TURNING WASTE INTO ENERGY – CASE STUDY OF UTTARAKHAND CITIES

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SECTION 1

INTRODUCTION

Uttarakhand was carved out of Uttar Pradesh on 9th November 2000. Major portion of Uttar Pradesh (especially western part) became Uttarakhand. Uttarakhand is also known as the "Land of Lord" or "Dev Bhumi". Uttarakhand is one of the most beautiful places which attracts people from India as well as from Foreign. Due to high rate of tourist activities the government decided to maintain its beauty as natural as possible and therefore, government formed the Municipal Solid Waste (Management and Handling) Rules in 2000. There were many projects launched by the government to manage the solid waste in major cities of Uttarakhand which includes Dehradun, Rishikesh, Haridwar, Tehri, Haldwani, and Nainital and as of now these ventures are in different phases of culmination.

Improper management of waste and environmental issues are causing hazardous effects

[2] The aim of Ascension's discussion paper series is to encourage researchers to share their work within research fraternity and to obtain feedback to enhance quality of the research and to also to take up new researches on the related topics based on the feedback obtained. All views expressed in discussion papers published by ACRA are solely of the authors and not of the organisation.

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on the cities. Waste is generated naturally, as it is a part of human activity which is unavoidable but with the proper management of waste, energy can easily be generated, and proper management of energy could solve many problems and provide new life to everyone. Increasing level of waste is causing many problems to everyone especially people who are living in urban areas are facing health issues. The main sources of solid waste are residential, commercial, institutional, constructional, industrial and agricultural. Due to these issues, major administrative steps are being taken concentrating on "3 R's" - Reduce, Reuse and Recycle for the advancement of human wellbeing.

Government of India Ministry of New and Renewable Energy 12th PLAN PERIOD (2012-17) focuses on promotion of projects which would help in recovery of energy from urban, industrial and agricultural wastes; and to create conducive conditions and environment, with fiscal and financial regime, to develop, demonstrate and disseminate the information of utilization of wastes and residues for recovery of energy. Ultra-High Temperature Hydrolysis (UHTH) project was set up by the government to establish India's first UHTH plant in Roorkee using German technology. The project uses seven major cities' solid waste and convert it into electricity and as per the contract signed between the parties this production of electricity will be supplied to Uttarakhand Power Corporation Limited. The privately financed plant will have the capacity to receive, handle and process 550 metric amount of unsegregated strong waste regularly exuding from urban and modern zones every day. The plant will have a shut reactor where ultra-high temperatures of up to 1,300 degree Celsius are utilized to separate natural materials and create power. This is for the first time that the innovation concocted in Germany will be utilized outside Europe. Meanwhile, Center has coordinated with Union service of the new and sustainable power source to characterize the innovation as an "inexhaustible wellspring of vitality" and to investigate ways it can be utilized to encourage Swachh Bharat Mission. Maximum amount of waste is generated by companies which if not controlled could be extremely hazardous. As more individuals move to urban regions and as livelihoods increment, utilization levels are probably going to ascend, so are the rates of environmental issues. It is estimated that the rate of waste generation is increasing day by day. Every year, about 1-1.33% per capita waste generation increases in India (estimation).

Waste to Energy i.e. WTE uses different kind of methods and technologies that convert the

solid waste into energy which includes electricity, heat and fuel. The disposal of organic waste can be used in the form of composting and various kinds of composting of degradable wastes can be generated. But the disposal of hazardous and inorganic waste can cause landfills and health issues therefore, to avoid these issues inorganic wastes can be used in the form of filling in the road construction and low lands. There is a complete procedure which is to be followed for converting waste to energy and this procedure includes incineration, gasification, pyrolysis, anaerobic digestion, and landfill gas recovery. This process is very simple and is used by many private plants in converting the waste to energy. From the business point of view Waste to Energy is a very profitable and recession free business because there is free supply of the raw material and abundance of waste generation as it is a part of human life.

Research objective

Energy management is a very important concept from the point of view of economics, as it explains the energy generated from various sources in various dimensions and ways such as alternative current, high, low or medium voltage, high and low amps, time variant etc., all these combinations can be used in smart ways. It is used to decide the amount of energy which is required and then is stored for the long as well as short terms to avoid power cut and failure issues. The municipal solid waste (MSW) is also one of the major issues which mainly increases due to urban population. The conventional dumping and treatment techniques for the MSW have some major ecological difficulties.

The following are the objectives of this study-

- To make people aware of the process and to explain that waste to energy is an alternative source of energy which can be utilized for their consumption.
- Calculation of energy potential from waste of Uttarakhand.

Research hypothesis

H0-: Waste to energy method are viable for energy production and fulfilling demands in Uttarakhand.

H1-: No, the energy production potential is not viable and is unable to fulfill the demands.

Methodology

The purpose of this research is to know the answers of questions (gap) by applying methodologies and mathematical analysis procedures. To have the best results of the research work, it is very important to have proper and prepared planning for the study in advance for the analytical study using the data collection from secondary data sources, so that conclusions could be drawn from the results. For the fulfillment of the objectives and testing of the hypothesis various are to be collected. There is a direct and positive relationship between waste generation and the population size. Therefore, the data of Uttarakhand is divided in various classes on the basis of their population and with this procedure, it will provide the best results of the analysis presenting which area has the best potential to produce energy from the waste.

From the sources' observation the population of each city in Uttarakhand could easily be estimated, such as Class-A, greater than 100000, Class- B, 80000-100000, Class-C, 60000- 80000, Class- D, 40000- 60000, Class- E, 20000- 40000, Class- F, less than 20000.

Table – 1 Town classes, no. of towns, and average waste generation.

Class	Population	Number of towns / cities	Average Waste generation
Class A	More than 45000	8	0.397416907
Class B	45000- 35000	5	0.321620535
Class C	35000- 25000	6	0.482520499
Class D	25000- 15000	7	0.361473138
Class E	15000- 5000	22	0.401258625
Class F	Less than 5000	12	0.361373215
Total		60	

Source – As compiled by author

In-depth the study of the potential of energy production from waste generation and results are based upon the data provided by the municipality of Uttarakhand on their website. This study also identifies the potential of calorific value from the municipal solid waste generated in various cities of Uttarakhand. All the related and relevant information are used to analyze energy penetration through proper literature reviews of different research papers and articles.

