LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE IN SHIMLA, HIMACHAL PRADESH

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

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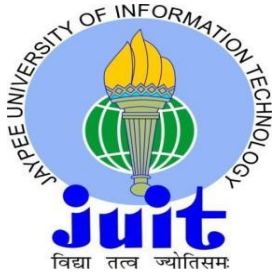

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MAY,2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE IN SHIMLA"** submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Rishi Rana and Mr. Akash Bhardwaj**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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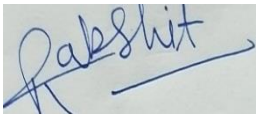

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This is to certify that the work which is being presented in the project report titled **"LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE IN SHIMLA"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat , Solan , H.P.** is an authentic record of work carried out by **Ritvik Sharma (171649), Mehul Kumar (171639) & Rakshit Sharma (171604)** during a period from January, 2021 to May, 2021 under the supervision of **Dr. Rishi Rana and Mr. Akash Bhardwaj** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat , Solan , H.P.

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ACKNOWLEDGEMENT

Foremost, we would like to express my sincere gratitude to my advisor **Dr. Rishi Rana** for the continuous support of our study, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance has helped us in all the time of this study and writing of this report. We could not have imagined having a better advisor and mentor for my thesis study. We would also like to thank her for lending us her precious time when we gone to her.

Our special thanks are due to **Prof. Ashok Kumar Gupta**, Head of the Civil Engineering Department, for all the facilities provided.

We are also very thankful to all the faculty members of the department, for their constant encouragement during the project.

Last but not least we would like to thank our parents, who taught us the value of hard work by their own example.

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ABSTRACT

Though Shimla is a well -planned city, but it has an undeveloped waste management plan.
In this report we are trying to give the general outline of environmental influence of various Solid Waste Management options in the city Shimla with the assistance of LCA. The rapid growth in the population in the recent years and industrialization has intensified the waste generation. The waste has to be appropriately managed so that it would have minimum influence upon the environment. Management of municipal solid waste (MSW) is a time-consuming process that necessitates balancing technological, economic, and social constraints. Solid Waste management deals in generation, collection, transportation, treatment, disposal. The information was collected about the sources, characterization and techniques used to treat waste. Various alternative scenarios for the management of municipal solid waste were considered. Each scenario differs in core treatment method. For the comparative analysis of different scenarios Life Cycle Assessment is the most feasible method. LCA is an analytical software to assess Municipal Solid Waste Management environmentally acceptable alternatives. LCA is presently active in many countries to scrutinize different treatment choices of solid waste. We used OpenLCA software version 1.10.3 which works on several environment impact assessment methods with different databases. In our results we found that the combination Composting, Sanitary landfill and Recycling, has the minimum amount of environmental impact therefore this scenario is most environmentally friendly solution for management of solid waste in Shimla.

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LIST OF ACRONYMS & ABBREVIATIONS

ALM	Advanced Locality Management
CPCB	Central Pollution Control Board
CO2	Carbon Dioxide
CBO	Community Based Organization
GIZ	Gesellschaft Internationale Zusammenarbeit
ISWM	Integrated Solid Waste Management
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Inventory Analysis
MBT	Mechanical–Biological Treatment
MSW	Municipal Solid Waste
MTPD	Metrics Ton Per Day
MCS	Municipal Corporation of Shimla
NEERI	National Environmental Engineering Research Institute
NGO	Non-Governmental Organisation
NMVOCs	Non-methane volatile organic compounds
RDF	Resource Derived Fuel
SWM	Solid Waste Management
SWDS	Solid waste disposal sites
SEHB	Shimla Environment Heritage Conservation Beautification
TPD	Tons Per Day

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Chapter 1

INTRODUCTION

1.1 Background:

The generation of waste is an act of human life. People were uncivilised in ancient times, there were no developmental innovations, resources and production were self-sufficient, and there was no surplus to produce waste that resulted in detrimental outcome on human health and environment. People gradually became more civilised, adopting various methods of developmental practises, population growth, and eventually urbanisation and industrialization, resulting in waste generation.[1] Many forms of material rejected can be renewed or reused, and this waste can, if properly conducted and managed, be used as a resource in the manufacturing and power generation industries. As we can see, waste management had been and still has been an engineering function. It is generally directly linked to the development of society with all the advantages of mass production, which has produced major problems with the disposal of solid waste. Solid waste is all wastes generally solid and disposed of as unsuitable or unwanted from human and animal activities. The management of solid waste is a complex and multidisciplinary environmental issue which is technical, economic, environmental and social considerations Sustainability-based aspects.[26]

Solid waste is an unwanted or useless substance made by human works in residential, industrial, or commercial areas. It can be divided into three categories:

1.) **On the basis of origin,**

2.) On the basis of composition,

3.) On the basis of effect on health.

1.1.1 On the basis of origin:

Under first category which concerns with basis of origin the site of production of solid waste is taken into account which includes waste produced from household, factories, construction sites, commercial. For example: Discarded fruit, vegetable peels, paper wastes from classrooms, universities, offices, Municipal waste covers gravel, leafy substances, construction debris, waste treatment plant sludge. Industrial waste consisting primarily of process waste, ash, waste demolition and building, hazardous waste.

1.1.2. On the basis of composition:

Under second category, it categorises waste into organic, inorganic, plastic, metal. For example animal and plant waste, paper, cardboard, cloth, rubber, Glazed and non-ferrous materials, bottles, aluminium containers, tin and gravel.

1.1.3 On the basis of effect on health:

Under third category we divide the waste into toxic, non-toxic, radioactive, infectious. For example, Manufacture of pesticides, refining of oil, electroplating and other scrap metal finished products, waste containing dioxin.

Considering above categorization, we can conclude that solid waste is omnipresent in some or other way and also has a harmful effect on the environment and also on the human life in a form which can be toxic, non-toxic, radioactive, infectious. Therefore, proper removal of the waste from the environment becomes essential as its non-removal will lead to hazardous impact on one or the other way.

Waste if left open in the environment can act as a breeding ground for various harmful vectors resulting in spread of infection to humans and if waste is released in the water bodies without any treatment it leads to water pollution affecting marine life as well as polluting our water reservoirs. Hence, proper gathering, treatment and disposal of waste becomes necessary.

Therefore, Solid waste management acts as an umbrella for the above given problems. It is a technique which aids in removal of waste from the environment with a more logical and scientific way. A number of processes like gathering, carriage, recycling, pre-treatment and disposal.[28]

Generally, MSW is made up of waste generated by different sources like domestic, industrial, and institutional activities. MSW is a general term which is used to describe the products that are discarded from above mentioned sources from their day-to-day activities. MSW is divided as follows:

i) Dry waste, which consists of non-organic wastes for example as plastic, glass, tins, cardboard,

ii) Wet waste, which consists of organic wastes such as, rotten and peels of vegetables and fruits, leftovers.

1.2 Waste generation - Global level

Globally, the generation of waste is increasing at a rapid rate. Across the world 2.01billion tonnes of MSW is being generated yearly out of which 33% is not handled in an environmentally friendly manner. Worldwide per capita waste per day averages 0.74kg but ranges per 0.11-4.54kg. It is estimated that by the year 2050, the global waste produced will be double the population in the same era. A positive coherence is seen between the waste production and the income level.[23]

And same can be interpreted from the figure 1 where we can see that as the years are increasing there is a general trend of increase in the waste production. Production of waste is followed by its collection which in itself is a crucial process and according to Fig. 1.2 (b) we can conclude that countries with high income have more efficient collection rate of about 96% as compared to that of countries having low income where collection rate is 39%. More economic power means more collection rate and therefore more portion of waste being treated in a more scientific and efficient manner. Therefore, we can conclude that economic status of the country plays a vital role in waste management.

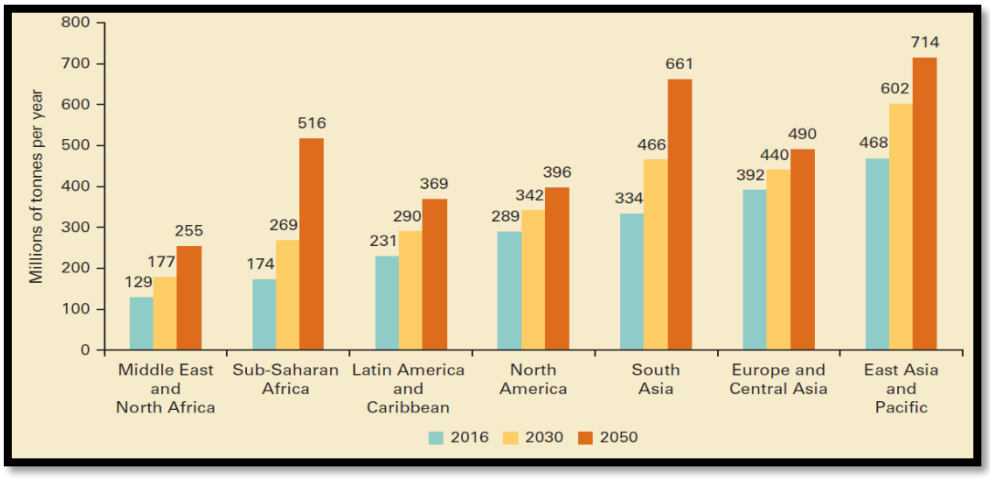

Fig 1.2 (a) Projected waste generation, by region (millions of tonnes/year) [23]

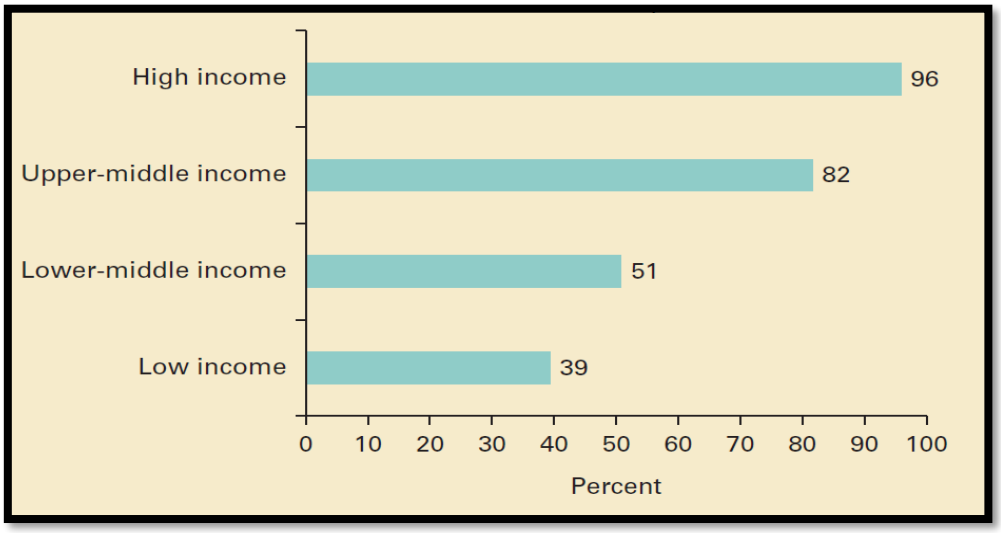

Fig 1.2 (b) Waste collection rates, by income level (Percent) [23]

1.3 Waste generation- India:

Urban India faces a major challenge in addressing the infrastructure required for the ever-increasing population according to the census of 2011, population of India was 1.2billion, 31% of whom live in cities. Improper and inefficient management of waste causes air, water, soil and environmental pollution [2].

Because of rapidly growing population of India, MSW is also gaining popularity in India as it is being seen as a major problem that could become serious if proper implementation of different laws and reports for effective treatment of MSW are not followed.

As many municipal authorities around the country are still to develop in their own capability to independently monitor their solid waste, the central and the State Governments here play a vital role by formulating different policies, technical and capital assistance for the infrastructural growth including managing day to day municipal waste. [11].

In 2004-05, CPCB-NEERI a study done on the waste gave results that cities like New Delhi, Greater Mumbai and Chennai to be biggest emitters of the waste in our country and were producing 5922 TPD, 5320 TPD and 3036 TPD respectively. In 2011 inventorisation by CPCB again exposed that metropolitan cities, which are the economic hubs of the country are the prime waste emitters. Delhi: 6800 TPD, Mumbai 6500 TPD, Chennai 4500 TPD, Hyderabad 4200 TPD and Kolkata 3670 TPD.[5]

Therefore, from the above waste generation, we can conclude that the bigger/ metropolitan cities are producing much more waste as compared to small cities in our country. So, our priorities should be to tackle solid waste of municipalities in such metropolitan areas if model is successful the same should be applied in small cities also.

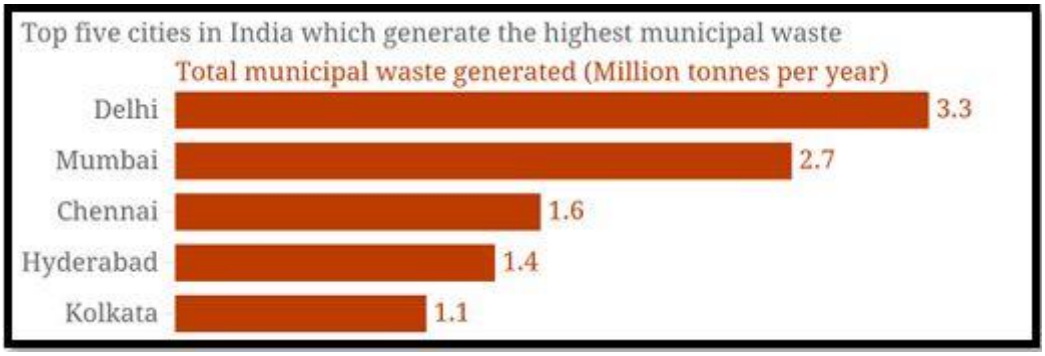

Fig 1.3 Top five cities which generate the highest municipal waste [27]

1.4 Treatment Processes

The amount of waste produced is the unmanageable as cities increase in size and the population is increasing. Local companies have modified various techniques for waste management:

- Composting
- Incineration
- Sanitary Landfilling
- Recycling

1.4.1 Composting

- Composting is the natural recycling method of decomposed organic materials to a fertile soil called compost.
- The process of composting is as follows:

$$\text{Waste} + O_2 + H_2O \longrightarrow \text{Decomposition} \longrightarrow \text{Compost} + CO2 + H2O$$

- Organic materials are reduced by the composting process. This decrease is due to the release into the atmosphere of CO2, H2O and other gases & compost is the result of the end.
- Microorganisms, decomposition products and Organic matter which cannot decompose these species.

