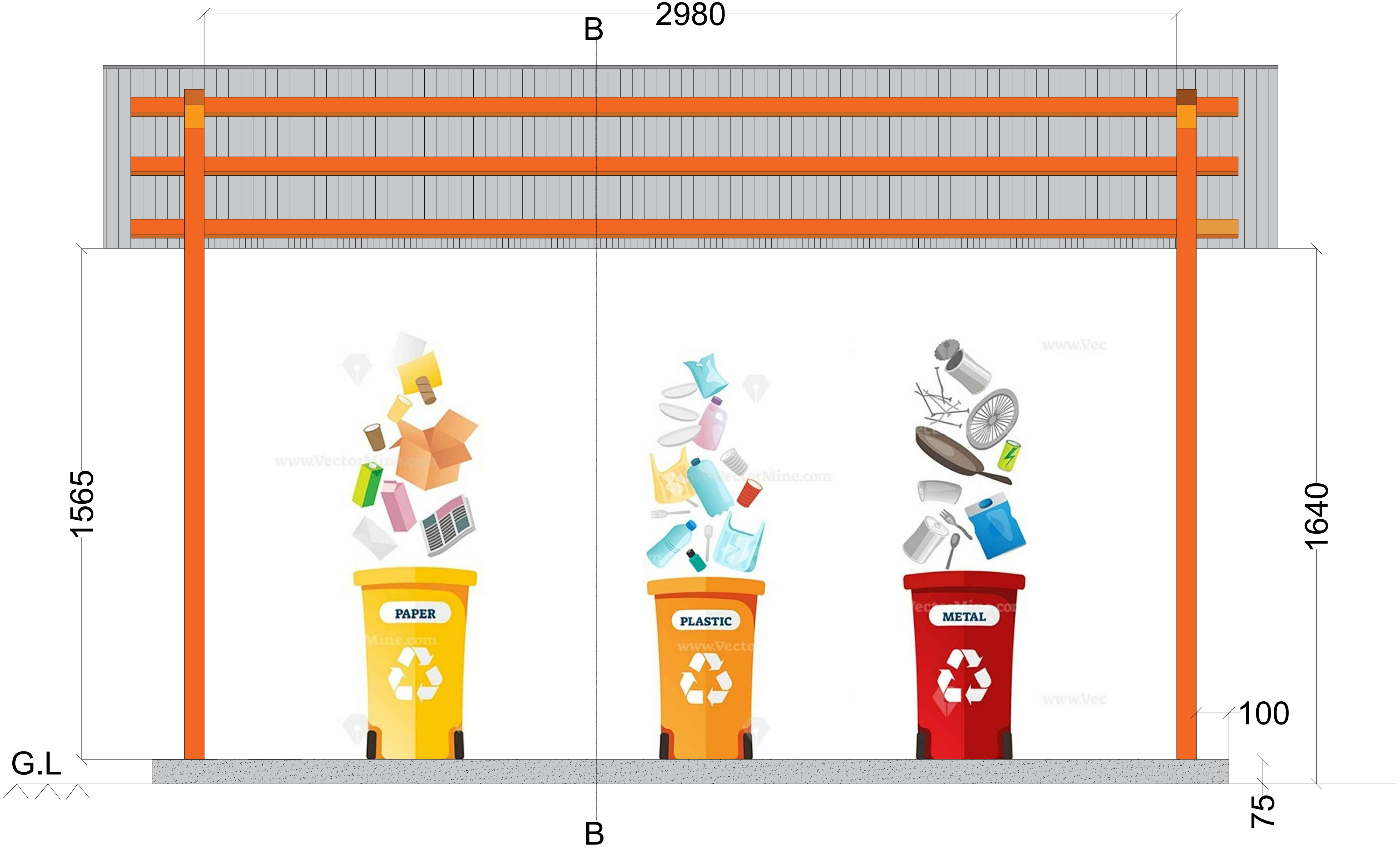
Conclusion

This research envelopes the solutions in the mix of recommendations and mitigations to improve the waste management practices in the community and educate people on the current waste mismanagement trends that has been persisting in the Thromde . As per the findings the current landfill does not have an engineered lining system or measures to control environmental pollutants such as leachate and landfill gas. There is no phasing of the landfill, which results in large expanses of waste left uncovered, leading to the inherent problems of scavenging, odour, litter, excessive leachate production and uncontrolled gas escape. The landfill currently has no in placed leachate collection system, thus precipitation readily enters the waste and leachate emerges, escaping at a series of levels and flows out of the waste and downhill into the stream at the base of the site which subsequently joins the river. Above all, there are no proper segregations nor stringent protocols to reduce the waste inflow at the site.

At present, waste generation is not humongous but over the time it may lead to conundrums resulting in unimaginable ramifications. Even from the statistics, it is observed that there is increase in daily wet waste generation from 4.78MT/day in 2018 to 5.35MT/day in 2030. And that of daily dry waste generation from 6.41MT/day in 2018 to 7.20MT/day in 2030. So, if we can manage the bio-degradable and non-degradable waste at the grassroot level by proper segregation or by other means, there will be controlled waste flow into the landfill. As per Thromde, JNEC is amongst the major waste generator in the area.