SECTION 2

MUNICIPAL SOLID WASTE MANAGEMENT

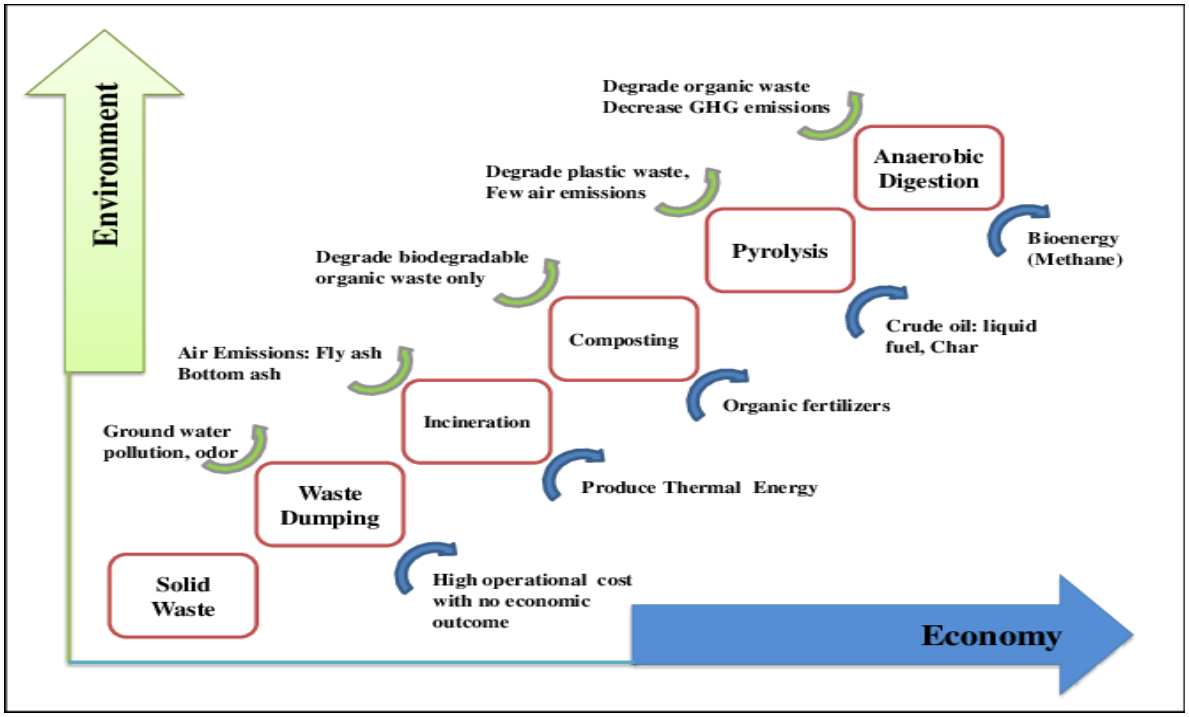
Waste -:

Waste can be categorized into three parts viz. solid waste, liquid waste and gaseous waste. It is commonly believed that, waste is that thing which is not in use or which cannot give any economic value addition to the society. It is true that waste is generated out of a natural process which cannot be stopped. However, it can be managed in a proper way. Majorly, solid waste gets disposed of by various methods, the easiest and bad practice of which is landfilling, which is being continued at various sites outskirts of cities.

Solid waste management-:

It is a common practice adopted by the world to deal with their daily pile of waste generated. Several methods are used like incineration, waste to energy, decomposition, landfilling, etc. The most dangerous and harmful practices of all is landfills of solid waste. Landfills generate more diseases due to exposure to harmful gases such as methane and Co2 in the ratio of 90% and 10% other gasses. They spread health problems, water pollution as well as air pollution. Still, it is the most common practice being adopted by municipalities responsible for city-level waste management.

Figure- 1: Solid waste management hierarchy for various technology.



(Anjum et al., 2016)

This figure shows the hierarchy of solid waste management practices. The top of the pyramid is the best option of management of solid waste and going down it shows the least favoured option of treatment.

Reduction of waste-:

This is one of the most common strategy used to prevention the waste generated by the society in the course of their daily chores. Many countries used this strategy to control the waste production. As per the statistics, it has been seen that developed countries produce more waste per capita than the developing countries. America is also known as the throw-away society, wherein about 4 pounds average waste is generated by per capita. Japan took various steps to make it a zero-waste production country, but even after applying various technologies, it produces 0.36 M/T of waste each year.

Packaging of goods produce about 50% of waste, so if we reduce the packaging, waste can be minimized. At the national level, there are several methods which can be employed to prevention the production of waste. In developed nations, mass production of

consumer goods makes a product cheaper than those of developing nations. It leads people to develop a throw-away mind-set, and they simply throw away goods rather than bearing the repairing cost.

Reuse /Recycle-: This is the second and the most popular strategy used to prevent waste in small cities or municipalities. To some extent, segregation takes place in a household, followed by several segregations by the local waste picker during waste collection from door to door. This segregation helps in reduction of area required for landfills. Recycling is an economically viable activity, helps in generating money by transferring to the small business enterprises. In the posh areas of cities, many buyers of waste collected can be seen. Recycling has a potential to become an economically viable activity for households also. Only a little more direction is required to make the proper recycling practices in society. In India, collection of recyclable waste by a buyer at every house is a common practice since long. They pay a decent amount money per kilogram based on the material bought like cardboard, plastic, paper, glass, etc. Government of Uttarakhand decided to prevent waste of polythene and plastic and for this they start buying waste from people and in exchange of money at the value decided by supplier. It has been observed, about 50% of plastic and polythene waste is in every 300 M/T of waste collected.

Anaerobic Digestion or Composting-: This strategy of waste management requires very less technological interventions. Composting is the process of converting the waste into manure and this manure can be used to make land more fertile in producing the organic foods items. This process will also reduce in occupying the area required for landfills. In developing countries like India, composting works as an ideal process of reduction of waste.

Table – 2: State-wise number of composting plants in India.

State	Number of plants (Composting/ Vermi - Composting)
Andhra Pradesh	32
Chhattisgarh	15
Delhi	3

Goa	5
Haryana	2
Gujarat	86
Himachal Pradesh	13
Karnataka	5
Kerala	29
Madhya Pradesh	4
Maharashtra	125
Meghalaya	2
Orissa	3
Punjab	2
Rajasthan	2
Tripura	13
Uttarakhand	3
West Bengal	9

Source- Cathay Pacific Catering Services (2013).

Incineration-: It is one of the technologies used to convert waste into energy. It utilizes waste as an input variable into a process of conversion into energy which can be used to produce electricity. The waste which cannot be disposed off through recycling or composting, is disposed through incineration process. In many of the countries, incineration process of converting waste to energy is banned. This method is also called mass burn. With new technology of incineration about 90%-95% of waste can be compressed and converted into gasses. Remaining 10% of ash, transported to the construction industries. Other than incineration there are several other technologies used in converting waste to energy. Technologies are of two types,

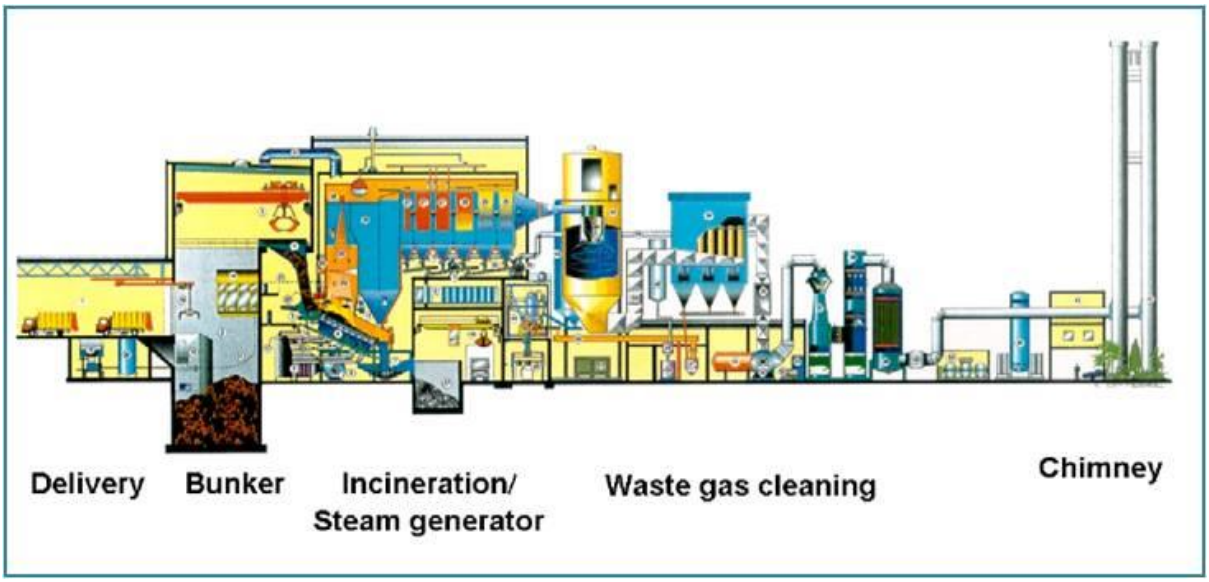
Thermal technologies

1. Pyrolysis
2. Thermal DE polymerization
3. Plasma arc Gasification
4. Gasification

Non- thermal technologies

1. Ethanol Production
2. MBT+ Anaerobic digestion
3. MBT to Refuse Derived Fuel
4. Anaerobic Digestion
5. Mechanical biological treatment