- Compost is an admirable gardening and vegetable fertiliser.
- Composting enhances the soil, contributes to the retention of humidity, eliminates plant diseasing and pests.
- It leads to growth of beneficial bacteria and fungi, which split the organic matter to make a rich substance filled with nutrients, humus.
- It diminishes the carbon footprint by reducing methane emissions.[29]

1.4.2 Incineration

- The method of burning of waste in furnaces is known as incineration.
- The recyclable waste is separated in these plants and the remainder of the material is burned.
- All that remains is ash at the end of the operation. Any of the ash floats in the hot air during the process known as fly ash.
- The above have elevated levels of toxic contaminants such as dioxins and heavy metals in the oven after burning. It's a challenge to remove this ash. The ash buried in the sites leaks the area and causes extreme pollution.
- Burning waste is not a clean operation since it contains loads, pollutes air and water.
- Incineration is still sustained as the last resort and is primarily used for infectious waste treatment.[28]

1.4.3 Sanitary Landfill

- Sanitary Landfill is a technique of controlled treatment and disposal of solid refuse.
- They are packed with non-permeable materials like plastics and clay and are constructed on waterproof soils.
- Building sanitary sites is very expensive and they have challenges of their own. Some bodies claim that the plastic lining also forms cracks as it interacts with different chemical solvents in the waste.
- There are also highly variable decomposition rates in sanitary waste dumps. This is may be because of less oxygen is needed when the waste is very closely packed.
- Layers are compacted & levelled compacted with some mechanical equipment. The fill will settle over time.

- The organic matter is degraded by microorganisms. Bacteria hydrolyze organic complex matter into basic organic soluble water. These spread through the soil, where fungi and other bacteria turn them into aerobic carbon dioxide and water.[28]

1.4.4 Recycling

- The method of recycling is the collection and reuse of items which would otherwise be thrown away as waste and turned into new goods.
- Materials are collected through various collection centres. Then, Recyclables are shipped out for sortation, cleaning and treatment to a recovery plant into products that can be reused.
- Reduces pollution submitted to sites with waste and incinerators
- Conserves natural resources like wood, water and ore.
- Improves economic safety by taping a domestic content supply.
- Prevents waste by reducing the collection of new commodities.
- Promotes Energy savings.[28]

1.5 Life Cycle Assessment

The Life Cycle Assessment (LCA) is a vital method for reducing environmental influences through recognising the noteworthy consequences of inadequate waste management.

The method of collecting and processing data and eventually assessing the environmental impact of product system during its life cycle is known as life cycle assessment (LCA). LCA is a significant instrument that aids in the environmental issues and their considerable effects. The LCA begins with the acquisition of raw materials and continues through processing, use, and disposal. The LCA consists of four components: (a) an objective and possibility that define the product & activities; (b) a life cycle inventory study; (c) a life cycle impact assessment; and (d) a consequence interpretation.

The objective and extent of LCA involves the target of investigation. The planned utilization of findings, time-dependent study, technological study, device limits, natural inclusion and impacts, mode of study, etc are all part of the first step of LCA.

Inventory analysis, which is the basic flow associated with the outcome life cycle, second step of LCA. In general, inputs in terms of material and resources, as well as the yield in terms of waste, all the processes that take place inside system's confined boundary. Life cycle impact evaluation, third stage of LCA, in which the findings are first categorised into impact categories that are related to the first step of the LCA analysis, i.e., the target and scope of the study. The key goal is to address environmental issues and energy use, as well as the potential for global warming, acidification, and human toxicity (i.e., classified as carcinogenic, non- carcinogenic and respiratory effects). The effects were measured as in parameters of environmental & human health effects. Final step of LCA is crucial because it is here that the results of the study and the conclusions made are discussed. [3]

1.5.1 Advantages

- LCA helps to measure product's life cycle, by which we can build alternative strategies and provide accurate and important facts to help address concerns about the case that protect the atmosphere.
- LCA can assist to develop eco-innovations to cut costs and raise awareness of the climate in general. Studies show that saving money is the product of low environmental effects.
- LCA analysis can aid to deliver a clear message to the public about the project, whether it is innocuous for the environment.

1.5.2 Disadvantages

- The biggest challenge in assessing the life cycle is the difficult it takes a lot of time, however, to collect data that can help to work through it. Some software's can, of course, eliminate the allowance for error, but maximum times manual calculations has to be done to ensure that everything is accurate.
- The assumptions, scenarios and scope of each analysis can vary and lead to different LCA findings. This inconsistencies in LCA methods and outcomes, in particular for non-experts, can be confounding.
- Furthermore, the findings of an LCA analysis are not easy to transmit.

1.6 Discussion

In the last ten years, Shimla has experienced massive urbanisation. The city limits have grown dramatically, putting additional strain on the current infrastructure. Via various programmes, the city has steadily developed its SWM infrastructure. Technical knowledge has been roped in with aid the private sector, development agencies, MoUD, initiatives in recent years. MSW (M&H) Rules, 2000 compliance is certified by High Court involvement, strict laws, community engagement, resulting in an increase in the city's aesthetic value and environmental health.
Executives in charge of waste should not just move around waste collection, storage, and disposal but the intermediate processes of handling and waste treatment or final disposal of waste should be done on more scientific basis.

The basic model in India is that the item is delivered to the customer, who then creates waste. The district collects it and dumps it, reuses it, decimating the important characteristic properties in the process. Isolating waste at the source and advancing reusing or reuse of isolated products, reduce waste and weight in landfills while also providing crude materials to manufacturers. Since waste synthesis is primarily a natural problem, composting can be a good technique for soil treatment and formation.[7]
Problems often arise as a result of inefficient and illogical waste handling activities. At the location, appropriate liner arrangement, capacity for leachate and gas collection should be installed. Ideal setup would be decentralised biogas plants that rely on strong waste. It will also help with power generation, giving you a little more leeway. The risks of waste should be taught to the masses by public awareness. Furthermore, the collection of city waste from house to house should be organised using techniques such as assortment of city waste can coordinated by techniques such as assortment on ordinary pre-educated planning & booking can be used to coordinate the collection of city heavy waste.[2]
Currently not much have been done in order to separate waste at initial phase or first step, more efforts are need for division of compostable waste source from other types of waste such as recyclable and non-biodegradable.[2] If proper separation of waste is followed with aid of new and advanced scientific ways of handling waste which can also be done with roping in private individuals and government can also do its bit by increasing the funding to substantial or adequate levels so that MC can also treat different wastes with proper treatment. And treatment of waste can in return yields profits to authorities and environment as whole.

Finally, the investigation concludes that the city of Shimla's solid waste management is hampered by a lack of resources such as funding, base, adequate planning and knowledge, and initiative. Although many good initiatives such as separate types of dustbins, fine on public littering, RDF technology are few to name but still there is long way to go.

1.7 Need of the Study:

- Reflecting on the present ecological and civic health issues our study targets to inspect the existing waste management techniques in city Shimla, Himachal Pradesh.
- Study data can help Shimla MSW management to achieve the purpose of reducing environment influence of different treatment choices.
- For the simulation of various scenarios and collection system choices, by taking into account transient variations in primary waste management system parameters of Shimla.
- To identify the most significant causes of the impacts in MSW management in Shimla.
- To identify global warming, pollution & human health influence control opportunities in Shimla.

1.8 Objectives:

- To study the current waste management activities in Shimla, Himachal Pradesh.
- To investigate the characterisation of Shimla's Municipal Solid Waste (MSW).
- To Conduct a Life Cycle Assessment of Shimla's future urban solid waste management strategies.
- To compare the alternatives and possibilities in the Municipal Solid Waste Management phase.

CHAPTER -2
LITERATURE REVIEW

2.1 Review of Literature:

In this chapter we have discussed in detail about the Life Cycle Assessment of Municipal Solid waste management system and there impacts on environment which is produced by the waste. As the waste generation is increasing day by day at a very high rate it is important to do the Life cycle assessment of waste for the purpose of determining the suitable management system for different types of waste so that it causes the least impact on environment. The study conducted **[25]** showed that recovery of material facilities like process of recycling and retrieval of waste caused very least effect on environment as compared to disposal of waste. Thus, to achieve the flexible and effective technique for management of solid residue Life Cycle Assessment method was built. With this method we can determine the different environmental risk. Life Cycle Assessment consists various processes and models to decide that how our wastes should be treated accordingly. These processes and models we have discussed below:

The study conducted **[16]** intends towards improvement in the waste management techniques by utilizing LCA tools as it comes out to be the most suitable to solve this problem of waste treatment. Actually, LCA is the Life Cycle Assessment (LCA) evaluates the ecological and resource effects of a waste management system that considers a combined framework that begins with garbage generation and comprises all forms of waste for transportation, treatment, and then finally disposing different portions and remainders, as well as material and energy exchanges with the environment. Generally, LCA is divided in four segments – Aim and scope definition, Life Cycle Inventory Analysis, Life Cycle Impact Assessment and Interpretation.

- **Aim and scope definition**- It consists the purpose of performing the study. This phase describes the functional unit of LCA study. Functional unit includes procedure of material and its results that specify handling of waste.
- **Life Cycle Inventory Analysis**- It is combination of mass flow within the garbage managing system. It contains the complete information about types of waste, proportion of material and its mass balance, budget for both processes and machinery in terms of energy.
- **Life Cycle Impact Assessment**-Its aim is to determining the extent and importance of the studied system's future environmental impacts. Basically, it normalises inventory data into

common possible impacts. These impacts are applicable for general purpose not for the residue management. The general problem of odour are not consider in ordinary impact assessment that's why it is left out from garbage LCA studies.

- **Interpretation-** It evaluates the results in respect of previous segments or we can say results are compared to the aim and scope. LCA modelling takes many assumptions and estimation so repetition of interpretation is required to get more accurate sense of balance and system coverage between previous segments.

  Basically, according to this paper, we will understand a prevailing garbage management system. LCA models will demonstrate how new methods and procedures can enhance a current waste management system's environmental efficiency. Decision-makers may use LCA to estimate the environmental value for future changes or we can say improving existing waste management systems.

The study **[22]** identified eight various mechanical–biological treatment (MBT) technologies: Utilizing home-grown data on waste configuration and method efficiency, eight full-scale MBT plants were designed. Parting technology and biological handling technology were used differently by the plants. The outcomes were in terms of global warming. LCA models can be used to compare different technologies: What are the flow characteristics and environmental profiles of the two options? LCA (Life Cycle Assessment) when comparing substitute technologies, it's critical to have a good understanding of the technologies and a well-defined functional unit. LCA modelling is used to evaluate substitute technologies or substitute performance of technology. LCA is especially useful for evaluating emerging technologies or systems where data is scarce or not accessible. Scale, that is important LCA modelling should ideally, constructed on longstanding data from full-scale amenities with variety of functioning situations. This study shows that due to the investment in equipment and services, new national waste management legislation along with strategies for local MSW management structures will be used for decades. This ensures that new systems' environmental profiles should be resistant to variations that will come up in the period of 30 years. LCA may be used to assess how well solid waste management systems react to changes in the environment. LCA modelling of complex waste management systems allows for a detailed assessment of recovered materials and resources, as well as possible environmental impacts such as loads and savings. The preliminary work required for arrangement of LCA is strenuous. Though, after sometime, when a solid residue scheme would be reflected in LCA, result for subsequent ages may requiring

just minor adjustments in key parameters. As a result, it will be straightforward that LCA may provide crucial information about CO2 emissions, resource retrieval and/or reduction of CO2 emissions. Quantity of residue dumped on the ground.

A lot of studies were done to solve the problem of garbage management like- Maimone has done the study in 1985 to solve the garbage management problem in the Netherlands. His study determined that composting was the solution for this problem of garbage management but, a new study was conducted for the United Kingdom by Powell in 1996 and he concluded that refuse of derived fuel was the solution for garbage management problem. Similarly, other many studies propose various types of method to resolve this problem but there is requirement of integrating the different studies and to look for the one final solution. So, the study **[17]** was conducted to solve the problem of garbage management in Mumbai. Various option comes out from the study to resolve the problem and these are discussed below:

- **Community compost plant**- As a consequence of an effective urban authority programme that began as a cooperative project between the Government of India and the MCGM in partnership with the United Nations Centre for Human Settlements, community engagement in waste management has been began in Mumbai. This decentralised model is an Advanced Locality Management in a waste management system. ALM is a community-based strategy for achieving positive results. Administration of municipal programmes at the grassroots level for managing public amenities at the local level, focused on the principle of joint action and collaboration among Community Based Organizations (CBOs), Non-Governmental Organizations (NGOs), and the MCGM. The ALM model works as follows: each group that joins the scheme forms a committee that is in charge of preparing, executing, and examining numerous features of community growth. It also acts as a liaison between the MCGM and local residents to ensure that public services run smoothly. At the ward level, the MCGM appoints an officer to investigate citizen grievances and work with the local group. Populaces that are part of the ALM programme must separate their trash into biodegradable and recyclable materials. NGOs organise and train rag pickers to gather these wastes and separate them further. They recycle the recyclable material after processing biodegradable waste. The MCGM provides financial and technical assistance for the construction of composting pits in these areas, as well as prioritising these areas for other municipal services. NGOs play a critical role

in this scheme by arranging rag pickers and providing them with the requisite training for gathering and composting garbage.

- **Mechanical Aerobic compost plant**- Excel Industry Limited, which is one of our nation's largest agrochemical firm, established in 1941, has a mechanical aerobic compost facility. It uses mechanical aerobic composting to turn the biological portion of MSW in Mumbai into fertilizer. It can handle 30 to 40 tonnes of garbage every day. The MCGM provides waste to Excel Industry for free. The MCGM collects and transports waste as part of this relationship, and Excel Industry composts it aerobically. The MCGM transports all inactive material sorted by the company back to disposal sites.
- **Sanitary Landfill-** MCGM functions were defined for different requirements of Municipal Corporation of Mumbai. To provide garbage management system services to Mumbai is one of them. Service includes collection, transportation and disposal of garbage produced in Mumbai. Existing method used by Mumbai to treat waste is sanitary landfill.

  These are the method which comes out as conclusion for solving the problem of garbage management but for more ecologically and economically better impact combination was required. Then community compost plant comes out as the best result for this problem. The best approach is based on the different assumptions that are- there is no separation of garbage ate domestic level, deliberations of ecological costs.

  In today's world, waste is no longer seen as worthless trash; rather, waste is seen as a resource. One of the primary goals of a sustainable waste management system is resource recovery. Combined methods were used to solve the issues of garbage management system with more effective way. The study **[18]** was also conducted regarding the garbage management system. This study mainly focused to examine the ecological burden for garbage managing technology. This study considered three various garbage treatment technology by LCA tool. This paper concludes that among other thermal treatments, sanitary landfill has a considerably lower ecological effect, whereas gases are used for fuel through a controlled pollution environment. In the areas of global warming, acidification, eutrophication, and eco-toxicity, pyrolysis gasification is relatively more environmentally friendly than open burning. The outcomes of the comparative analysis will be useful in evaluating the environmental efficiency of the technologies in decision-making procedures. However, landfills are not a desirable waste disposal choice from a socioeconomic and environmental standpoint. Disposal of final residue in thermal waste treatment systems is an ecological issue.

In study **[19]** Using Life Cycle Assessment Approach shows, management solid waste in municipality has become a grave problem, posing a threat to environmental quality and long-term growth. Cities are under unprecedented strains as a result of inadequate MSW management, such as a shortage of MSW treatment capability and the use of ineffective technologies, resulting in environmental degradation.

This paper also shows that significant quantities of methane (CH4) are generated during the treatment and disposal of urban, agricultural, and other solid waste. Solid waste disposal sites (SWDS) emit biogenic carbon dioxide (CO2) and non-methane volatile organic compounds (NMVOCs), as well as trace quantities of nitrous oxide (N2O), nitrogen oxides (NOx), and carbon monoxide (CO). The main source of CO2 produced from waste is decomposition of organic material derived from biomass sources (e.g., crops, wood). Since the carbon is of biogenic origin and net emissions are accounted for under the AFOLU Sector, these CO2 emissions are not included in national totals.