In nutshell, the followings are the conclusions drawn from this study:

1. The door to door collection of waste is poorly monitored by the thromde and the segregation protocols are almost nil.
2. The waste collection and management of the areas not under Thromde need to be considered by the responsible organisation or agencies.
3. Compost pile, indoor composter and garbage shed may assist the Thromde to reduce and manage the waste at grass root level i.e. at sources.
4. The existing landfill needs to be improvised for proper management of the waste as it is already overflowing with waste.



ALL THE DIMENSIONS ARE IN MILLIMETER (MM)

PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY

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DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING

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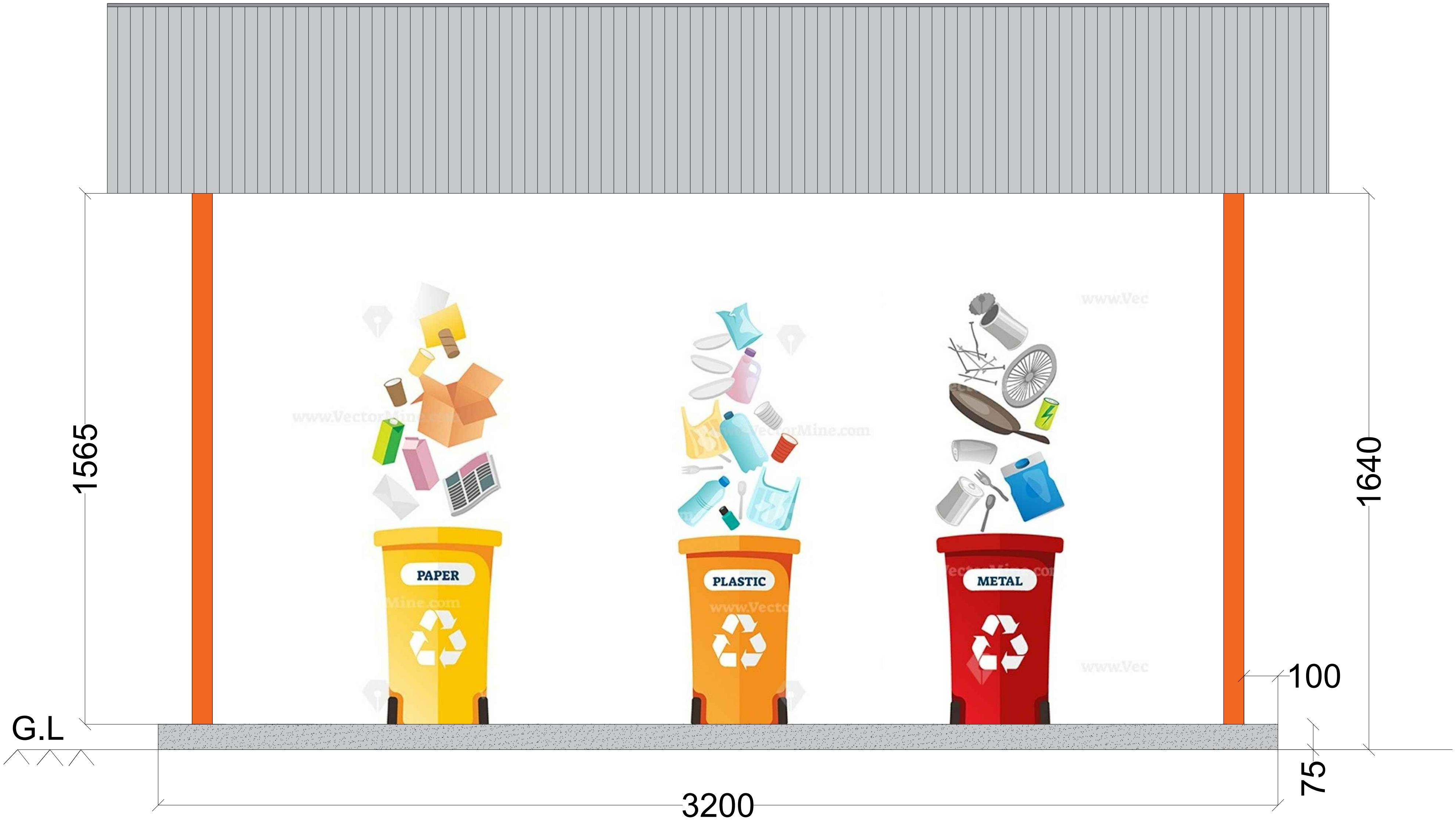
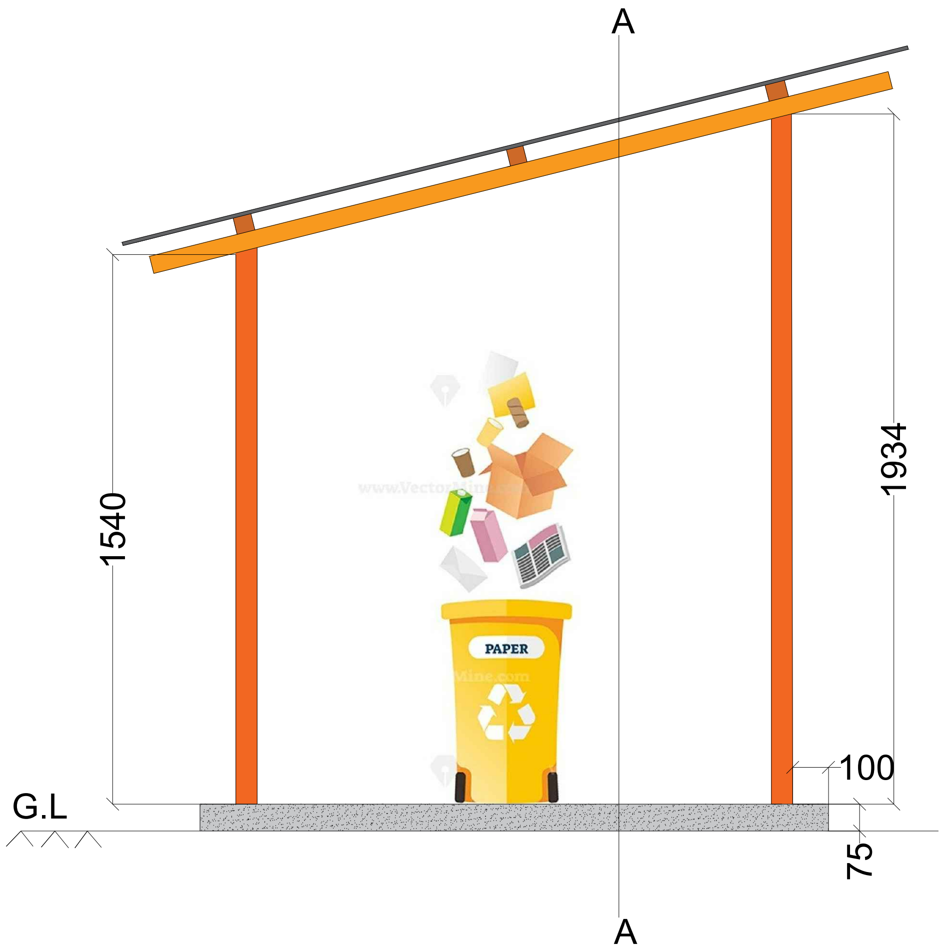