Figure 2: Layout of municipal solid waste incineration plant



Source – Waste Control (Database for waste management technologies)

Landfills-: Landfills are the most common practice worldwide for MSW final disposal. The U.S. Environmental Protection Agency defines landfill as a "waste disposal site in which waste is generally spread in thin layers, compacted, and covered with a fresh layer of soil each day". A more complex definition is a waste disposal method that does not generate health or public safety risks or hazards, utilizing engineering principles to confine the waste in the least possible surface area, reduced to the minimum possible volume, and covered by a layer of soil at the end of the operational day, or the most needed frequency. There is a wide range of landfills, from the most precarious and non-regulated "open dumps" to the most advanced sanitary landfills employing landfill gas capture and utilization as an energy source, including those landfills with landfill gas capture followed by flaring.

Table – 3: MSW action plan for major cities in Uttarakhand in August 2017

Name	land status (In Acre)		Identified location	Current status
	Required	Identified		
Dehradun	76	20	Sheesham Bara, Dehradun	EIA approved
Haridwar	30	49.4	Sarai Village, Haridwar	EIA approved
Roorkee	15	25	Saliar Village, Roorkee	EIA yet to perform
Rudraprayag	3	0.19	Rudraprayag	EIA yet to perform

(Development, Dehradun, Final, & Report, 2017)

Sources and types of solid waste

S.No.	Source	Typical waste generators	Types of solid wastes
1	Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes).
2	Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
3	Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
4	Institutional	Schools, hospitals, prisons, government centers.	Same as commercial.

5	Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Roofing & Sheathing scrapes, Wood, steel, broken concrete, dirt, plaster, pipe, wire, insulation etc.
6	Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
7	Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off- specification products, slay, tailings.
8	Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

(Tochikubo, 2011)

General practices adopted for waste disposal

S.No.	Source of Waste	General Practices to follow
1	Household waste	1. Don't throw solid waste in the neighborhood, on the streets, open spaces, and vacant lands, into the drains or water bodies.
		2. Keep food waste/biodegradable waste in a no corrosive container with a cover (lid).
		3. Keep dry, recyclable waste in a bin or gag or a sack.

2	Multi-storied buildings, commercial complexes, private societies	1. Provide separate community bin or bins large enough to hold food/biodegradable waste and recyclable waste generated in the building or society.
		2. Direct the members of the association to deposit their waste in community bin.
3	Slums	1. Use community bins provided by the local body for deposition of food and biodegradable waste.
4	Shops, offices, Institutions, etc.	1. If situated in a commercial complex, put the waste in bins provided by the association.
		2. Keep dry and wet biodegradable waste separately.
5	Hotels & restaurants	1. Adopt In house composting and waste for 2000 Waste Disposal.
		2. Sell Non-biodegradable waste to end-user.
6	Vegetable & fruit markets	1. Provide large containers, which match with transportation system of the local body.
		2. Shop keepers not to dispose of the waste in front of their shops or open spaces.
		3. Waste shall be used for composting.
		4. Deposit the waste as and when generated into the large container places in the market.
7	Meat & fish markets	1. Not to throw any waste in front of their shops or open spaces around.
		2. Use waste for composting.
8	Street	1. Not to throw any waste on the street.
9	Marriage halls, community	1. Not to throw any solid waste in their neighborhood, on the streets, open spaces, and vacant lands, into the drains or water bodies.

	halls, kalyanam andapas.	2. Provide a large container with lid, which may match with the transportation system of the local body and deposit all the waste generated in the premises in such containers.
10	Hospitals, nursing homes, etc.	1. Not to deposit construction waste or debris on the streets, footpaths, pavements, open spaces, water bodies etc.
		2. Store the waste within the premises or with permission of the authorities just outside the premises without obstructing the traffic preferably in a container if available through the local body or private contractors.
11	Garden waste	1. Compost the waste within the garden, if possible. Trim the garden waste once in a week on the days notified by the local body.
		2. Store the waste into large bags or bins for handling over to the municipal authorities appointed for the purpose on the day of collection notified.

(Delhi, Hill, & Delhi, 2003)

SECTION 3

CASE STUDY- DEHRADUN

Overview of Uttarakhand -:

Uttarakhand is one of the Northern states of India. It is the 27th state of the country, which was the part of Uttar Pradesh before 9th November 2000. As per the geographical dimensions, the state spans across 53,483 square kilometres of of land area.46,035 square km of area are hilly regions and the remaining being plains. It covers 1.6% of total land of India.

State has 13 districts, divides into two regions: Garhwal and Kumaon. Ones lying within Garhwal region are Chamoli, Tehri, Dehradun, Haridwar, Uttar Kashi, Rudraprayag . On the other side, ones within Kumaon region are Nainital, Almora ,Champawat , Bageshwar and Pithoragarh.

Industries-

Uttarakhand is also called as Herbal State in India. It has an abundance of natural resources which attracts most of the following industries such as **Fast-moving Consumer Goods Companies, Pharmaceuticals, Trekking and Tourism companies, Information Communication technology, Agro -based companies, Hydropower industries, Engineering Industries, Floriculture** etc.

Figure 3: Districts of Uttarakhand

Source – Government of Uttarakhand

Budget of Uttarakhand has many sources of incomes, but Tourism is the major contributor in inflow of revenue for the state. For example, 2016-17 total revenue receipts are **Rs. 32275.87 Crores**. Out of which 60% of revenue are received from Tourism industries. About **29.84 million** Tourists arrived in Uttarakhand in 2016-17 for enjoying the natural beauty of hilly areas, trekking, Char-Dham Yatras, national wildlife etc.

Government of Uttarakhand makes various policies to attract tourism industries, proper disposal of waste management, working on the mission of clean and green environment.

Municipal solid waste management in Dehradun-

Dehradun is the capital of Uttarakhand. With the population of **500000**. Dehradun generated 291.840 metric tonnes of municipal solid waste per day. Government has many policies and projects to manage the waste.

Table – 4: Physical Characterization of the MSW

Organic waste	44.76

Fuel Potential	12.83
Organic waste	44.76
Fuel Potential	12.83

(Development et al., 2017)

Table – 5: Current Estimates of Waste Composition

Income Level	Organic (%)	Paper (%)	Glass (%)	Metal (%)	Plastic (%)	Other (%)
Low Income	64	5	3	3	8	17
Lower Middle Income	59	9	3	2	12	15
Upper Middle Income	54	14	5	3	11	13
High Income	28	31	7	6	11	17

(Series & Papers, 2012)

Organic waste is generated by low level income groups of people such as wood, food waste, grasses, leaves etc. Paper waste, highly made by high income level groups includes wrapping paper, books, magazine, newspaper, cardboards etc. The generation of waste is directly related to the income of people. With the increase in the level of income of person the paper waste increases positively.

So, we can say that, the composition of various wastes is highly dependent upon the income level of the person rather than any other factors.