Recent studies have shown a high level of interest in offering multiple solutions for an integrated management of solid wastes around the world. The study **[20]** takes into account both the environment and the economy to find the best solution. “Net energy analysis” experiments were the first to introduce LCA. In 1972, only the amount of energy assumed over the life cycle of a product or a process was considered based on these studies. Following that, waste and pollution were entered into the model, but none of them went any further than quantifying materials and resources. In addition, the work of the Society of Environmental Toxicology and Chemistry and the International Organization for Standardization greatly strengthened LCA methodology in the 1990s (ISO). In 2006, the final version of the LCA standard, ISO 14044, was issued.

Three combinations were chosen as the best realistic solid waste management scenarios for Lavan island among the various disposal methods such as landfilling, composting, recycling, and incineration. Their environmental impacts are calculated and compared using the Eco-indicator 99 guideline. The findings indicate that landfilling, along with recycling, incineration, and composting, has the most beneficial effects on human health, habitat quality, and resource availability. Methane and CO2 are present in both situations. It has the greatest impact on air pollution. Scenario two generates the heaviest metals, especially Cd, among the others, as a result of the incineration. Furthermore, heavy metals such as Cd and Hg play a significant role in water contamination.

In scenario one the landfill is believed to be free of any leachate or gas disposal systems. Wet waste is taken to a composting plant, while glass, plastics, ferrous and non-ferrous metals, and paper are all processed. In this scenario, Sox and NOx are the most powerful contaminants. Land occupancy is a major problem on small islands, and the findings show that scenario one has the highest rate of land use, whereas scenario two has the lowest. In scenario two Recycling, incineration, and landfilling are also part of the second example. It must be noted that in scenario two, the landfill is supposed to have a leachate storage system with a 70 percent reliability. Furthermore, scenario two has the most favourable effects on energy use, while scenario one has the least favourable effects. The incinerator burns firewood, wet wastes, paper, glass, plastics, ferrous and non-ferrous metals are reprocessed; and several other wastes are disposed of in landfills. But scenario three considers recycling, composting, incineration, and landfilling. In this case, a landfill leachate collection system with a 70 percent efficiency is presumed. While the final weights of all three examples are almost identical, there is a small variation. In Lavan Island, scenario three is recommended as the proper solid waste management scheme.

In study of paper [2], was mainly concerned with study area of Shimla, according to it chief constituents of waste in Shimla are organic matter, recyclables and inert. Due to unaccounted informal picking of waste, true percentage of recyclables discarded as waste is unknown. According to research done of Shimla in the paper, Municipality of Shimla are facing problems mainly due to inefficient and non-scientific approach being followed. Solution which has been considered in this is include instalment of proper liner systems, facilities for leachate and gas collection. Biogas plant has been considered as an ideal answer as it will also aid generation of electricity. One of main problem which is being talked is that there is no segregation of waste which is being generated and collected at the source. Another concern being raised is that some automobiles such as trucks which are used for solid waste removal are usually open from the back and are usually not kept covered; therefore, when transporting garbage is often spilled on the road, leading to unhealthy conditions. Two process which constitute transportation and gathering of waste has been found to have major 80-95% portion in total budget. Study has been concluded that due to deficiency of resources in the city of Shimla's solid waste management is hampered by a deficiency of resources like funding, base, adequate strategy, data are main difficulties being presently being faced.

Solid waste management has become a difficult challenge for every municipality due to increasingly rising waste volumes, the environmental concerns, more complex waste composition, and restricted waste treatment and disposal capability. In order to run a municipal solid waste management system that is both cost-effective and safe, decision-makers must see the big picture from a long-term perspective. The study **[21],** is for long-term planning of urban solid waste management systems was introduced in this paper. This model is mainly based on water supply chain network. this study was done by Zhang et al **[24]**. Basically, MSWM is made up of three tiers of services local garbage collection, local storage, treatment and disposal. Local garbage collection is the first phase in a municipality's solid waste management scheme. The locally collected garbage will then be transported to a regional processing centre, where it will be separated and pre-treated in order to provide adequate input services to the garbage treatment and disposal plants. Finally, various forms of urban solid waste can be treated or disposed of appropriately using proper treatment methods.

Earlier, the majority of the literature focused on approaches and models for waste treatment facility and transfer station network architecture and location issues. The model built in this study is a bi-objective linear programming model that optimises the system operating cost and environmental emissions of a municipal solid waste management system while also providing an example for a better understanding of the model implementation.

2.2 Inference:

Disposal of solid waste of municipalities is the primary duty of municipal officials, according to literature review. The primary aim of the MSW administration authority is to reduce the risk of harmful effect to the environment by waste. According to the literature review, we knew that a massive quantity of garbage is generated annually, current waste administration structure is incapable of managing the massive amounts of waste generated each year. Residential areas, markets and business areas, institutional areas, and street sweeping are some of the major sources of urban solid waste. The majority of waste is disposed of in landfills, with only a small percentage of waste being processed. Local urban authorities and municipalities are primarily responsible for municipal solid waste disposal. Low management system efficiency is a sign of a lack of sense of duty, as well as a failure of the concerned authority and each person. According to many studies, improper solid waste administration is caused due to lack in

financial budget, which results in an inadequate numerical strength of assortment and carriage vehicles, sanitation staff, and protective equipment. The rising amount of solid waste created poses a threat to sanitation workers' health as well as the environment. Sanitation employees are constantly exposed to occupational health risks due to a lack of protective equipment such as gloves, eyewear, masks, and safety belts. Cuts, ligament and muscle sprains, back pain, eye irritation, and other health-related diseases were among the injuries sustained at work.

From the review of literature we can summarised it by saying that many studies were conducted in past many years to solve the waste management technique in the world , and from all the studies LCA method is most reliable . We assume there are several forthcoming usage, in which LCA can help with different features of waste administration, LCA has an advantage in providing a comprehensive, consistent, and straightforward summary. It quantifies the environmental profile of waste management systems by analysing flow patterns .LCA may also provide information about specific parts of a system. There is no other instrument that we can think of that provides the same amount of quantitative data. Six application areas have been established as a result various research from user's perspective:

(1) Comprehending a prevailing waste administration structure

(2) Enhancing prevailing waste administration structures

(3) Evaluating the efficiency of various technologies

(4) Technological growth/future development

(5) Strategy making/strategic growth, both of which have already been emphasised in the past few years in the most recent study

(6) Application of LCA modelling.

CHAPTER 3

REVIEW OF SOFTWARE

3.1 General

For LCA checking programme methods there are software's like OpenLCA, SimaPro, Gabi, including waste management mode for testing of solid waste system. These are used to evaluate existing waste management. In our study, we used OpenLCA software for assessment of environmental influence of various Solid Waste Management options.

3.2 OpenLCA

Openlca is a software which is created by GreenDelta providing an advantage of being a free software and is being used for lca around the globe. It is a desktop programme operating without Internet connection. It is available for Windows, Mac ,Linux, versions of 32 and 64 bit are available and run directly on these operating systems. OpenLCA may also be designed to communicate with a web-based database to be used for data sharing and model exchange. With the knowledge of product on which we want to perform lca and use of different database which is being provided by openlca nexus one can perform his required research. Openlca is free to use without any license cost and thus this results in its edge over different or other types of software performing the same function which are costly and are also difficult or complex to use, thus we can conclude that one of the other feature of openlca software is that it is user-friendly and easy to interact with. At the outset, OpenLCA was mostly used to evaluate the life cycle (environmental), LCA.

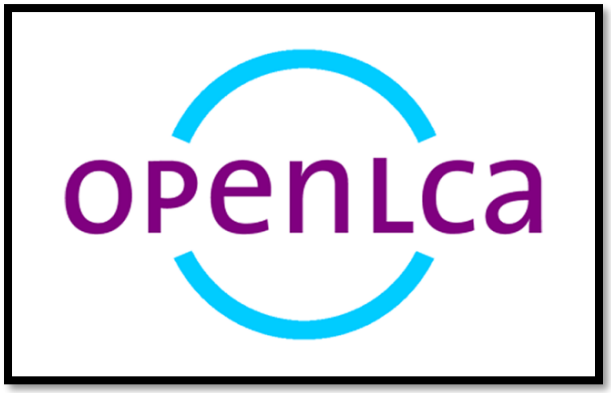

Fig 3.2 OpenLCA [14]

3.2.1 Openlca Nexus

OpenLCA nexus act a repository of different database and has both free and to purchase database and as a result a user can choose, download and thus use the database according to his requirements. Datasets once downloaded can be imported into the software provided downloaded datasets works with the software version and thus after the database is downloaded and imported into the software whichever dataset is needed to be used into the software according to the need of the user.

Database which are provided by the openlca nexus are some free of charge and some require certain amount of money to be paid in order to use such database into the software.

Following are some of the databases which are being provided by openLCA nexus:

- ecoinvent
- IMPACT World+
- exiobase
- Agribalyse
- NEEDS
- bioenergiedat

All these data sets can be downloaded and imported into OpenLCA. [14]

3.3 Features of OpenLCA

- **Data Quality**

The user can create their own data quality systems or use old ones. There are three stages to which these matrices can be applied:

- For the common data quality of a process- this is just for documentation purposes for your own or existing systems, and cannot be used for calculations.
- Data quality for every exchange in a process; when “assess data quality” is chosen, this data will be included in the estimation. After that, an average is determined for each flow and effect group.
- Data quality of public aspects- this assist only as certification at the moment. The matrix multiplication can also be used to measure uncertainty values, which can be used as in Monte Carlo simulation.[14]

- **Programmed Chart modelling**

OpenLCA helps for both automatic and visual product system development.

- Select the (Add linked processes) function in the product system toolbar if you want programme to build the connections directly.
- In the Model graph, you can even use the “Build supply chain” choice from right-click option of every operation. Automatic modelling is suggested for datasets where the standard providers are listed in all input exchanges or where there is only one available provider per commodity or waste flow.
- If you want to make a graphic representation of the product method, drag and drop procedures from the navigation panel into the model chart, then make connections by clicking on the product title and drawing a link with the matching product in the giving process. Current links can also be deleted.

- **Parameters**

  When it comes to defining values in OpenLCA, you can do so by entering a specific value, using an equation, or using intricate calculation rules. Parameter values may be used at various levels, including the database (universal), procedure, product system, project, or even impact assessment tool. A value must first be specified, which requires a default value must be allocated to it before it can be used. Parameter values may also be described as a function of others.[14]

- **Developers tool**

  After version 1.4.1, openLCA has allowed users to access Python and JavaScript programmes as well as SQL queries direct from within the application. You can use this function in openLCA to simplify measurements. Execute sensitivity analysis analyses by changing parameter, and construct your own dataset imports or exports.

CHAPTER 4

LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE IN SHIMLA

4.1 Introduction

It is a reality that cities and towns are polluted with garbage (MSW), which creates an unsightly appearance in many areas. Only the most significant parts of a city or town are kept clean, leaving many other areas choked with trash. The collected waste is disposed of in unattended landfills, and there is still a long way to go before all of a city's or town's waste is processed and only the remnants are disposed of in landfills. Municipal Solid waste management is a multifaceted matter for urban local bodies but is vital for civic health, environment and quality of life of residents.[31]. Large amount of waste is being produced by the people as a result of modernisation and shift in the lifestyle of people from agriculture to urbanisation. This voluminous waste needs to be contained in a particular place, needs to be ported at a safer site away from the residential area and needs to be eliminated in a much effective way and at a rapid rate so that less impact occurs to the environment. Waste if left open in the environment can act as a breeding ground for various harmful vectors resulting in spread of infection to humans and if waste is released in the water bodies without any treatment it leads to water pollution affecting marine life as well as polluting our water reservoirs. Hence, proper gathering, treatment and disposal of waste becomes necessary.

Owing to the huge population and the use of outdated waste management methods, the issue becomes much more complicated. The use of unsanitary practices for disposing of solid waste poses a significant health risk. Techniques and technologies are available, and indigenous methods for properly managing these wastes can be created. As a result, Indian Government via Ministry of Urban Development has launched various programs for proper disposal of waste.[2]

4.2 About the Study area – Shimla

Shimla was the British Summer Capital of India.[36] Shimla has a population of 1,69,758 people according to the 2011 Census with an average decadal growth of 35% . It is located at a latitude of 31° 4′–31° 10′ N and a longitude of 77° 5′–77° 15′ E. It is positioned at an elevation of 2130 metres above sea level.[12] Shimla, discovered by the British in 1819, has grown from a small hill settlement to one of the most popular tourist destinations. In 1966, a piece of Himachal Pradesh was carved out of the former Punjab province, and Shimla became the new state capital. Himachal Pradesh was founded in 1971.

Since the merger of New Shimla and Totu (which includes portions of Jutog) and Dhalli, the total area under the authority of MC Shimla has also grown. to 35.00 square kilometres Currently, The Shimla Corporation (MCS) is divided into 25 wards.[32]

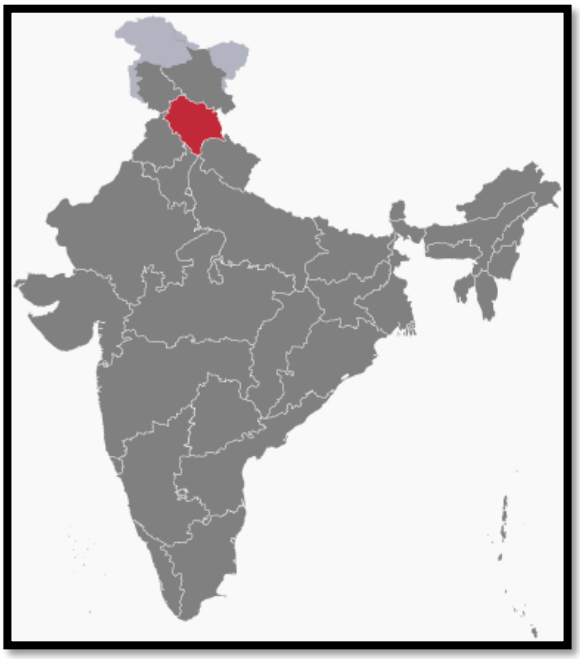

Fig4.2(a) Location of Himachal Pradesh in India (Source-Wikipedia)

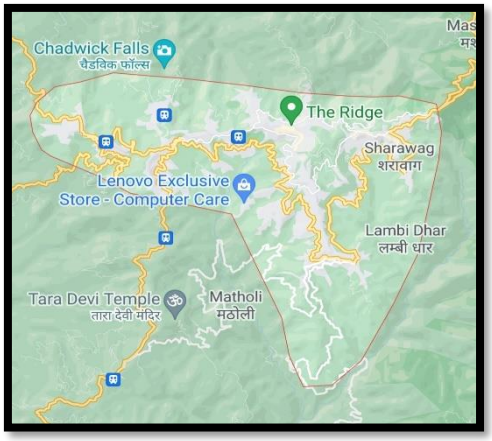

Fig4.2(b) View of Shimla (Source- Google Maps)

4.3Test methodology

4.3.1 Site Survey

A thorough investigation was conducted to collect information about the city and its waste management practises. The dispersion of the population, the fundamental sources of the waste generation region were all observed.