ALL THE DIMENSIONS ARE IN MILLIMETER (MM)

PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: BACK ELEVATION	LOCATION:JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			



ALL THE DIMENSIONS ARE IN MILLIMETER (MM)

PROJECT: STUDY ON SUSTAINABLE LAND-FILLING APPROACHES IN BHUTAN:A CASE STUDY IN SAMDRUP JONGKHAR MUNICIPALITY			
TITLE: SIDE ELEVATION	LOCATION:JNEC	GUIDE: Mr. Phurba Tamang	SCALE: NTS
DEPARTMENT: DEPARTMENT OF CIVIL ENGINEERING AND SURVEYING			
JIGME NAMGYEL ENGINEERING COLLEGE			

Recommendations

As mentioned earlier Jigme Namgyel Engineering College is one of the major waste generators in the area. JNEC generates the highest amount of waste per day. As per the stats, biodegradable waste of 103 kg per day is generated. So, in order to reduce the amount of waste at sources a compost pile has been proposed for the college.

In order to reduce the amount of waste at landfill the waste at the sources needs to be managed and well taken care. If an individual household could come up with their own ideas in managing waste, their contribution could make a huge difference for the Thromde to manage waste at macro level. Thus an indoor composter as designed shall benefit the residents to manged bio degradable waste and use the compost for flower and kitchen gardens. This shall help the individuals and the thromde as there will be reduction in waste quantity at landfill over the time.

The main problem that JNEC faces is in managing waste. Even though every student knows the importance of waste segregation, no one tries to segregate waste and on top of that there is no proper disposal area where one can dump and segregate their waste. So a garbage shed has been designed to be used for collection point with segregation compartments. This garbage shed can also be used in Dewathang area as well as along the highway where the populace has been facing issues in identifying a common waste collection point.

Furthermore, the following are the generic recommendations that are being deduced from this research:

1. The frequency of waste collection in the Thromde especially in Dewathang area needs to be considered with strict waste segregation protocols.
2. Waste Management like repurposing approaches as implemented by Samdrup Jongkhar Initiative can be adopted in the community.
3. Prototype projects on management of both bio-degradable and non-bio degradable waste in collaboration with relevant stakeholders/organisation could share awareness on waste minimisation in the community.
4. Proactive sanitations and advocacy programmes should be frequently and collaboratively carried within the Thromde.

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