Present waste management system in Dehradun-

Before shifting of Solid waste management department to the health department, city was not having proper door to door solid waste collection facilities. Households, mainly low income residing in the city dump their daily wastes on street, river or hills. Middle- or high-income groups appoints private sweepers on the monthly basis. Waste remain

untreated because of unavailability of treatment plants in Dehradun. Authority weren't concerned about processing of garbage.

Table – 6: Number of existing vehicles with Dehradun Municipal Corporation

Type of vehicles	No. of vehicles
Tipper Lorries	4
Dumper Placer Lorries (Eicher & Tata)	7
Tractor Trolley	2
2 tractor containers	2
Big RCs	2
Small RC	1
TATA 709	1
JCB	2
Loader 710 (Scott)	2
Cattle Catcher (Mazda)	1
Mini RC	1
RC	1

Source – Nagar Nigam Dehradun

Proper waste management and disposal practices were proposed by government and now comparatively better waste collection and processing systems are taken up. Vehicles of waste collection have been increased and modernized (segregated blocks). Their size depends upon the income of the people of area located. Still 40% of the collected waste remain unutilized or unmanaged by municipal authority. After a long wait, Dehradun got its first waste treatment plant at **Shishambara** ,20 km away from the city of Dehradun.

Sample Survey in Dehradun area –

Annexure 1.

To record the behaviour of public towards the environment and understanding the treatment process of solid waste management system in our society.

A small sample survey was conducted to get the better understanding of general public behaviour towards Waste Management. **Systematic sampling approach** was used to get the best result and a **respective size of households** were taken into consideration. In the systematic sampling, sample population included all types such as students, household, employee, business men, senior citizens primarily.

As per the analysis, we get to know that **out of the total households, 75%** of them do not have any knowledge about policies of waste management in Uttarakhand. Government is taking various initiatives for proper waste management in Dehradun. About 85% of the household, still do not practise segregation of waste at home level and majority reason lying behind is **Lack of knowledge about Biodegradable and Non-Biodegradable waste**. And many states the reason, that it is not their responsibility to do segregation. General public produce wastes on their daily routine but aren't aware, where their generated waste goes. **60%** of the public of sample aren't aware about process of **Composting** of waste. And **35%** do not know where their waste goes after they are thrown out. Through this survey we get to know there is enough lack of awareness in people of Uttarakhand, about waste management. From the sample of selective households, about 55% hasn't ever heard about **WASTE TO ENERGY** method of disposal of waste

Results of case study-

Dehradun is known for its natural beauty which attracts most of the tourists. The results are in the form of suggestion that requires to be establishing to have proper Solid Waste Management system.

1. State Municipal Waste Management should be focused towards their duty and responsibility towards the society including creation of proper supply chain management from waste collection to waste disposal.

2. There is enough lack of awareness among the people about health issues, environmental issues, etc. which can be caused due to faulty disposal methods. Currently, there are no sufficing segregation systems, that should've been adopted by waste collectors or by households.

3. There should be strict control over illegal disposal of industrial wastes, hospital wastes, e-wastes. Heavy fines must be levied accordingly.

4. NGO's are not in great numbers, as per the population.

5. Educating the people about alternative sources of utilization of such as composting, waste to energy, incineration etc. is highly necessary.

SECTION 4

MUNICIPAL SOLID WASTE OF UTTARAKHAND

Current Situation-

After a long wait, Government of Uttarakhand got permission to install its first Waste to Energy plant. This plant is situated in **Roorkee**, having Ultra High Temperature Hydrolysis Reaction plant. This treats the waste of 7 residential towns of Uttarakhand, converting **550 metric tonnes** of municipal solid waste and commercial waste into electricity, per day. This project is funded by the private sector and regulated by the public sector. Uttarakhand Power Corporation Limited is the only buyer of this energy. Before all the wastes are collected by State Municipal Solid Waste Corporation and supplied to the regional companies, such as for Kumaon region, wastes are taken by A2Z waste management company. This initiative has not only helped in fulfilling the power production supply but has also helped in achieving the benchmark set by The Government of India.

Calculation of Calorific Value-

Calorific Value is defined as the total quantity of heat liberated from the complete combustion of a unit of weight in the presence of oxygen and air. Calorific value is measured in **kcal/ kg**. Due to the presence of heavy organic and moisture content in the waste, **Incineration** is the most common method used in India. Before waste is used as a raw material for converting the input waste into energy as an output, it should be properly dry, such that there should not be any moisture in the waste, which can reduce the quantity of energy production. Sample of the waste after segregation should be weighed to get the quantity.

Table – 7: Component of waste, generate in cities of Uttarakhand

S.no	Waste Components	Dehradun		Haridwar		Nainital	
		(Weight)	(%)	(Weight)	(%)	(Weigh)	(%)
1	Wood	0.28	1%	0.24	1%	0.2	1%

2	Paper	5.47	25%	5.85	27%	4.63	24%
3	Textile	7.21	32%	7.02	33%	6.78	35%
4	Glass	4	18%	3.86	18%	3.62	19%
5	Leather	1.35	6%	1.1	5%	1.05	5%
6	Plastic	2.45	11%	2.14	10%	1.89	10%
7	Metals	0.35	2%	0.28	1%	0.18	1%
8	Flower	0.85	4%	0.61	3%	0.62	3%
9	Stone	0.35	2%	0.4	2%	0.3	2%
Total		22.31	1	21.5	1	19.27	1

Source -As complied by author

Considering the literature review, taking percentages by theoretical calculation are given below:

Proximate Analysis is the analysis of moisture content, volatile matter content, ash content and fixed carbon content of the waste. **Ultimate Analysis** is the analysis of element wise waste composition determining composition of Carbon, Hydrogen, Oxygen, Sulphur. For calculating Moisture content, sample of waste is taken in a dry and accurately weight crucible and heated up to **105 degrees for one hour**. Moisture content in percentage is **[{(W-W1)/W} *100]**. Volatile content is taken in the platinum crucible and heated at 950 degrees for next 7 minutes. Volatile Matter content percentage is **[{(W1-W2)/W} *100]**. Ash content waste is heated at **700 – 750 degree** until all carbon burns away and ash remain. Ash content percentage **is (Weight of crucible+ lid+ ash)-(weight of crucial+ lid) / weight of sample waste**. Fix Carbon percentage is **100 - (% moisture +% volatile + % ash content)**.

KEY:

W= weight of waste

W1= Weight after heating up

W2= Weight after heating at 950 degree

Table – 8: Proximate Analysis

Parameters	Units	Result
Moisture	%	30.85
Volatile Matter	%	51.72
Ash	%	48.28
Fixed Carbon	%	9.8

Source- As complied by author

Table – 9: Utility Analysis

Carbon	%	31.39
Hydrogen	%	2.65
Oxygen	%	13.50
Sulphur	%	0.72

Source- As complied by author

Waste to Energy calculation

Using Dulong's formula for calculating the heat energy generated from the sample waste used:

Dulong Formula = 338.2*C + 1442.8* (H - O/ 8) + 94.2* S

C = Carbon

H = Hydrogen

O = Oxygen

S = Sulphur

So, 338.2 * 31.39 + 1442.8 * (2.65 – 13.50/ 8) + 94.2 *.072

Therefore, Heat value = 12011.58 kJ/kg

Steam Energy includes 70% of heat energy. It will help in moving the turbine and generated electricity. (1 KW = 3600 kJ/h)

Stream Energy = 70%* 12011.58 = 8408.106 kJ/Kg

In practice there is always a conversion efficiency of 31. 6% of heat input require