4.3.2 Data Collection

a) Over the initial period of days information was collected from different sources and data was sorted from Elephant Energy Plant and Municipal corporation Shimla.

b) The inspection of different categories of the waste was done by collecting waste from various sources in different wards.

c) Four scenarios were proposed for waste life cycle evaluation, with the boundaries of each framework established. The waste management scenarios were modelled using the OpenLCA. The data for the project was gathered from the research papers, software, and the municipality of Shimla in Himachal Pradesh.

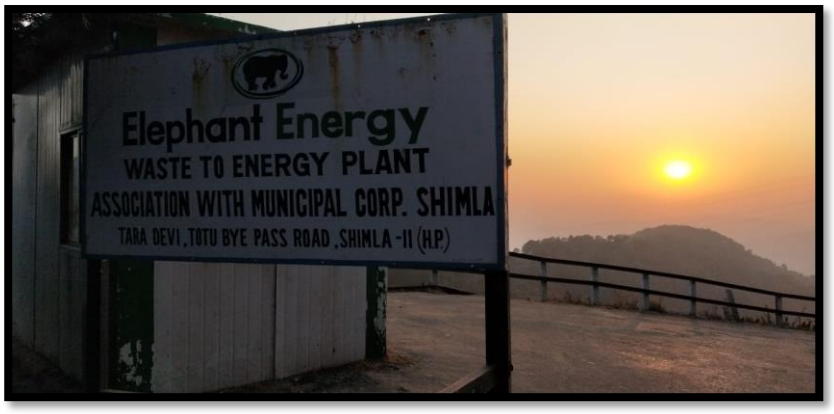

Fig 4.3.2 Elephant Energy Plant (Source- Self clicked)

4.4 Waste Generation

Waste Generation in Shimla under different categories of waste was collected. And according to it we can consider a high amount of organic waste. Daily waste disposal in Shimla town is approximately 84.5 Ton/day (calculated@350gm/capita for 242000 population including floating population) (information collected personally from office of municipal corporation, Shimla)

The generation of waste in the district varies seasonally. Since Shimla receives heavy snowfall in December-march months the institutes remain closed, chilly weather is present which limits the locals to come out owing to less littering and garbage production. Summers in the district are more pleasant as compared to that in plains which attracts a large bulk of tourist influx in summers resulting in more waste production.

4.5 Waste Storage and Collection

The essential elements of a solid waste system are waste collection and storage. Shimla lacks a proper waste storage facility. MC Shimla has made many efforts to improve waste management, but it is also haphazard, even after the enactment of Bye laws for door – to-door Garbage Collection Act in 2006. In 2009, the Himachal Pradesh Societies Registration Act 2006 was used to register the Shimla Environment, Heritage Conservation and Beautification (SEHB) Society. This community is accountable for the assortment of waste from each house. The community has given two barrels - yellow coloured and green coloured for families, trading centres etc., for basic storage and distribution. The yellow-colored bin receives non-perishable waste, and the green bin receives decaying waste within the area. Residents are found to be dumping outside the bins, causing further unhealthy conditions around the area. Shimla

Municipal Association should provide appropriate house-to-house garbage assortment facilities, dustbins should be positioned in multiple locations to dodge any contamination and unhealthy circumstances. Because of low availability of bins people dump waste in overflowing barrels. [2].

The Shimla Municipal Association has partnered with many private individuals' companies to increase the efficiency of garbage collection and laying emphasis on each door collection of solid municipal waste. By door gathering services, Shimla Municipal Corporation can achieve vacant spaces by reducing the number of containers as well combined bins. The containment of solid waste at the source point is deficient in district Shimla.[2] Common bins have also been given for gathering of waste in various locations and thus sometimes resulting in mixing of both types of wastes. And sometimes their can also be seen a portion of the municipality solid waste laying uncollected on the streets.[2] And sometimes the bins are seen as host to different animals like monkeys and dogs which causes littering of waste here and there.

On an average **65-75** tons/day waste is collected. There are **842** workers deployed through SEHB Society and **243** regular workers. Workers are deployed as per the density of population for example in area such as Sabji Mandi more workers are deployed and in other wards less workers are deployed. There are 34 Administrative Wards and waste is collected from all the wards.

The waste collected is mainly of two types –

- Wet Waste,
- Dry Waste.

The waste is collected on daily basis and door to door collection is being conducted out through SEHB Society. Different days have been fixed for collection of two types of waste.

The **Wet waste** is collected on **Monday, Wednesday and Friday.**

The **Dry waste** is collected on **Tuesday, Thursday and Saturday.** (information collected personally from office of municipal corporation, Shimla)

There is two types collection which is being implemented in Shimla which are as under [13].

4.5.1 Primary Collection

Residential population which is being covered under door-to-door waste gathering is 85% (approx.) and the remaining 15% depends on the community bins. [13].

So, considering a majority percentage of solid waste which is being collected at primary step if its treatment is done is an effective and an efficient manner and separation of different waste is also being done in a proper way then burden of such a waste on environment can be tackled in an efficient manner and such a scenario for treatment can be opted that has least environment impact and adverse effects on humans. In Primary collection system the manpower is being provided by SEHB for the purpose of gathering the garbage from all the areas coming under municipal corporation.

Fig 4.5.1 Primary Collection from household (Source-Self Clicked)

4.5.2 Secondary Collection

In this type of collection, the community bins are being provided with concrete dust bins which are 20 in number and 93 small dust bins which are of 1 cu.m placed for throwing of garbage for the local populace of the district.[13]

The concrete bins and small bins are placed at different locations so that the locals do not face difficulty in disposing of the waste and it is done in an appropriate way[13], rather than littering here and there, the waste reaches the dustbin and from there the waste can be collected and thereafter can be disposed in a proper and appropriate way.

4.6 Transfer and Transportation of Waste

With the assistance of GIZ, MC Shimla built a ward-level routing and loading strategy. At the primary stage, manual loading is used. MCS also plans to construct a waste transfer station at Darni ka Bagicha, which was initially used for the treatment of disposed waste. This transfer station would also aid in the city's routing and loading operations being optimized. transportation of waste from generation point or source point to final site plays a very vital role as a lot depends upon it.[32] If transportation of waste is followed in a proper way without waste or garbage overflowing from the vehicles and with proper rules and regulations then a proper and sound waste disposal environment can be created and waste can reach properly for its effective treatment, but sometimes generally it can be seen that vehicles while transporting the waste to final sites in order to save capital on manpower and transportation try to overload the vehicle carrying the waste and thus causing unhealthy or harmful conditions due to spillage of the waste.

Fig4.6(a) Transfer of waste collected by the worker [12]

In Shimla vehicles operating includes

- 25 Pickups vehicles (hydraulic operated),
- 7 Tippers,
- Compactors,
- 7 Dumper Placers,
- Swachhta Vahans (pickup vehicles)
- 2 Road Sweepers.

And the people employed for vehicles include – 49Drivers+11Conductors.

No of Sanitation Worker – 939(information collected personally from office of municipal corporation, Shimla)

In Shimla, garbage is pulled from bins placed in nearby areas moved to disposal area. Trash removal from source to handling centre and a landfill site is operated by the Municipality of Shimla. The entire waste of the city is gathered and ported through different automobiles with different sizes. For transportable reasons the district municipality has partnered with a number of private organizations to provide automobiles. These automobiles are called-

- Tippers,
- Pick-Ups (hydraulic and non-compression test vehicle),
- Compactors of varying sizes.

Some automobiles such as trucks which are used for solid waste removal are usually open from the back and are usually not kept covered; therefore, when transporting garbage is often spilled on the road, leading to unhealthy conditions.[2]

Fig4.6(b) Transportation of waste (source 12)

4.7 Waste handling-

The handling of waste through different techniques such as composting, recycling, landfill play a very vital role in tackling the menace of waste and if technique such as recycling and composting is done results in the formation of useful products like fertilizers through composting and renewed material by recycling that further helps in reducing the impact on the environment.

In 2001with Norwegian assistance, the Municipality of Shimla established the very first scientific waste processing and treatment unit at a place known as Darni-ka-Baghicha. Later under the directions of High Court of HP, a new treatment and disposal unit was setup by the government as the earlier was creating a lot of annoyance for the public.[32] In present

conditions the waste is directly transported to the Centralised Waste to Energy Plant set up at the Bhariyal village. The plant is based on the Gasification Technology through RDF (Refuse Derived Fuel). After the waste is received at the plant it is processed through RDF Section, where manual segregation of the stones, glass and other unwanted material is carried out. Similarly, the metals are separated through magnetic separators. Then the waste is shredded in the Primary and Secondary shredders and ultimately passes through driers to produce RDF which is a fuel for the power plant. Recyclables are separated, and some remaining waste is directed is landfill (as per information collected personally from Municipal Corporation Shimla).

4.8 Present Scenario

Waste production in Shimla region is estimated about 84.5 tons daily. Presently the waste is being collected through Door-to-Door garbage collection, practised through SEHB Society by deploying 457 doors to door Collectors and 46 garbage collecting vehicles. There is no secondary dumper containers in the public places. Only 15 No dumper containers are placed in the different premises and 102 litter bins are installed. (as per information collected personally from Municipal Corporation Shimla). The waste is directly transported to the Centralised Waste to Energy Plant set up at the Bhariyal village. The plant is based on the Gasification Technology through RDF (Refuse Derived Fuel). After the waste is received at the plant it is processed through RDF Section, where manual segregation of the stones, glass and other unwanted material is carried out. Similarly, the metals are separated through magnetic separators. Then the waste is shredded in the Primary and Secondary shredders and ultimately passes through driers to produce RDF which is a fuel for the power plant. Recyclables are separated, and some remaining waste is directed to landfill. (as per information collected personally from Municipal Corporation Shimla).

4.9 Environment Legislations-

- Plastic Waste (Management and Handling) Rules, 2011
- Batteries (Management and Handling) Rules, 2001
- Municipal Solid Wastes (Management & Handling) Rules, 2000
- Bio-medical Wastes (Management & Handling) Rules, 1998
- Hazardous Wastes (Management & Handling) Rules, 1989

- The Parliament has enacted Environment Protection Act, 1986 [12]

4.9.1 State/local legislations-

- Door to Door Garbage Collection Bye-laws (MC Shimla)- 2006
- Himachal Pradesh Non- Bio-degradable Garbage (Control) Act,1995
- Himachal Pradesh Municipal Corporation Act, 1994 [12]

4.10 Goal and Scope

The aim of our report is to analyse the effects on environment because of solid waste management techniques in Shimla region through LCA way. In this regard, we have considered different instances of municipal waste management, to select a comprehensive waste management system that includes waste management, processing and disposal areas and are compared in relation to global warming, acidification, and human toxicity (effects on human's health like carcinogenic, non-carcinogenic and respiratory effects were studied) in Shimla region of Himachal Pradesh.

4.11 Material Collected

The information needed for the life cycle assessment of municipal solid waste was collected from Elephant Energy Shimla (Waste management service), municipality of Shimla in Himachal Pradesh and the database of the software was used.

S.No	Data Required	Data Available
1.	Waste Generation	84.5 Ton/day (Calculated @ 350 gm/capita for 242000 population including floating population)
2.	Type or category of waste	Wet waste & Dry waste
3.	Pick Ups for Waste	The collection of the garbage is done on everyday basis , SEHB is playing its role by door to door waste collection. Wet waste -Monday, Wednesday and Friday Dry waste- Tuesday, Thursday and Saturday

4.	No. of Blocks Divided	34 administrative wards
5.	Collection Rate	On an average **65-75** tons/day waste is collected.
6.	No. of Workers	There are **842** deployed through SEHB Society and **243** regular workers. **Total: 1085**
7.	No. of Vehicles	**25 pick-up vehicles** **7 tippers** **2 compactors** **7 dumper placers** **2 Swachhta vahans** **2 road sweepers**
8.	People employed for vehicles	**49 Drivers + 11 conductors**
9.	No. of sanitation workers	**939**
10.	No. of workers per household	Workers are deployed as per the density of population e.g. in Sabji Mandi area more workers are deployed and in other wards less workers are deployed.

Table no. 4.11 (a) Data collected (information collected personally from office of municipal corporation, Shimla)

S.No	Category of waste	2020(%)
1.	Kitchen waste/Hotel waste	46.7
2.	Paper waste	10
3.	Multi-layer plastic	8
4.	Single use plastic	5
5.	Pet Bottle	6.5
6.	Metal	5.5
7.	Electronic waste	0.2
8.	Glass Bottle	6.5
9.	Rubber/Leather	0.1
10.	Textile	1
11.	Green waste	5
12.	Others	5.5
	Total	100

Table no. 4.11 (b) Types of waste collected (information collected personally from office of municipal corporation, Shimla)

4.12 Life Cycle Assessment (LCA)

LCA - study for evaluating environment impacts linked with different stages of any product, process or service. So, we can say this is an important study concerning to know that what impacts are associated with which service or process. So, by studying different process we have the liberty to choose the process having the least environment impact. In today's scenario where so much focus is being given to environment and people from different parts are raising their voices to defend the environment than such a study can prove to be very beneficial.

In our study we will be looking at effects on environment on basis of-

- Global warming,
- Acidification,
- Human toxicity or impacts on humans on the basis of like- 1) carcinogenic, 2) non-carcinogenic and 3) respiratory effects will be studied.

- **Global Warming –** Heating of the earth atmosphere over the period of time due to emissions of different greenhouse gases into the atmosphere from human activities mainly fossil fuel burning can be termed as global warming.[33] Climate change is caused by global warming, and it poses a significant danger to human life on the planet in the form of massive floods and severe weather.[37]

- **Acidification-** is a process that is characterized by increasing concentration of hydrogen ions(H+) in soil or water**.** As a result, rising acidification is often understood as a decline in environmental sustainability. Acidification is caused by a variety of natural and anthropogenic factors, but the most prevalent issues are linked to a condition known as acid rain**.** [34]

- **Human Toxicity –** These are chemicals emitted into environment in different forms like soil, air, water etc. during all life cycle and these have the potential to cause toxic impacts on humans like cancer and non-cancerous effects which are termed harmful to humans.[35]

4.13 Results and Discussion

4.13.1 Baseline Scenario

The results of the Baseline line scenario which we considered was being followed prior to present scenario - which is approximately 10% of waste is recycled, 40%of waste is directed at the compost plant and remaining 50% to dumping site.

