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Estimation of Electrical Energy Generation from Waste to Energy using Incineration Technology

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Abstract

This paper mainly deals with viability of Waste to energy Incineration technology in Roorkee City, Uttarakhand by estimating the total municipal solid waste generated and evaluating the energy potential by using the incineration technology. Day to day increase in waste generation demands Renewable technology for solid waste management for an effective economic and social growth of the people. This paper focuses on technical feasibility only.

1. Introduction

There are several parts of the beginning of waste-to-energy technology in India. This technology of waste to energy (WTE) incineration is a renewable source of supplying electricity and also solves the problems of landfills. The current trend of economic growth and standard of living of people increases municipal solid waste (MSW) generation and effects on current landfill scenario, unavailability of land, open burning landfill causes pollution and has greatly effects on public health. There is urgency for an effective solid waste management due to all of these reasons. WTE incineration helps in reducing greenhouse gases (GHGs) by avoiding dumping to landfill, foils the methane emission from landfill and generating renewable energy in form of electricity which further helps in reducing dependency on fossil fuels. Currently largest source of GHGs emissions in the world are landfills with an assessment of almost21% of the total methane production. As a GHG Methane is 21 times stronger than carbon dioxide.

2. Literature Review

Mufeed Sharholy et.al (2007)[1]used ArcGIS technique which included MSW sample collection and questionary survey on randomly selected houses and concluded that 45.3% of organic matter and 40% miscellaneous material (glass, paper, plastics etc.) and mentioned the qualitative and quantitative characteristics of MSW for MSWM for developing GIS maps for city of Allahabad. He also explained MSWSM collection, storage and disposal methods. Tsai et.al (2014)[2]did content and chemical analysis of MSW from year 2008 to 2012 with the use of CHP technology and compared the efficiency of plants of Taiwan with different parts of Europe, Germany and Netherlands. He also classified plants on the basis of capacity of waste handling, power generation and efficiency was done and discussed use of district heating and cooling and its use and advantage. S Rathi et.al (2014)[3] used Dulong Formulae heat energy in incineration technology to calculate and analyse potential generation of electricity in Kanpur city of 33MW from MSW of 1200 tonnes/day by considering conversion efficiency, station allowance, unaccounted heat loss and net power generated and classified solid wastes on physical and chemical composition. NIE et.al (2008)[4] explained new technology of circulating fluidized bed and emission of reduction by using equipment such as house filtration, flue gas cleaning and activated carbon in incinerator, adopted by 30 plants for development of China. Biodegradable matter shares 31-36% of total MSW in big cities and 65% in small cities having calorific value of around 5000KJ/Kg. Dioxin emission was limited to 1.0ng TEQ/Nm^3. Ojha et.al (2011)[5] explained, classified and compared cities on the basis of population, MSW composition, total waste generated; very big city, big city, medium city, small city and calculated potential of 1700 MW electricity from WTE incineration with some solutions and suggestion to problems occurring in MSWM. Arena et.al (2015)[6] proposed the opinion to solve waste problem as using it as a resource. He explained WTE technology was successful and reliable because of thermal conversion, heat recovery and air pollution technique to reduce health and environmental risk, landfill substitute. Vikash Talyan et.al (2008)[8] discussed first incineration in Delhi, setup in 1989 at Timarpur to produce 3.7MW from 300 Tonnes of waste of calorific value higher 1000 Kcal/Kg but was closed in 21 days only due to falling of calorific value. First composting plant was setup in 1980 in Okhla and was shut down due to absence of market and high production cost. He explained three landfills in at Gazipur, Okhla and Bhalswa with LFG potential of energy generation 12.98*10^5 Kwh/year. Ityona Amber et.al (2012)[7] calculated potential generation of 700KWh/tonne of electricity with calorific value of 17.23 MJ/Kg and conversion efficiency of 25% from incineration technology in Nigeria by considering methodology of analysing 5