= 3600/ 31.6 %

= 11395 kJ/ Kwh

So the electric power generation = Stream Energy – Electrical Energy

= 12011.58 / 11395

= 1.054109697 Kwh/kg

Table – 10: Total waste generated per day in cities of Uttarakhand

	Dehradun	**Haridwar**	**Nainital**
Per day waste (tons)	260.8	217.7	19.491
Total Electric Power Generation	(1.054109697*260.8) = 274911 kWh/ day	(1.054109697*217.7) = 229478 kWh/ day	(1.054109697*19.491) = 20545 kWh/ day
Station service allowance (6%)	(274911* 0.06) = 16494.66 kWh/ day	(229478* 0.06) = 13768.68 kWh/ day	(20545* 0.06) = 1232.7 kWh/ day
Unaccounted heat loss (5%)	(274911* 0.05) = 13745.55 kWh/ day	(229478* 0.05) = 11473.9 kWh/ day	(20545* 0.05) = 1027.25 kWh/ day
Net Electric Power Generation	274911 – (16494.66 + 13745.55) / 100 = 244.67 MWh/ day	229478 – (13768.68 + 11473.9) / 100 = 204.24 MWh/ day	20545 – (1232.7 + 1027.25) / 100 = 18.30 MWh/ day
Net Electric Power Generation (per hour)	244.67 / 24 = 10.19 MW	204.24 / 24 = 8.51 MW	18.30 / 24 = 0.76 MW
Net Electric Power Generation (approx.)	10 MW	8.5 MW	1 MW

Source – Computation by author

Capacity to- built waste to energy

Dehradun-

As per the data collected by Nagar Palika Parisad, 2017 population count is about 500000, whereas waste generated per day is around 260.8 tonnes, with a capacity to generate approximately 10 MW of electricity per day, or in a month we can have 300 MW, and in a year, we will have 3.6 GW of power to fullfill the gaps of power cuts. Supplying the same to the Uttarakhand Power Corporation Limited will help in substantial reduction of prices. Solid waste generation is directly proportionate with the number of populations in an area. As the population increase waste will also increase.

Haridwar-

As per the data collected by Nagar Palika Parisad, 2017 population count is about 425000, whereas waste generated per day is 217.7 tonnes ,with a capacity to generate approximate 8.5 MW of electricity per day, or in a month we can have 255 MW and in a year, we will have 3 GW of power to fullfill the gaps of power cuts and might help in reduction of prices. Solid waste generation is directly proportional with the number of populations in an area. As the population increase waste will also increase.

Nainital-

As per the data collected by Nagar Palika Parisad, 2017 population count is about 500000, whereas waste generated per day is 19.49 tonnes, with a capacity to generated approximate 10 MW of electricity per day, or in a month we can have 30 MW and in a year we will have 0.36 GW of power to fullfill the gaps of power cuts and supply to the Uttarakhand Power Corporation Limited, helping in reduction of prices. Solid waste generation is directly proportional with the number of population in an area. As the population increase waste will also increase.

SIZE OF POPULATION ∝ WASTE GENERATION

$$\textbf{(WASTE GENERATION} \propto \textbf{ELECTRICITY PRODUCTION)} \propto \frac{\mathbf{1}}{\textbf{COST} \,\&\, SUPPLY}$$

SECTION 5

RESULTS AND DISCUSSIONS

The objective of this research is to make the people of Uttarakhand aware with that WASTE TO ENERGY is an alternative source of energy, which can be utilized effectively for their consumption. And, there is the positive relationship between population and municipal solid waste generated. As there is increase in the population over a period of time, there will be increase in per capita solid waste generation. This study also shows the importance of alternative requirements for disposal of waste without affecting the environment and health of the people surrounding. Waste to Energy is proved as the best technique for managing the waste with best outcomes of energy generation system. Municipal solid waste management from inputs of 260 tonnes generate electricity approximately 10 MW of power.

The table below shows the variables of municipal solid waste generation and population of various towns of Uttarakhand. These categorization of variables helps in finding the **R-Square value** and the relationship between the variables.

Table – 11: Relationship between Populations and Municipal Solid Waste per day

Source	SS	df	MS
Model	0.042423469	1	0.042423469
Residual	167.357577	58	2.88547546
Total	167.4	59	2.83728814
Number of Observations	=	60	

F (1, 58)	=	0.01				
Prob > F	=	0.9039				
R-squared	=	0.0003				
Adjusted R-squared	=	-0.0170				
Root: MSE	=	1.6987				
classes	coefficient	Standard Error	T- value	P> |t|	95% confidence	Interval
MSW per head ~y	-0.0872208	0.719326	-0.12	0.904	-1.527108	1.352667
_cons	4. 133983	0.3558623	11.62	0.000	3.421647	4. 846319

Source – Computation by author

Table –12: Summary of MSW per person per day

Variables	Observation	Mean	Standard Deviation	Minimum	Maximum
MSW Per Head~ Y	60	0.389617	0.3074376	0.0326477	2.048481
Classes (Population)	60	4.1	1.684425	1	6

Source – Computation by author

This regression also helps in testing the hypothesis, taken in the study. (H0) To check whether waste to energy is a viable method of getting electricity and fulfilling the demand. (H1) Or it is not the viable source of fulfilling the energy demand. The p value of the relationship between municipal solid waste and population is 0.904. Adjusted R-square is known as the **coefficient of determination** which help in explaining that how

the municipal solid waste generation is varied from the population. **From the given table we can observe that R-square = 0.017. which states that there is the variation of 1.7% of solid waste with the population.**

Table 13: Uttarakhand City wise per day Solid Waste generated by population

Name of Town	Total Population	Classes	Municipal Solid waste generated (Kg/day)	MSW per head/ day
Dehradun	500000	1	200000	0.40
Roorkee	96064	1	60000	0.62
Haridwar	500000	1	200000	0.40
Rudrapur	88815	1	50000	0.56
Kashipur	92978	1	35000	0.38
Jaspur	50520	1	12500	0.25
Rishikesh	56117	1	24000	0.43
Mangalore	42782	1	6000	0.14
Tehri Garhwal	33005	2	17550	0.53
Pithoragarh	41157	2	15000	0.36
Nainital	39000	2	15000	0.38
Ramnagar	47099	2	3000	0.06
Bazpur	36040	2	9500	0.26
Pauri	25000	3	7000	0.28
Mussoorie	25406	3	18000	0.71
Sitarganj	25000	3	5400	0.22
Kiccha	30517	3	10000	0.33
Tanakpur	15810	3	16200	1.02

Almora	30153	3	10200	0.34
Srinagar	19861	4	12000	0.60
Kotdwar	24930	4	16000	0.64
Uttarkashi	16220	4	4000	0.25
Lakshar	18240	4	4000	0.22
Landora	16022	4	3500	0.22
Khatima	15087	4	6000	0.40
Gopeshwar	19776	4	4000	0.20
Vikasnagar	12485	5	9000	0.72
Gocher	6130	5	800	0.13
Badrinath	8417	5	1000	0.12
Lohaghat	5858	5	12000	2.05
Karnprayag	6976	5	6000	0.86
Sultanpur Patti	7700	5	3000	0.39
Kaladungi	6126	5	200	0.03
Lalkuan	6524	5	800	0.12
Bhimtal	6245	5	800	0.13
Mahudabra	6110	5	2000	0.33
Kelakheda	7783	5	2000	0.26
Mahuakhedaganj	12584	5	2500	0.20
Dineshpur	11342	5	3000	0.26
Jhabrada	9378	5	2000	0.21