The Impacts given by this scenario are as under :

Indicator	Composting, Recycling and Dumping-Baseline Scenario	Unit
environmental impact (acidification)	2.28550e+2	moles of H+-Eq
environmental impact (global warming)	-7.22416e+3	kg CO2-Eq
human health (carcinogenics)	1.26320e+0	kg benzene-Eq
human health (non - carcinogenics)	3.02461e+3	kg toluene-Eq
human health (respiratory effects, average)	1.13883e+0	kg PM2.5-Eq

Table no. 4.13.1 Impacts of base line scenario

Single Indicator Results:

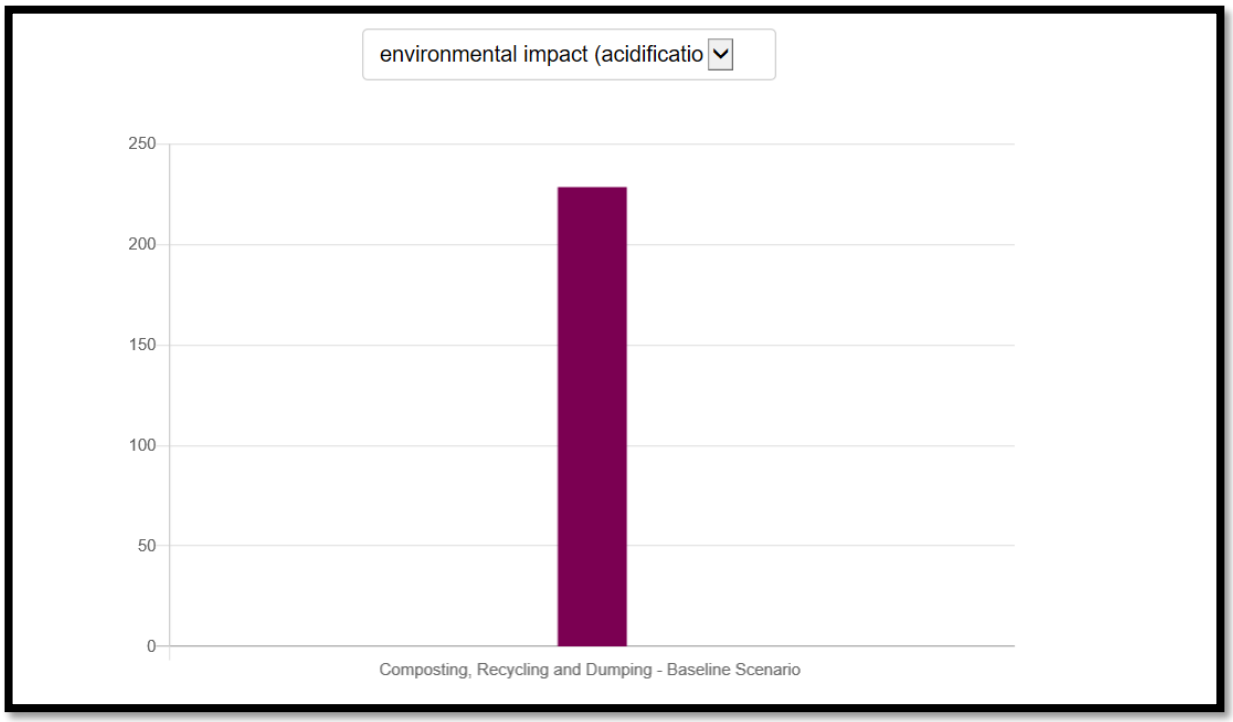

Fig 4.13.1 (a) Environmental impact (acidification)

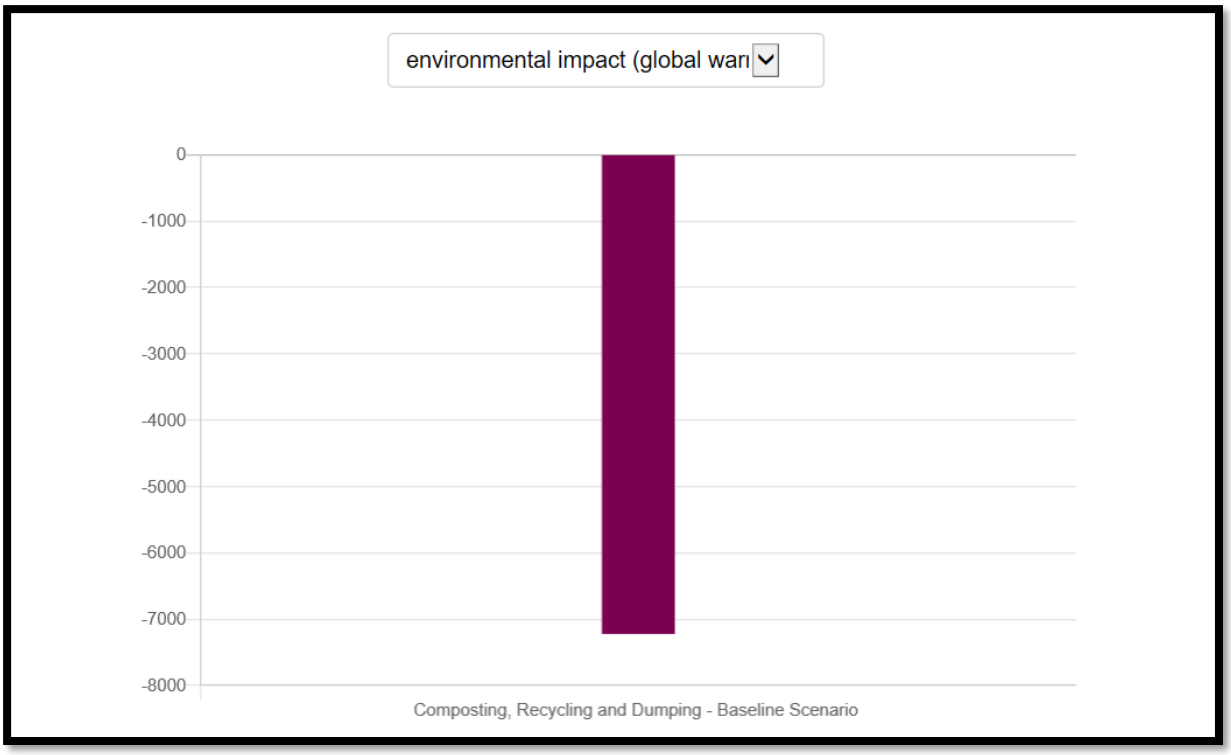

Fig 4.13.1 (b) Environmental impact (Global Warming)

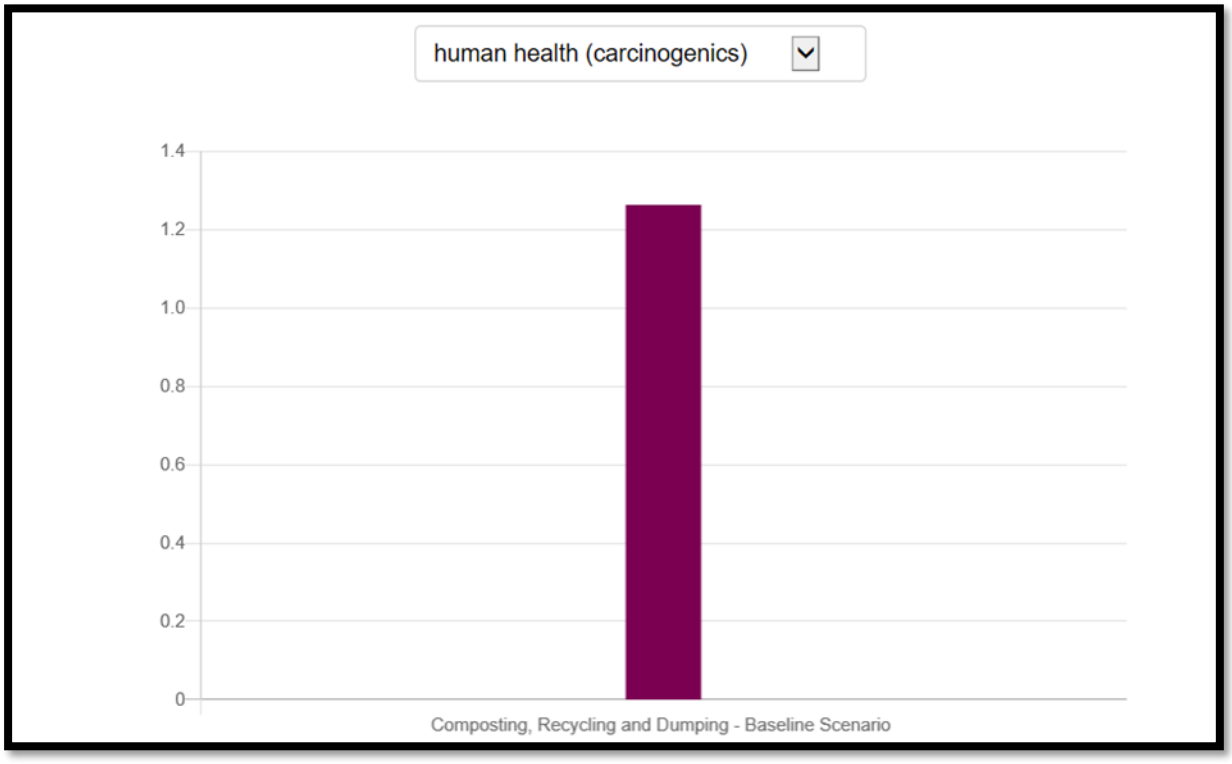

Fig4.13.1(c) Human health (carcinogenics)

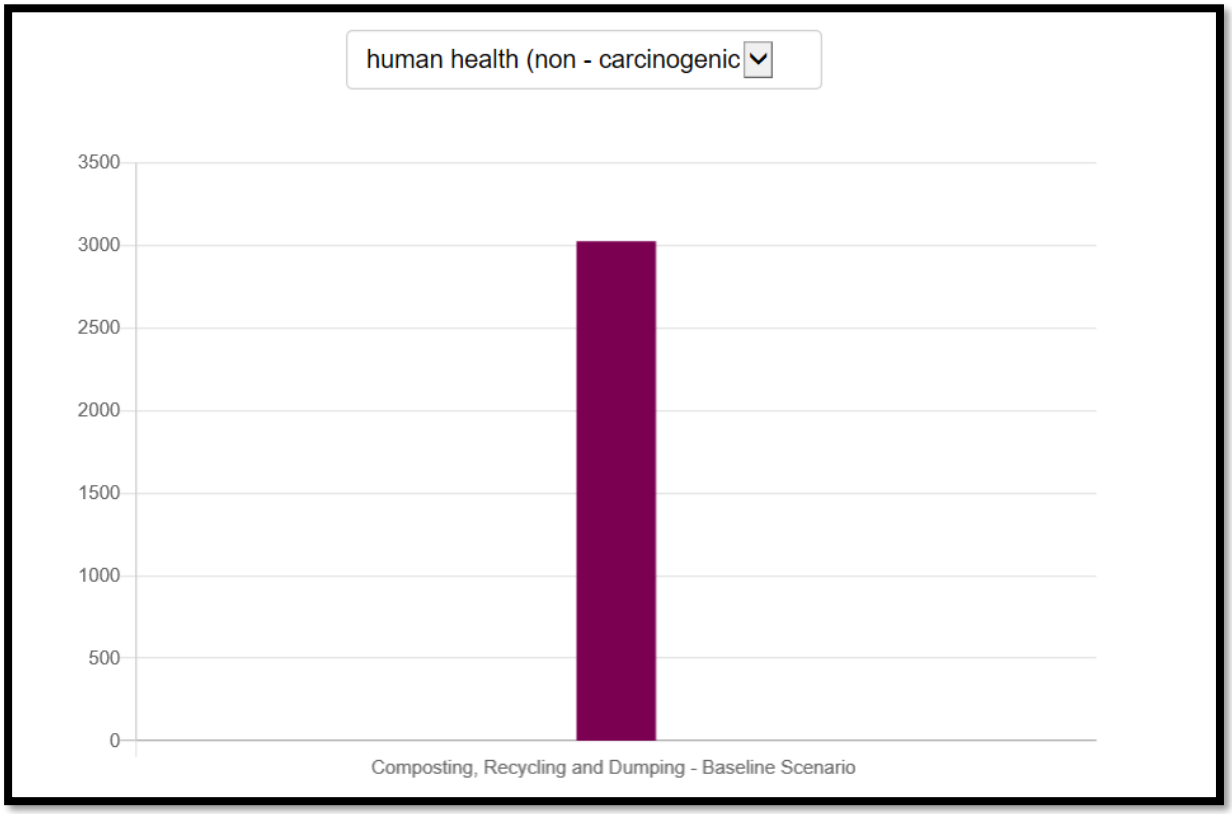

Fig4.13.1(d) Human Health (non-carcinogenic)

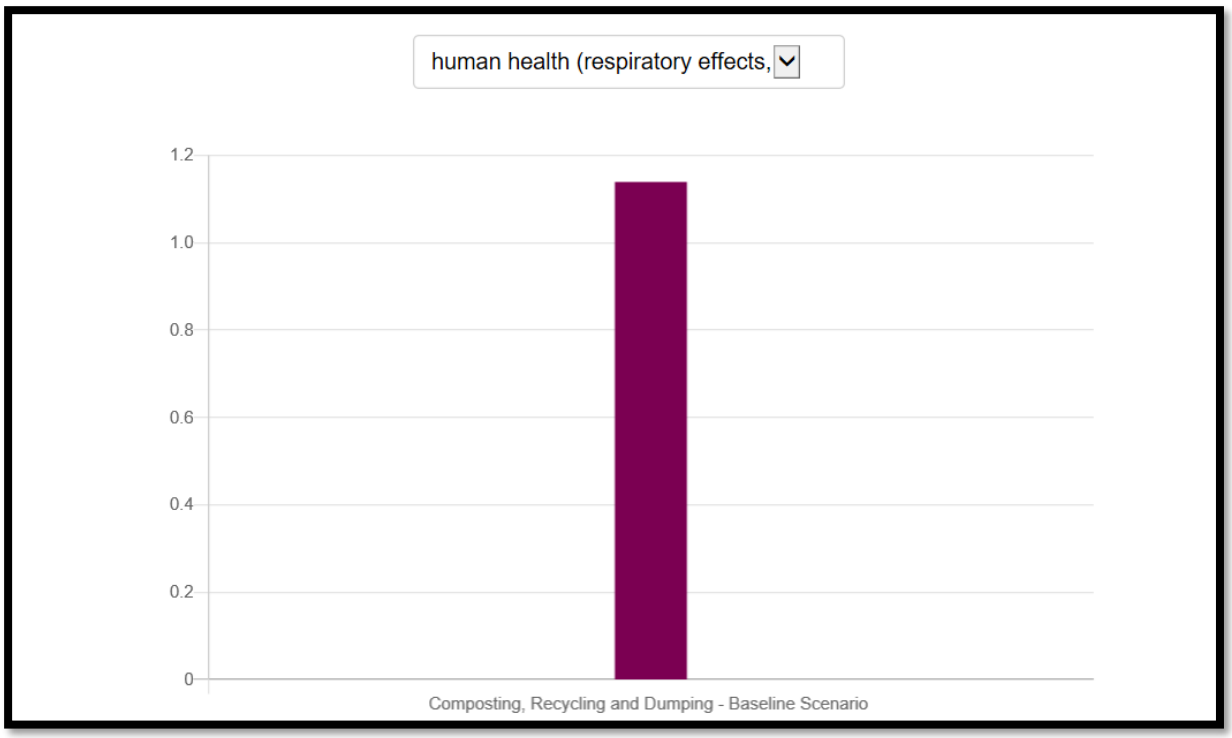

Fig4.13.1(e) Human Health (respiratory effects)

4.13.2 Scenario 2

The scenario considered by us in this for was treatment was 20%recycling, 40%incineration and 40%dumping.