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samples of 10 Kg each of waste and evaluated that 43% of total MSW organic components are present while 8% are paper, cardboard, plastics. E. Autret et.al (2007)[10] overviewed design and operation of incineration plant on basis of composition of different type of wastes, suitable technique, avoiding environment effects and risk of human health. He described various incinerators techniques such as grate, fluidised bed and rotary kilns. He observed incineration plants replaced fossil fuel made of 50% natural gas and 50% oil in France. V G Sister (2006)[9] simulated plant model to improve the performance of waste incineration plant by considered gas turbine and steam cycle heat from outgoing fuel gases which resulted in efficiency of binary system gas incinerator of 42-45%. In addition he said Pyrolysis in incineration increases its efficiency by providing high yield of components of CO, H_2, and CH_4. Sieting Tan et.al (2014)[11] compared three WTE technologies i.e. incineration, landfill gas recovery and anaerobic digestion (AD) on environmental and economic basis which included includes transportation cost, carbon credit and sale of by-product of Taman Beringin, Malaysia landfill which can yield in 287% of increment in profit. CHG emission was checked on basis of Intergovernmental Pollution Climate Change (IPCC) guidelines. Incineration plants produced 1430 MW/day of heat and 480 MWh/day of electricity from 100 tonnes/day of waste. Hefa Cheng et.al (2007)[12]carried out methodology to study two incinerators of capacity each 250 tonnes/day having technology based on co-firing of MSW with coal in grate circulated fluidized producing 46.2 million KWh of electricity having calorific value of 3000-6700 KJ/Kg lower than developed countries of 8400-17000 KJ/Kg. In addition he calculated coal equivalent to MSW fuel ratio of 0.14, with saving of 0.2 million m^3 landfill yearly. Sudhanshu Kaushik et.al (2011)[13] studied the MSW generation during KumbMela 2010 at famous temples of Haridwar City; Mansa Devi &Chandi Devi located at Shiwalik Foothills on seven days of Hindu festival which includes Makar sakranti, Magh Purnima, Mahashivratri, Chaitra Amavasya and Full moon days by recording observations of individual composition of MSW according to days. 7615.0 Kg of Waste was produced at Mansa Devi Site and approximately 5000 Kg of waste was produced at Chandi Devi Site. He observed that 64.7% was biodegradable waste and 12.3% was non-biodegradable at Mansa Devi hillock and at Chandi Devi hillock 62.7% of biodegradable and 10.2% of non-biodegradable. C Liamsanguan et.al (2007)[14] compared incineration, landfill & conventional power plants using Life Cycle Assessment (LCA) methodology and declared that incineration had higher advantages for global warming & photochemical ozone formation over conventional power plants but from acidification and nutrient enrichment aspect incineration was not suitable. He described landfill with gas collection and flaring systems were much favourable than incineration technology. In addition he compared conventional plant's energy content which was much higher than of Municipal Solid Waste (MSW) and also conventional power plants had higher efficiency than incineration plants. Dioxins emissions from incineration plants cause health issues.

3. Comparison of Current Technologies

Mainly there are four technologies for WTE:

- **WTE Incineration:** MSW is combusted in presence of oxygen. Heat produced then utilized to produce steam which turns the turbine and then alternator to produce electricity. Harmful flue gases are treated and then released in atmosphere. By product is utilized in cement factory.
- **Landfill gas Recovery:** Anaerobic biodegradation results in methane production in landfill which is recovered to produce either electricity or heat.
- **Biomethanation:** Organic matter of MSW is converted to biogas by means of anaerobic digestion in presence of methanogenic bacteria. This biogas can further be utilized for cooking or electricity production.
- **Refuse Derived Fuel:** This technology fuses whole MSW irrespective of individual calorific value of organic and inorganic matter. It forms briquettes and pellets which can be used further as a fuel in many applications.

4. Case Study Undertaken

"Roorkee is a city in Haridwar district, Uttarakhand that is spread over a flat terrain with the grand spectacle of Himalayas ranges flanking it in the East and the North-east. It is on the banks of the Ganges canal on the national highway 58 (Delhi - Sri Badnrinath - Mana). The dominant feature of the city is the Upper Ganges Canal which flows north-south and bisects the city. Also known for Roorkee Cantonment, one of the country's oldest, and the headquarters of Bengal Engineer Group (Bengal Sappers) since 1853.The renowned IIT Roorkee is located in this city." [16]

5. Current MSW Methodology

Door to door primary collection by engaging private sweepers. Waste is mostly collected through community bins/containers and road sweeping. Sweepers and sanitary workers engaged by the Roorkee Nagar PalikaParishad (RNPP) sweep the streets. They accumulated the collected waste into small heaps and subsequently loaded manually or mechanically onto the community containers/bins or directly loaded onto the solid waste transportation vehicles for onward transportation to the disposal site. RNPP presently utilizes the vehicles and equipment for transportation of solid waste.

Fig: 1. MSW Methodology used in Roorkee City

6. Amount of waste generated

The city generates, on an average, about 250 MT of MSW per day. The major sources of MSW generation of the city are domestic, shops and commercial establishments, hotels, restaurants, dharamsalas and fruit and vegetable markets. Number of registered hotels, restaurants and dharamsalas in the city are 90, 50 and 52 respectively. In addition there are 3 fruit and vegetable markets. Out of which 1 market is excluded as it is not under RNPP. Following is the table shows type of vehicles used to collect the waste and dump in open landfill.

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Fig: 2a. Dumping Vehicles

Fig: 2b. Dumping Vehicles

Table 1: Vehicle Carrying MSW

S. No.	Vehicle	Amount of MSW(MT)	Quantity of Vehicle	Total Waste (MT)
1.	TATA Ace	1.6	11	17.6
2.	Tractor trolley	2.5	7	17.5
3.	Compactor	3.2	3	9.6
4	Dumper	5	1	5
	Total			49.7