Muni Ki Reti	7878	5	5000	0.63
Rudraprayag	5236	5	3000	0.57
Gadarpur	13638	5	8000	0.59
Bageshwar	7803	5	1500	0.19
Chamba	6600	5	600	0.09
Doiwala	8047	5	5000	0.62
Herbertpur	9243	5	1000	0.11
Josimath	14402	5	3000	0.21
Dugadda	2690	6	1000	0.37
Narendranagar	4475	6	400	0.09
Champawat	3958	6	3500	0.88
Kirti Nagar	1040	6	500	0.48
Devprayag	3000	6	600	0.20
Barkot	4228	6	1000	0.24
Gangotri	606	6	300	0.50
Shaktigarh	4776	6	1500	0.31
Dwarahat	2543	6	1000	0.39
Dharchula	4508	6	1500	0.33
Didihat	4805	6	900	0.19
Nandprayag	1423	6	500	0.35

Source – as complied by author

CHAPTER 6

CONCLUSION

Waste to Energy is one of the best methods of disposal of waste without harming the environment and encouraging the Sustainable development of the Nation. Waste to Energy plant requires less space of land, in comparison of landfills. And, it is most cost-effective method of reducing the waste from the society. We generated energy in the form of gases, electricity, fuel etc., helping in reducing the energy crises in the society. This is one of the best Renewable sources of energy which produce Electricity with the sustainability.

This chapter of the study deals with the conclusion, it contains summary of the results of the above analysis with their effects. The current solid waste management system of Uttarakhand is not very much effective or either directed towards clean environment. Uttarakhand is also having the huge footfalls of national as well as international tourist. The Tourism industry contains major share in Uttarakhand. Solid waste generation in Uttarakhand is very uneven because there is high waste during trekking, camping, tour and travelling seasons. And as per the analysis, we can say that there is positive relationship in between the population of the towns and solid municipal waste generation. As the population increase, waste also increases. As per the estimates, Uttarakhand's major cities are capable to produce electricity from waste and fulfill the gap of demand and supply. Major cities such as Dehradun, Haridwar, Roorkee, Haldwani, Nainital, Tehri etc., help in contribution towards producing energy from waste.

Since long, Dumping was only the process, as used by the government of Uttarakhand, to settle every day waste. Then, the Private Players' intervention changed the method of disposal of waste. Municipal corporation started selling waste to the private companies of New Delhi, which are involved in converting waste to energy. And that produced energy had been purchased by Uttarakhand Power Corporation Limited.

Now, with the approval of Central Government, Uttarakhand is establishing their first energy to waste plant in near Dehradun city. So, it will reduce the transportation cost,

encourage employment, sustainable development. The survey report of this study states that people are not very much aware about the social, health and environmental problem caused through waste. Some questions are showing a larger section of people's unawareness about waste to energy technology. Some observations were shocking, when the people were asked to rank the risk causes due to following disposal methods. Some pointed, that Waste to Energy is a high-risk method of waste disposal than landfills.

Proper guidance must be provided by the municipal corporation of Uttarakhand on how to segregate the waste and how to utilize such waste into other forms. Such as Uttarakhand produces large amounts of organic waste. That organic waste can be used through composting method of disposal. Municipal corporation and many other agencies and NGO's must create awareness campaigns to educate the people about methods of segregation of waste at household basis, conduct various seminars in Colleges, School, Hospitals, Public places, Commercials offices, Industries etc. Proper education of Utilization of waste will help in reducing the waste and will take necessary care about Solid Waste Management.

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Annexure 1:

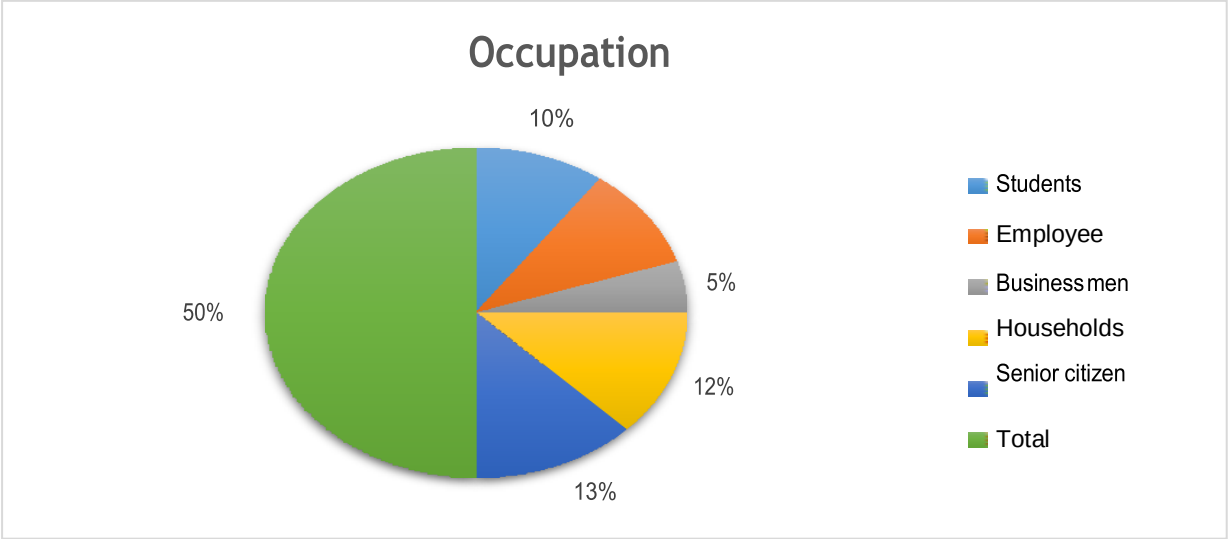
Survey -: Sample citizen of city Dehradun (Uttarakhand)

Question 1- : Age group

Age	Response
Less than 28	4
28-38	4
38-48	4
48-50	4
More than 50	4

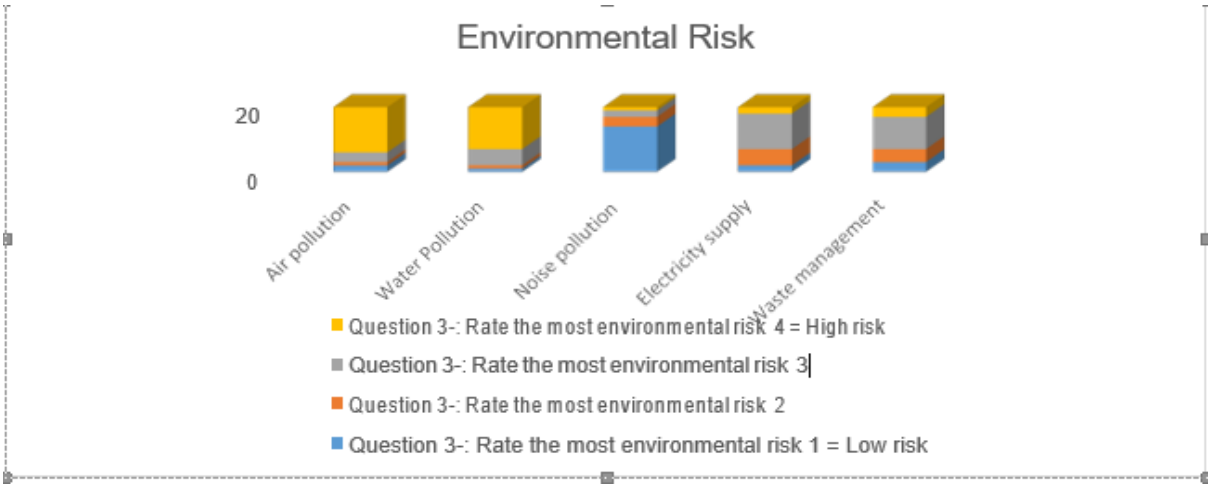
Question 2-: Occupation

Options	Response	Percentage
Students	4	20%
Employee	4	20%
Business men	2	10%
Households	5	25%
Senior citizen	5	25%