The Impacts given by this scenario are as under -

Indicator	**Incineration, Recycling and Dumping**	**Unit**
environmental impact (acidification)	4.39951e+2	moles of H+-Eq
environmental impact (global warming)	3.26826e+1	kg CO2-Eq
human health (carcinogenics)	3.38788e+0	kg benzene-Eq
human health (non - carcinogenics)	1.89469e+4	kg toluene-Eq
human health (respiratory effects, average)	1.73061e+0	kg PM2.5-Eq

Table no. 4.13.2 Impact of scenario 2

Single Indicator Results:

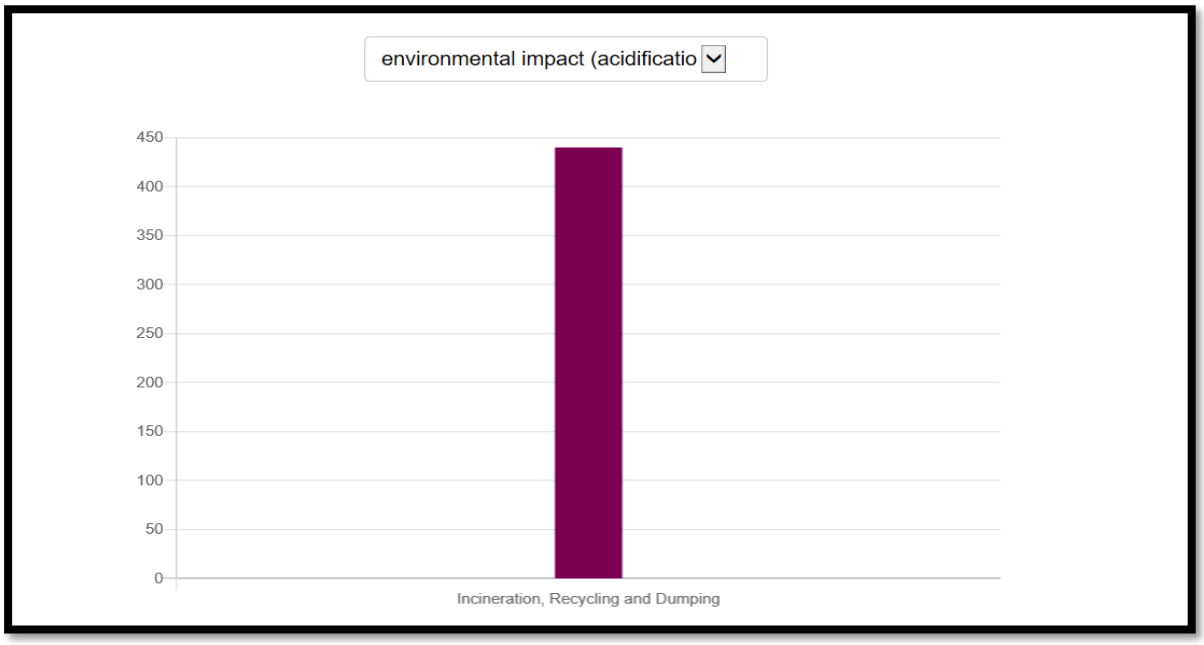

Fig 4.13.2(a) Environmental impact (acidification)

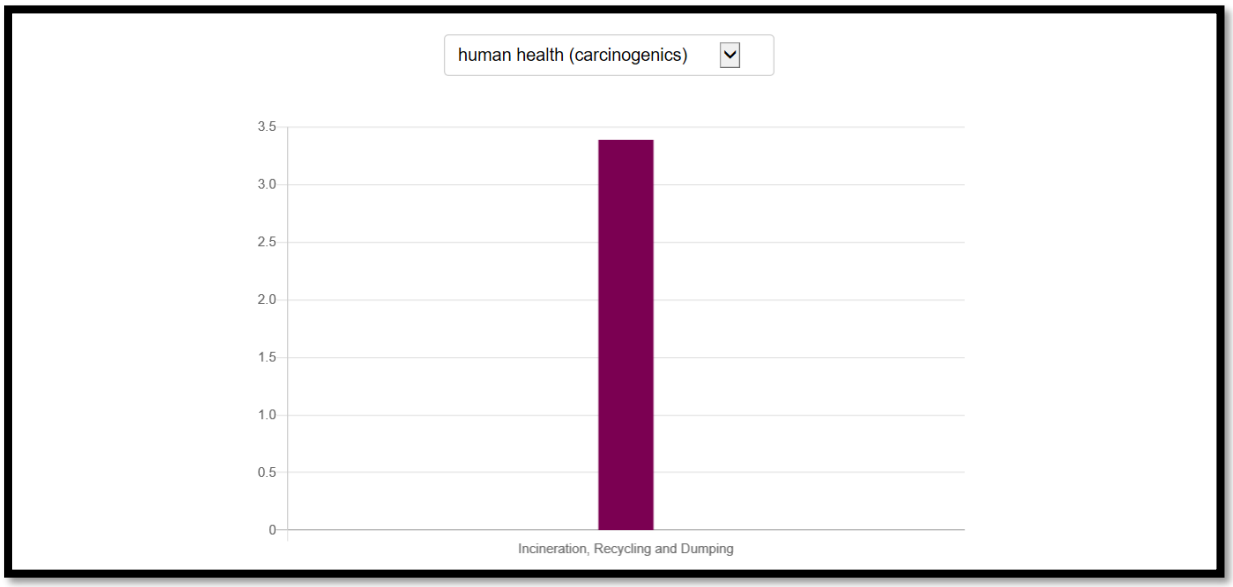

Fig 4.13.2(b) Human Health (carcinogenics)

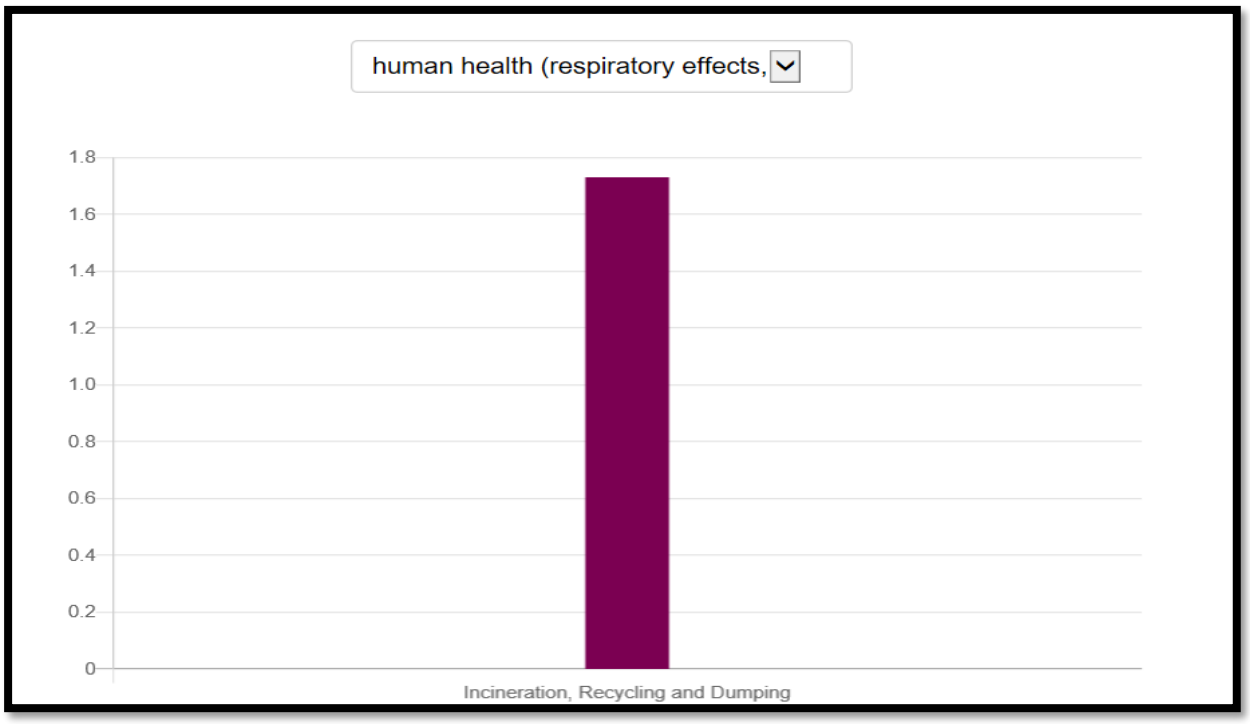

Fig 4.13.2(c) Human Health (respiratory effects)

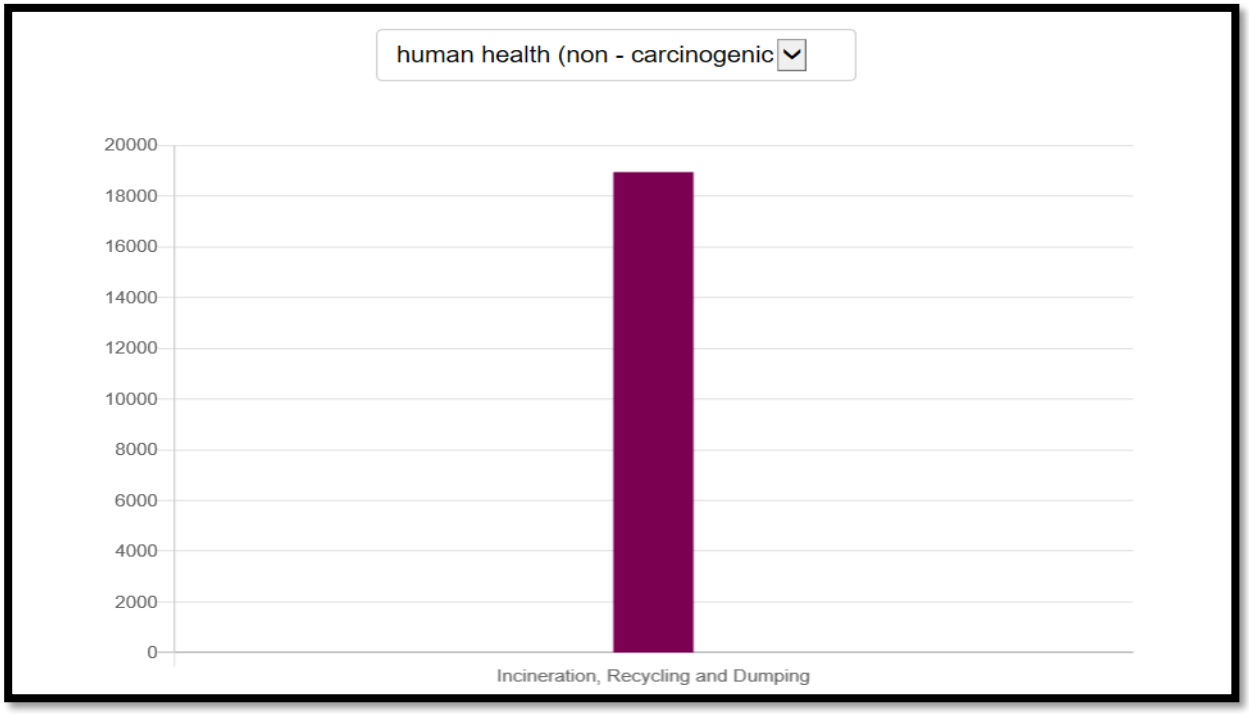

Fig 4.13.2(d) Human Health (Non -Carcinogenic)

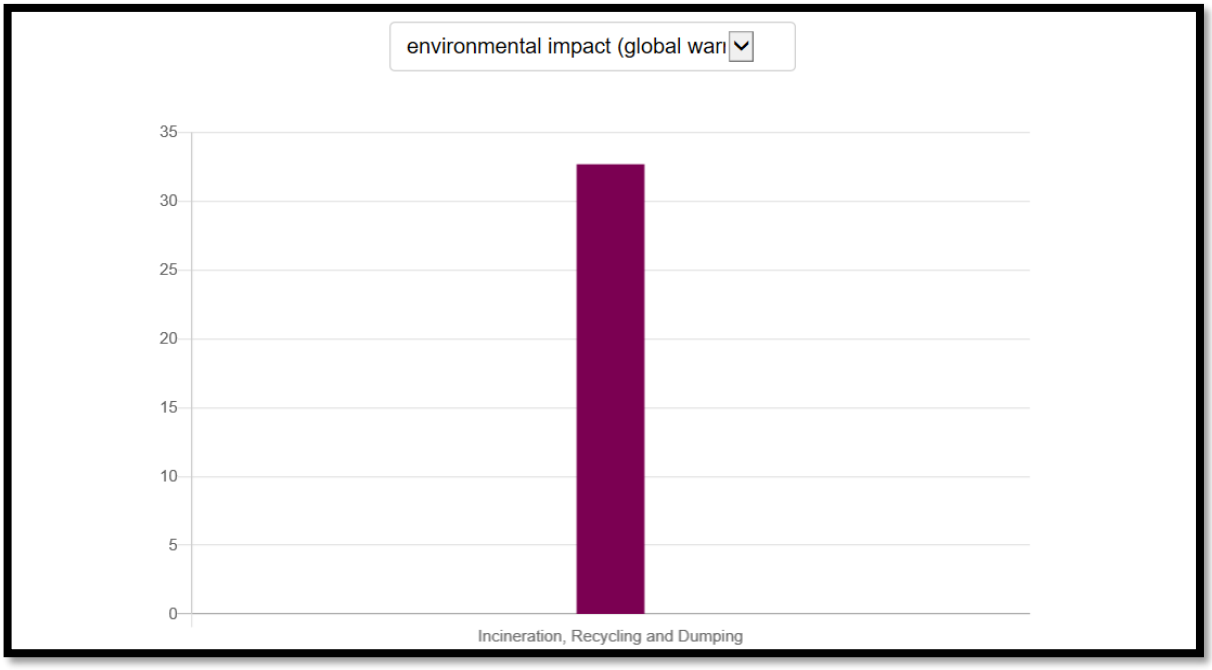

Fig 4.13.2(e) Environmental impact (global warming)

4.13.3 Scenario 3

The scenario considered by us in this for was treatment was 50% Composting, 20%Sanitary Landfill, 30% Recycling.