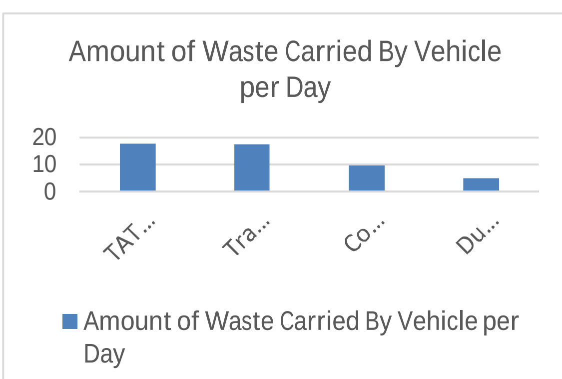

Chart: 1. Amount of waste carried by vehicle per day

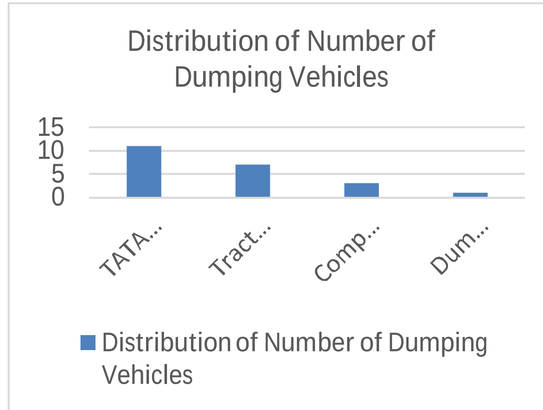

Chart: 2. Distribution number of dumping vehicles

These vehicles on average make 5 trips daily
So total MSW generated: 49.7*5 ≈250 MT

7. Computation of Energy Potential

Heat Energy (Dulong's Formula) to calculated heat energy generated by whole Roorkee
Dulong's formula:**HV(KJ/Kg) = 338.2*C + 1442.8*(H-O/8) + 94.2*S**
Where C, H, O and S are the % of these elements on dry ash free basis.
Considering Literature Review taking percentage by Mass theoretical calculations are as follows:
C= 31.22
H= 8.17
O= 55.68, Sulphur very small so neglected
Applying to formulae we get Heat Energy Generated = 12260.69 kJ/kg
First, heat energy generated is used to calculate steam energy which is 70% of heat energy.
Finally after steam energy calculation, net electric power generated by solid waste is calculated after accounting station service allowance and heat losses.
Steam energy available = 70% of heat energy
Steam energy available = (0.70 ×12,260 .69) kJ/kg
Steam energy available = 8,582.483 kJ/kg.
Above calculated steam energy is used to run the turbines, these turbines are coupled with generators which produces electricity. Heat rate is the heat input required to produce one unit of electricity (kWh).
1 kW = 3,600 kJ/h
But practically no energy conversion is 100% efficient, considering the conversion efficiency of 31.6% in a power plant heat input of 3600 ÷ 31.6% = 11395 kJ/kWh is required.
So, to produce 1kWh electrical energy 11395 kJ of steam energy is required.
Electric power generation = Steam energy ÷ 11395kJ/kWh
Electric power generation = (8,582.483 ÷ 11395) kWh/kg
Electric power generation = 0.753179728 kWh/kg
Total weight of solid waste collected from Roorkee city =250 tons/day
Total electric power generation = (0.753179728×250000) kWh/day
Total electric power generation = 188295 kWh/day

Station service allowance = 6% of total electric power generation
Station service allowance = (0.06 ×188295) kWh/day
Station service allowance = 11297.7 kWh/day
Unaccounted heat loss = 5% of electric power generation
Unaccounted heat loss = (0.05 × 188295) kWh/day
Unaccounted heat loss = 9414.75 kWh/day
Net electric power generation = Electric power generation – (station service allowance + unaccounted heat loss)
Net electric power generation = 188295 – (11297.7 + 9414.75)
Net electric power generation = 167582.55 kWh/day = 167.6 MWh/day
The above generated electricity is for one day and one day has 24 hours, so using this net electric power is calculated for per hour basis.
Net electric power generated = 167.6 MWh / 24h
Net electric power generated = 6.9 MW≈ 7 MW

8. Results & Discussion

The numerical computation has been carried out and following total energy potential is calculated which provides the feasibility of the WTE incineration in Roorkee City.

Total electricity production is 7 MW for 24hrs operation which can provides 5 Million units (MU) monthly, which fulfil the 16% of total energy need of Roorkee city as the demand of urban Roorkee is around 32 MU monthly.

9. Conclusion

None of the single solution is capable of solving the entire solid waste management problem, although by favourable use of methodology of combined technologies- decrease at source, reutilizing, composting and incineration can be supportive. Decreasing the waste generation at source level only. Recycling & reprocessing new materials from used matter like paper, plastics, metals, glass, etc. By decomposing organic matter like kitchen waste, food waste in aerobic or anaerobic way compost can be prepared which further can be utilized as a fertilizer for soil. Combustion of waste in presence of air at high temperatures in Incinerator technology, it lowers the volume of waste up to 90%. Therefore landfill can be avoided completely by above technologies. But from decades in India definition of energy means electricity and scarcity of electricity creates hindrance to growth and development so Waste to Energy Incineration technology should be used for solid waste management as it provides all kind of process- reduce, recycle and regeneration.

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