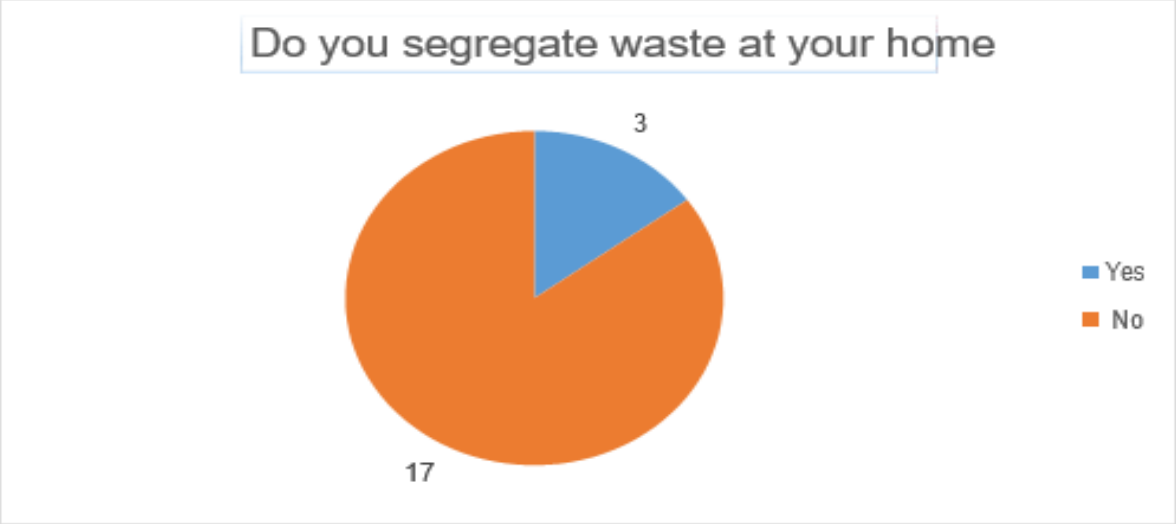
Question 3-: Rate the most environmental risk

Options	1 =Low Risk	2	3	4 = High Risk
Air pollution	2	1	3	14
Water Pollution	1	1	5	13
Noise pollution	14	3	2	1
Electricity supply	2	5	11	2
Waste management	3	4	10	3



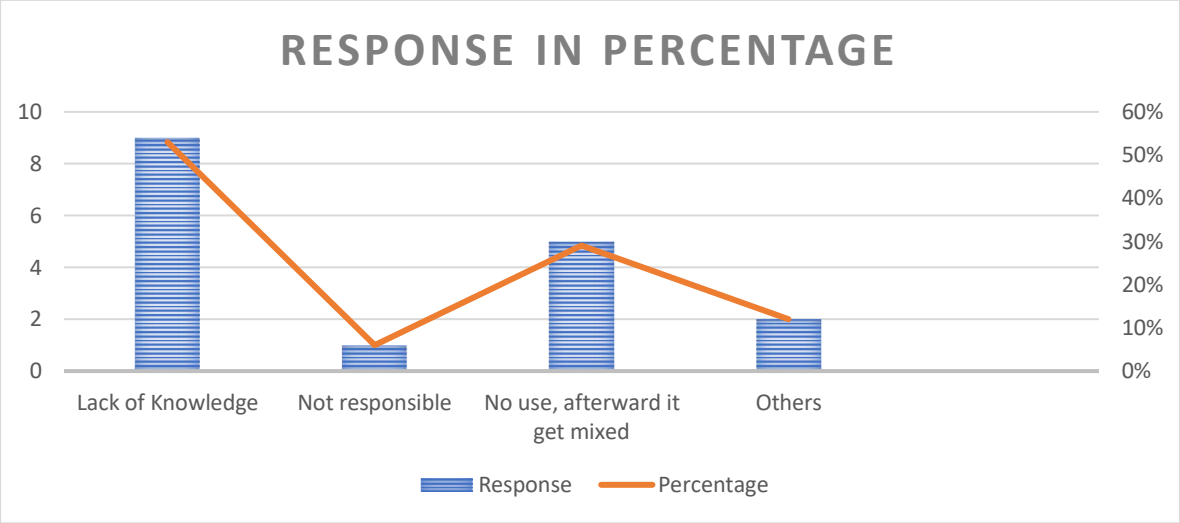
Question 4-: Do you segregate waste at your home?

Option	Response	Percentage
Yes	3	15%
No	17	85%
Total		100%



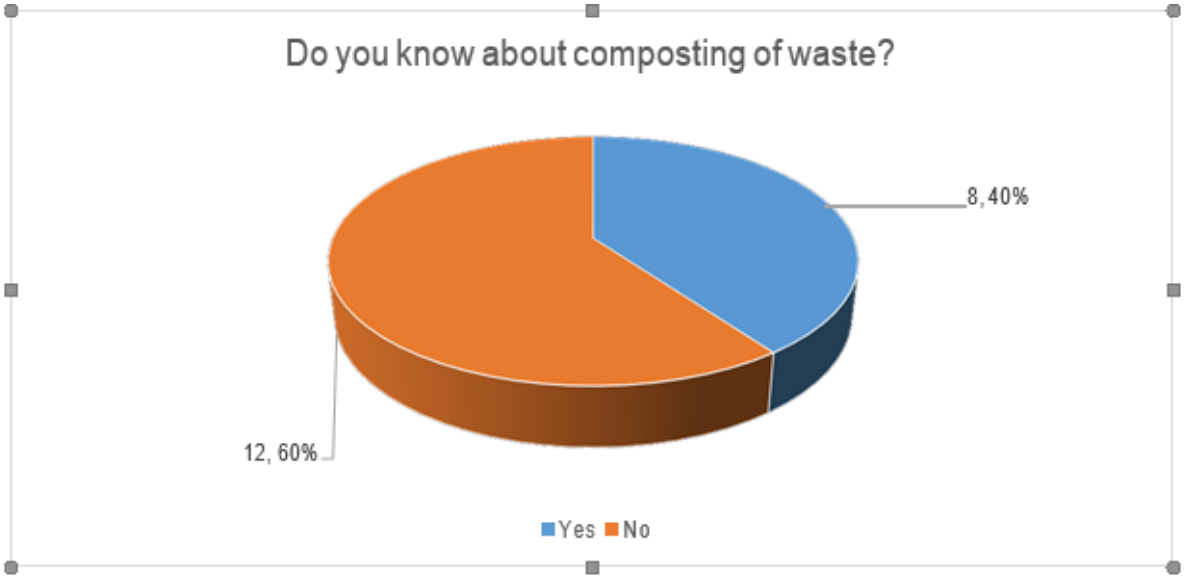
Question -:5 If no, why?