The Impacts given by this scenario are as under -

Indicator	**Composting, Sanitary Landfill, Recycling**	**Unit**
environmental impact (acidification)	-1.81496e+2	moles of H+-Eq
environmental impact (global warming)	-2.16635e+4	kg CO2-Eq
human health (carcinogenics)	-4.55363e-1	kg benzene-Eq
human health (non - carcinogenics)	-3.37093e+3	kg toluene-Eq
human health (respiratory effects, average)	-5.34365e-1	kg PM2.5-Eq

Table no. 4.13.3 Impacts of scenario 3

Single Indicator Results:

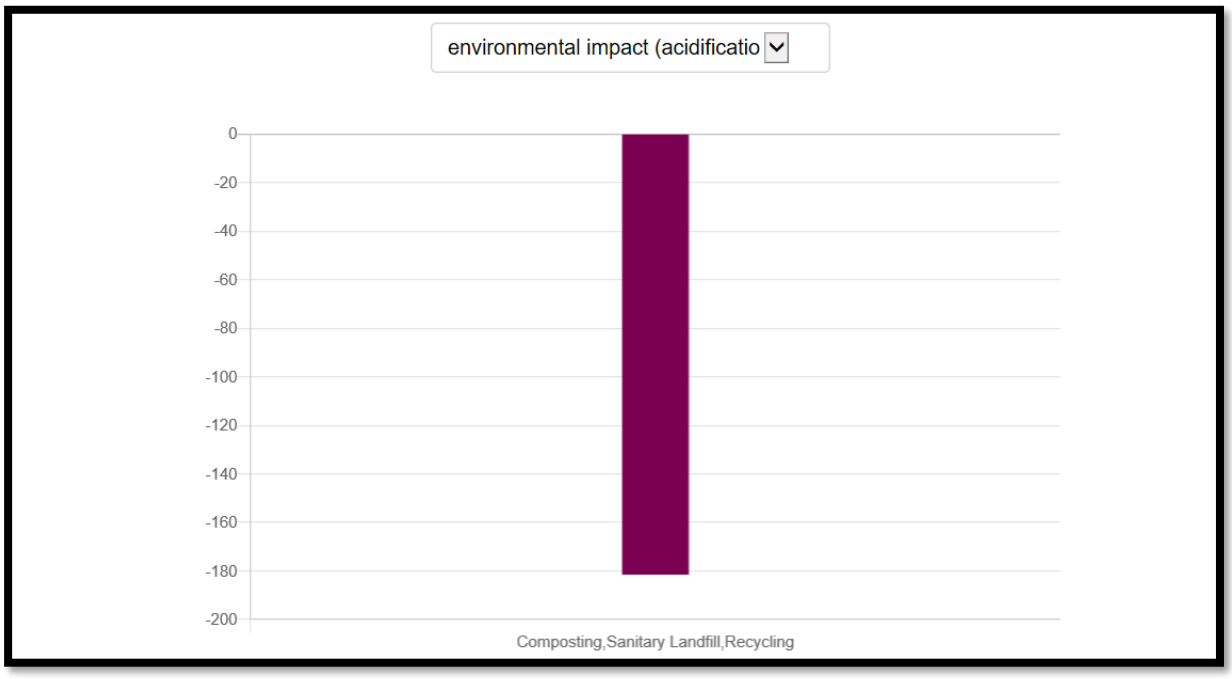

Fig 4.13.3(a) Environmental impact (acidification)

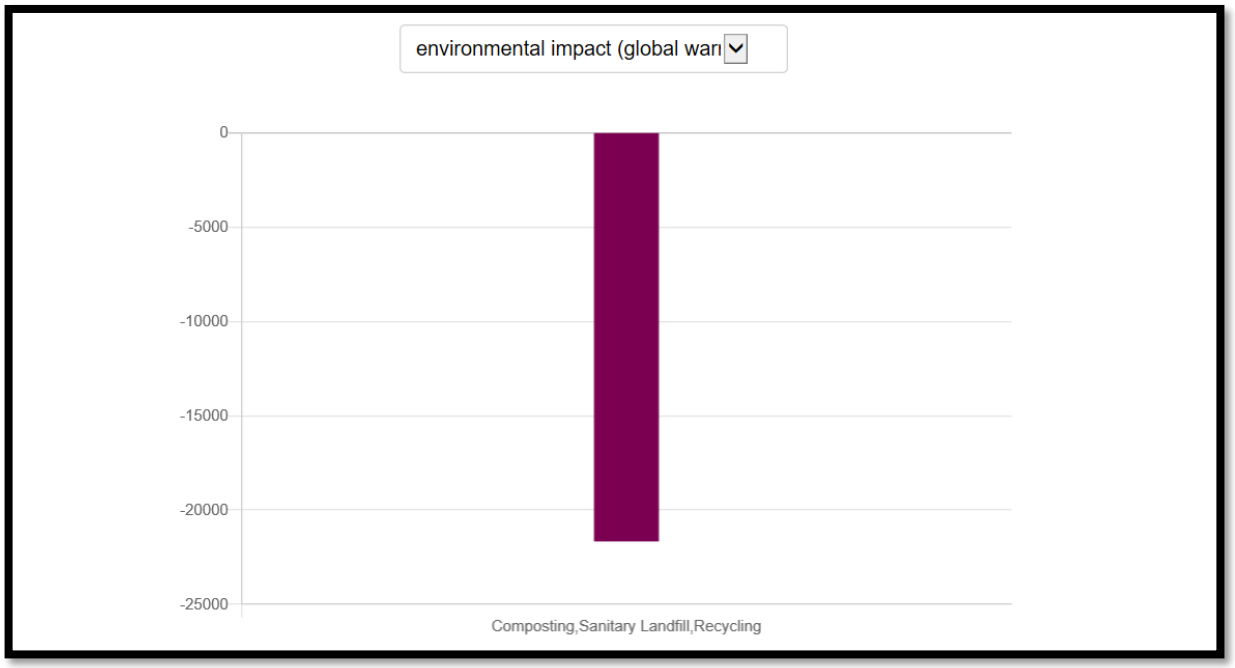

Fig 4.13.3(b) Environmental impact (global warming)

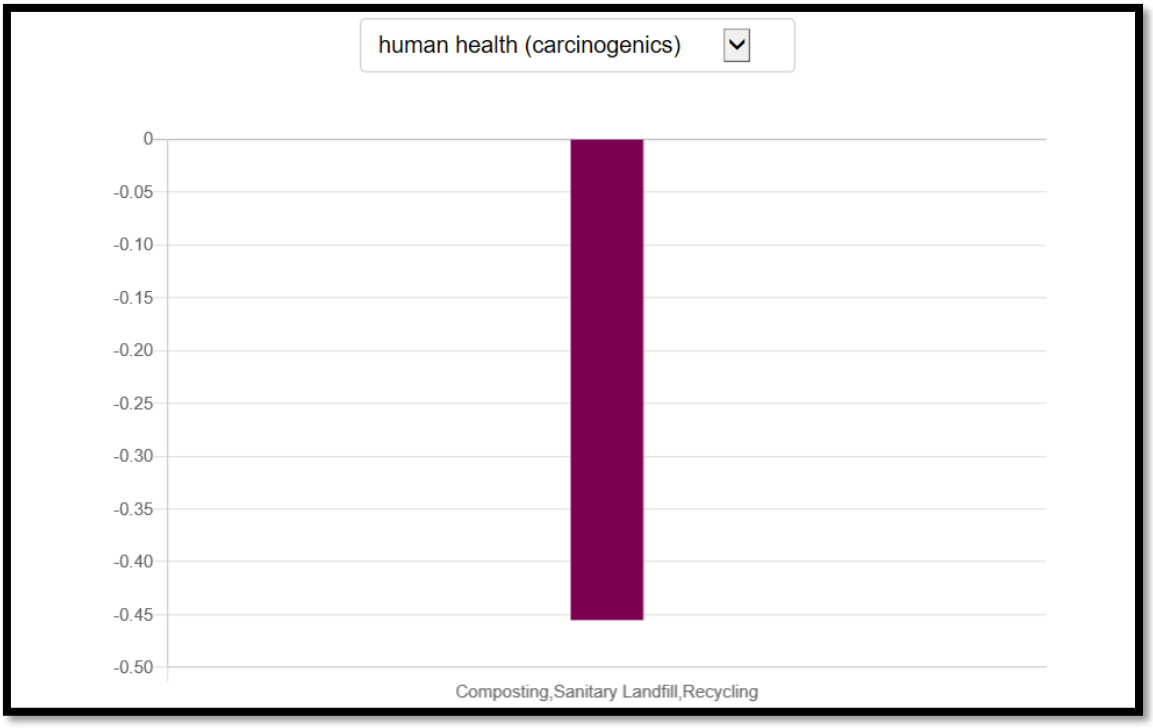

Fig 4.13.3(c) Human health (carcinogenics)

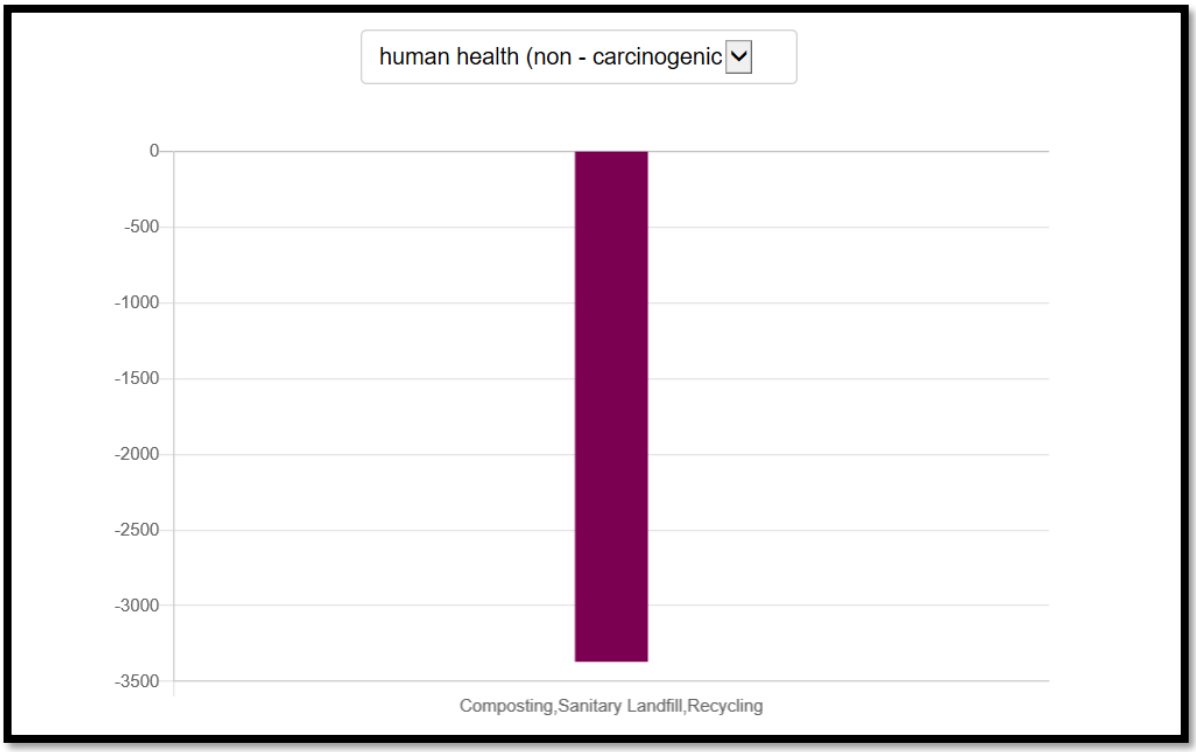

Fig 4.13.3(d) Human health (non carcinogenics)

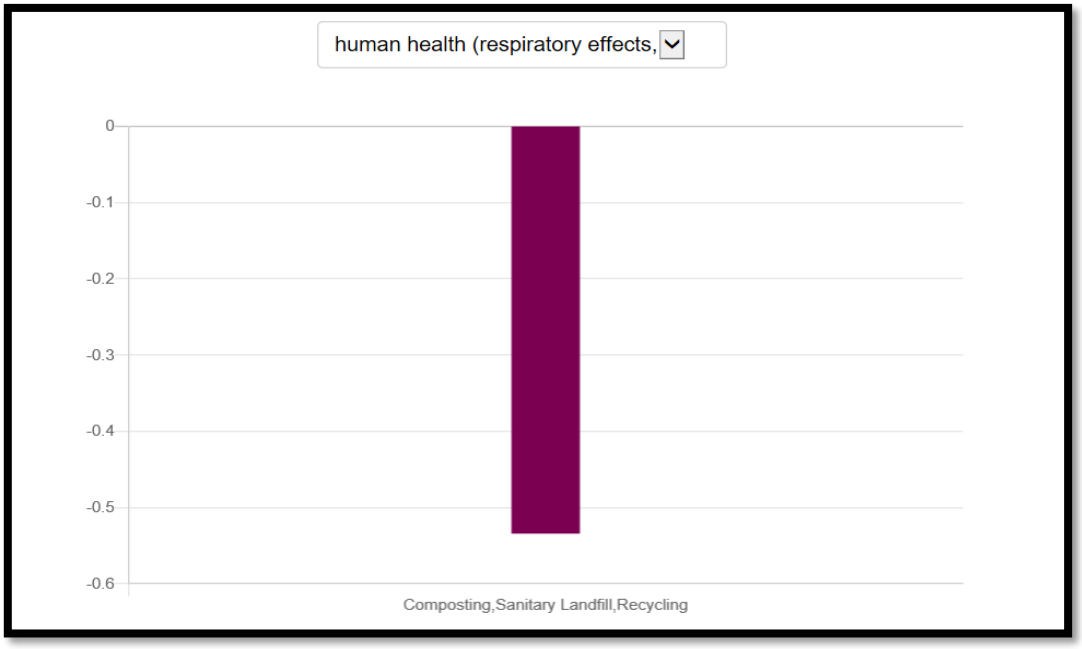

Fig 4.13.3(e) Human health (respiratory effects)

4.13.4 Scenario 4-

The scenario considered by us in this for was treatment was 50%Incineration, 30%Sanitary Landfill, 20%Composting.

The Impacts given by this scenario are as under -

Indicator	**Incineration, Sanitary Landfill and Composting**	**Unit**
Environmental impact (acidification)	-3.48037e+2	moles of H+-Eq
Environmental impact (global warming)	-1.25622e+4	kg CO2-Eq
Human health (carcinogenics)	2.62537e+0	kg benzene-Eq
Human health (non - carcinogenics)	5.49447e+4	kg toluene-Eq

Human health (respiratory effects, average)	-2.01023e+0	kg PM2.5-Eq

Table no. 4.13.4 Impacts of scenario 4

Single Indicator Results-

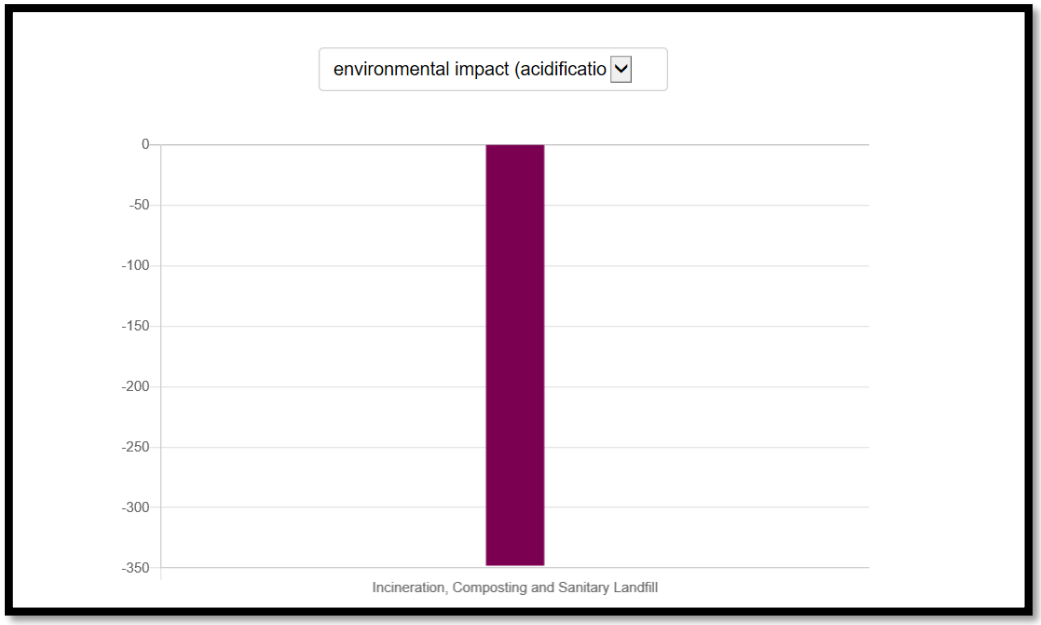

Fig 4.13.4(a) Environmental impact (acidification)