Options	Response	Percentage
Lack of Knowledge	9	53%
Not responsible	1	6%
No use, afterward it get mixed	5	29%
Others	2	12%
Total		100%



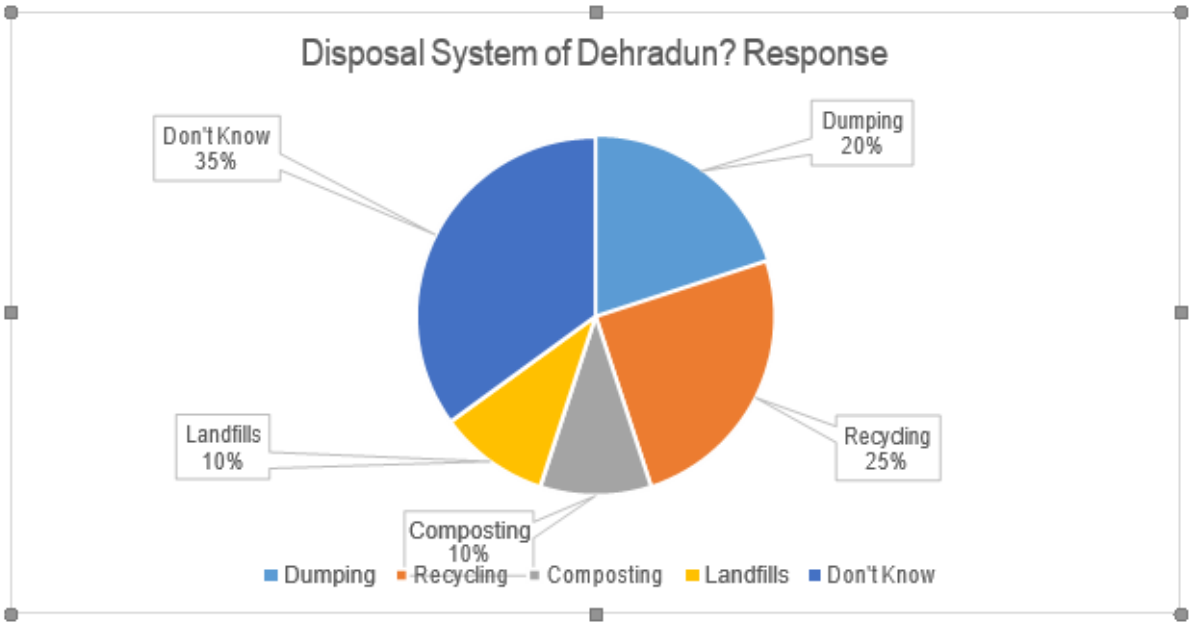
Question-:6 Do you know about composting of waste?

Option	Response	Percentage
Yes	8	40%
No	12	60%
Total		100%



Question-:7 Disposal System of Dehradun?

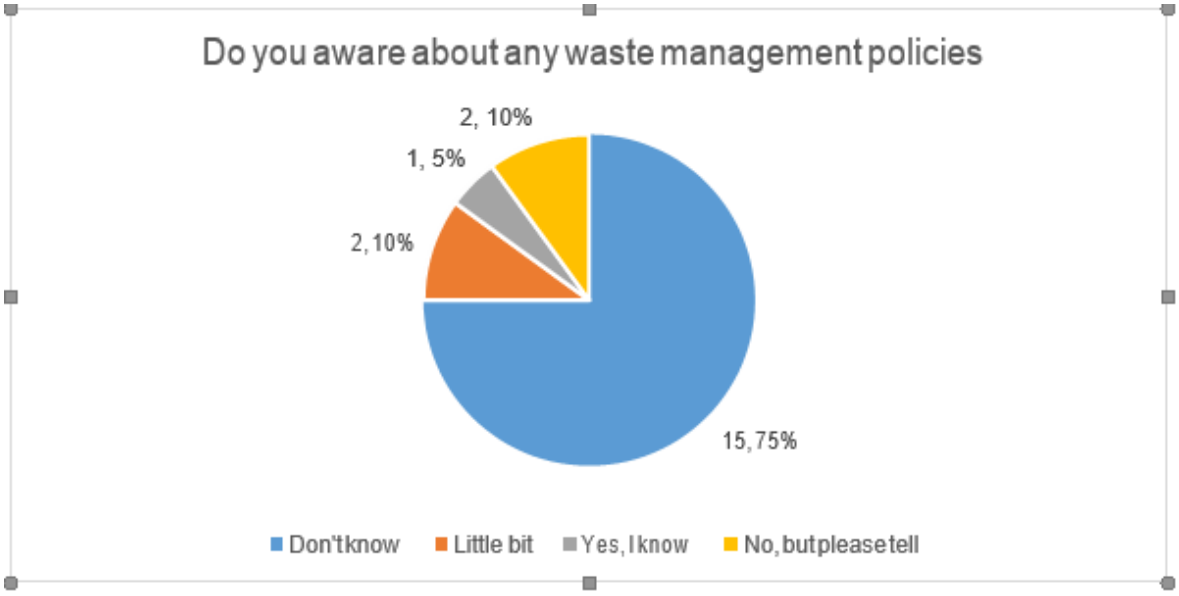
Options	Respons e	Percentag e
Dumping	4	20%
Recycling	5	25%
Composting	2	10%
Landfills	2	10%
Don't Know	7	35%
Total		100%



Option	Respons e	Percentag e
Don't know	15	75%
Little bit	2	10%

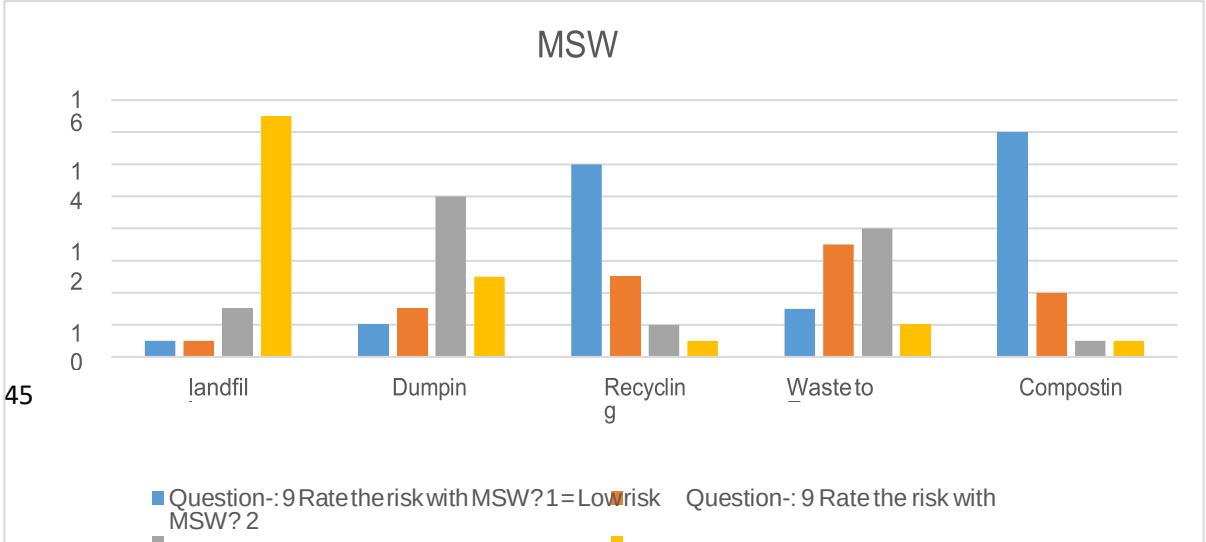
Yes, I know	1	5%
No, but please tell	2	10%
Total		100%

Question-: 8 Do you aware about any waste management policies?



Question-: 9 Rate the risk with MSW?

Options	1=Low risk	2	3	4 = High Risk
landfill	1	1	3	15
Dumping	2	3	1	5
Recycling	12	5	0	1
Waste to Energy	3	7	2	2
Composting	14	4	8	1



Question-: 10 Do you ever heard about waste to energy process?

Option	Response	Percentage
Don't know	11	55%
Little bit	5	25%
Yes, I know	2	10%
No, but please tell	2	10%