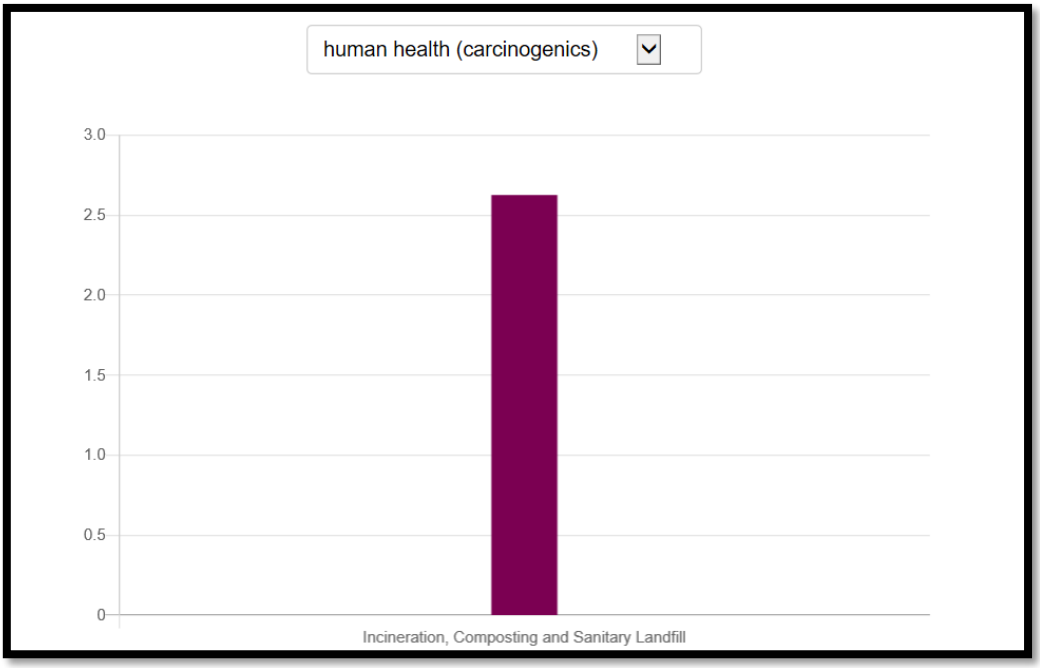

Fig4.13.4(b) Human health (carcinogenics)

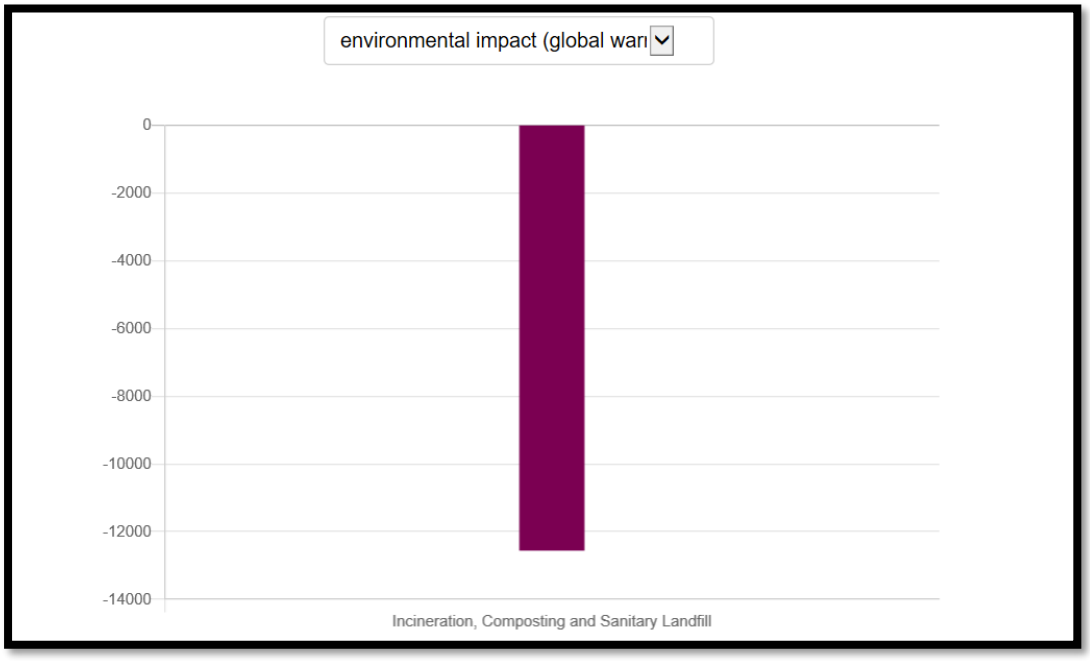

Fig 4.13.4(c) Environmental impact (global warming)

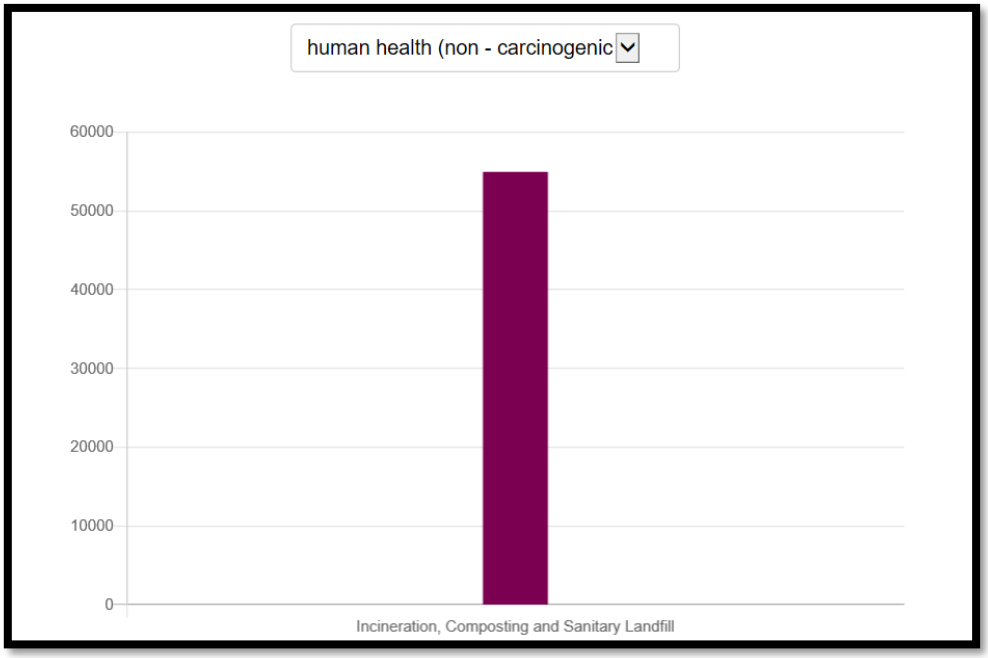

Fig 4.13.4(d) Human health (non-carcinogenics)

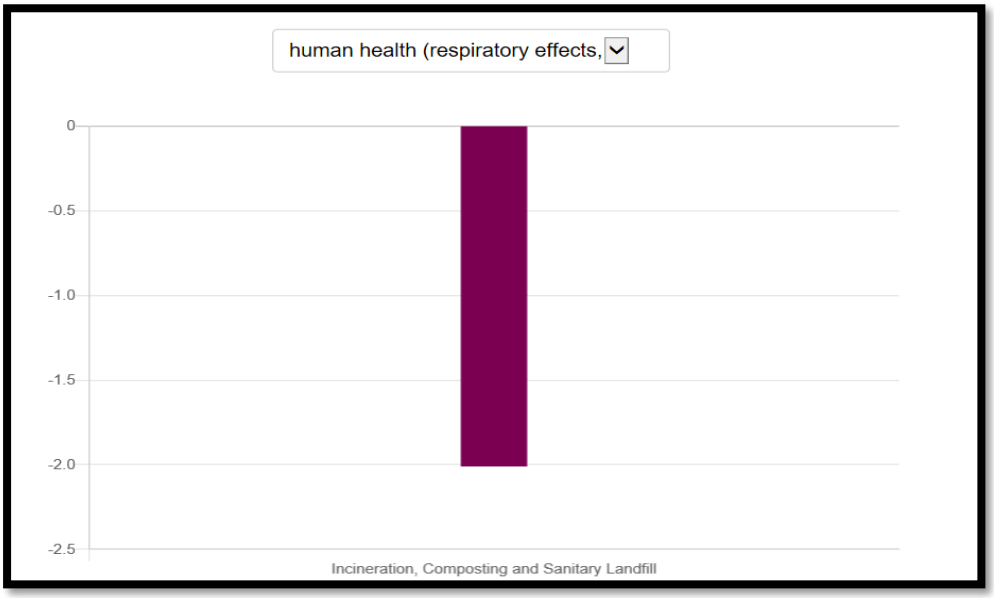

Fig 4.13.4(e) Human health (respiratory effects)

4.13.5 Comparison

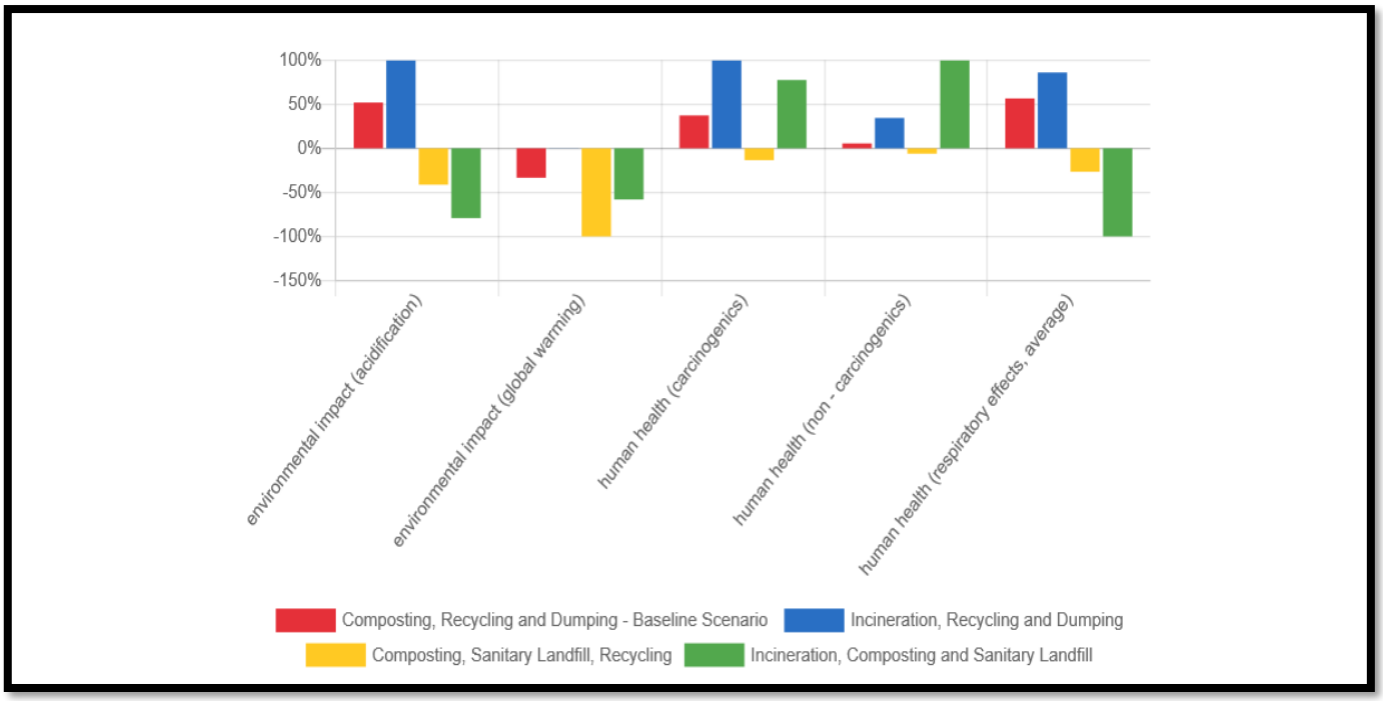

Fig 4.13.5 Comparison

By relative analysis results have shown that out of all scenario we have considered for our study, scenario 3 which included waste treatment through- Composting, Sanitary landfill and Recycling, has the least amount of environmental impact studied under the categories of acidification, global warming and human health which was studied under categories of effects like carcinogenic, non-carcinogenic and respiratory effects, therefore this scenario has minimum effect and is most viable answer for the management of waste in Shimla.

Use of LCA for various MSW management scenarios can help municipals to develop the best scenario, but although LCA gives the best solution for treatment of waste but certain countries also have to consider their economical capacity as different countries have varying capital which they can spend on treatment as in most cases most capital is spent on the operational costs. But still, LCA can provide them with imperative knowledge that which scenario is best for them in terms of both capital power and environmentally friendly.

CHAPTER-5

CONCLUSIONS & RECOMMENDATIONS

5.1 General

This chapter contains a description of the findings and conclusions reached as a result of the software and inquiries conducted during the report.

5.2 Conclusions

- Life Cycle Assessment of MSW in Shimla led us to the conclusion that Scenario 2 (as compared to all the other scenarios) has a large impact on the environment and human health. The environmental effect of the baseline scenario is the second highest among all the scenarios.
- It was concluded through our study that a slight variation in input would result in a great variation in the impact. Such as in Scenario 3 recycling and composting was increased than the baseline scenario which has reduced the impact on the environment.
- Scenario 2 and Scenario 3 had the highest and lowest values, respectively, for potential global warming, acidification, and human health potential.
- It is deceptive that the incineration has maximum contribution for global warming, acidification, and human health potential. In Scenario 2 and Scenario 4, incineration was used as the treatment for the waste. The relative study shows that is having detrimental impact on human health mainly under two parameters (carcinogenics and non-carcinogenics). So, it is should be our least for preference for management of waste.
- Finally, all of the findings and studies point to the importance of conducting a life cycle assessment of Shimla's MSW management in order to minimise environmental impact by selecting the most appropriate method of handling various forms of municipal waste.

5.3 Recommendations

- Improvement in the quality of the collection, additional sanitation workers should be recruited and trained.
- New sites must be considered in the construction of these engineering waste disposal facilities, such as nearby landfills are about to be built, and this can be achieved by raising

citizen awareness about the benefits of resource allocation and its role in waste management and the establishment of the unit used to recycle the city of Shimla.

- Sanitation staff should be inspected on a regular basis, and the use of preventive waste management methods is encouraged.
- Colouring bins should be more promoted because it aids in the separation of garbage into different categories such as living, inanimate, inorganic, and hazardous substances.

5.4 Future scope for the work

- Calculation of the costs and benefits of the proposed MSW requirements should be made for a complete picture of the MSW economic management.
- LCA can be conducted through numerical analysis in MSW.

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