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RESEARCH ARTICLE

ESTIMATION OF ENERGY GENERATATION FROM MUNICIPAL SOLID WASTE A CASE STUDY OF BOBBILI CITY, ANDHRA PRADESH

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ABSTRACT

In India, the electricity sector supplies the world's 6th largest energy consumer, accounting to 3.4% of global energy consumption by more than 17% of global population. About 21.53% by hydroelectric power plants, 2.70% by nuclear power plants, 10.42% by Renewable Energy Sources and65.34% of the electricity consumed in India is generated by thermal. The energy crisis and environmental degradation are currently two vital issues for global sustainable development. Due to Population explosion in India, people are migrating from villages to cities, and Rapid industrialization which generate thousands of tons of municipal solid waste daily, which are one of the most important contributors for environmental degradation at global level. One of the major environmental problems in India is Municipal solid waste management. The present study conducted bycollecting 100% solid waste in Bobbili municipality and separation then transportation from city to municipal solid waste management park located 5km away from municipality, then we separate the solid waste depending on dry and wet. Finally, electrical energy is calculated of all the Bobbili city solid waste which comes out. It is found that electricity production from MSW could be an alternative way of power generation as well as waste management.

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1. INTRODUCTION

The energy demand in India is increasing substantially and the energy supply is not in pace with demand. The recovery of energy from waste material is one of the best methods to tackle the energy crisis. The potential for recovery of energy from urban waste is high in Maharashtra followed by Uttar Pradesh, Tamil Nadu and West Bengal. Anaerobic digestion method is used to find the potential of energy recovery from the liquid and solid waste in the form of biogas. Thus the production of biogas from industrial and domestic waste is working successfully in small and large scale private projects in India. The potential of energy recovery has been estimated based on the available data.

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Also the carbon emission from the natural gas production plant is found and compared with the conventional coal based power production methods (Marimuthu and Kirubakaran, 2015). Waste disposal is one of the major problems faced by all countries. As urbanization trends are increasing progressively, rapid changes in the pattern of human life are significantly seen, giving rise to generation of larger quantities of wastes leading to increased threats to the environment. It is estimated that about 42 million tons of solid wastes and 6000 million cubic meters of liquid wastes are being generated (in India) every year by urban population, besides generation of huge quantities of liquid and solid wastes by the industries. Improper disposal of municipal solid waste leads to degradation of environment and poses health hazards to the public. The latest trend world over is to use urban areas and cities waste to generate energy. One such technology is known as anaerobic digestion or biomethanation technology, which is environmentally safe and indeed a scientific disposal of waste.

It means a process which entails enzymatic decomposition of organic matter by microbial action to produce methane rich biogas (Murugesan *et al*., 2015). Municipal solid waste (MSW) leachate samples were collected from the leachate pit, of Mayiladuthurai municipal solid waste open dumping site, Nagapattinam District, Tamil Nadu, India. Leachate samples were analyzed and multi heavy metal ions namely Cu, Zn, Pb, Cr and Ni were identified. Pozzolonicmaterial Alcoffine was collected used as solid adsorbent (Senthilkumar and Murugappan, 2015). In India, Plastic waste rising rapidly day by day due to increasing the living standards of human beings by leaps & bounds and due to increasing population. The plastic waste management is not developing in India however, India having Plastic Waste (Management and Handling) Rules, 2011. The collection, transportation and process of plastic waste management are unscientific and chaotic. Uncontrolled dumping of wastes on outskirts of towns and cities has created abundant landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have serious environmental implications in terms of ground water pollution and contribution to global warming. Burning of plastic waste leads to air pollution, which is equivalent to vehicular emissions at times (Vivek Prakash Pankaj, 2015).

The fiber boards from MSW and coir have shown less moisture content and better flexural strength (Kavitha, 2015). The energy crisis and environmental degradation are currently two vital issues for global sustainable development. Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, which generate thousands tons of municipal solid waste daily, which is one of the important contributors for environmental degradation at national level. Improper management of municipal solid waste (MSW) causes hazards to inhabitants. The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. In this regard, Waste to Energy (WtE) provides a solution towards complying with government regulations, and achieving integrated solid waste management (Leena Singh *et al*., 2014). The increasing level of municipal solid waste is a serious problem in the urban and rural areas. A high rate of growth of population and increasing per-capita income have resulted in the generation of enormous municipal solid waste and it posing a serious threat to entire environmental quality and human health. However, due to the limited resources and precise regulatory guidelines, the treatment and disposal of solid wastes in an effective and appropriate manner is grossly inadequate (Senthamil Selvan *et al*., 2016). Environmental friendly or green building materials are becomi ng more widely usedas our society becomes aware of harmful consequences associated with the use of standard practices in industrial production. This leads to growing tendency of recycling of waste materials and using them production of particle boards. Particle Boards are produced from Municipal solid waste, agro-waste materials such as rice husk, jute sticks, waste wood, sugarcane waste, kitchen waste etc (Muruganandam *et al*., 2016). Ground water table depletion would lead to the intrusion of saline water. This will further contaminate the aquifer and will affect the plant growth in the surrounding irrigation area (Abou Rayya *et al*., 2015).The villages that were taken for study was once fully cultivated at all the seasons. Now because of fluctuating rainfall, lack of labors and high labor cost, lack of knowledge about modern technologies and its negligence on agriculture and hence production get decreased. Because of increase in residential and commercial projects at those places without proper drainage and waste disposal facilities, the surrounding land and water is fouled (Ahmed Hassen Shntaif, 2016; Anil Kumar Reddy Chammi Reddy and Karthikeyan, 2016; Joydev Dutta, 2016; Mervat Sh. Sadak, 2016; Kouame Kouame Victor *et al*., 2016; Senthamil Selvan, 2016; Mohammad Razif *et al*., 2016). Salinity is a common abiotic stress factor seriously affecting on crop production in different regions, particularly in arid and semi-arid regions. It is estimated that over 800 million hectares of land in the world are affected by salinity (Maie Mohsen *et al*., 2016). Municipal solid waste management is an important as it impacts on health, environment and aesthetic society if it is not managed properly. Hence to improve quality and standard of living in the state, the Government of Andhra Pradesh (govt. of AP) has proposed to strengthen the Municipal Solid Waste Management system covering collection, segregation, recycling, transportation, processing and disposal with option for composting, waste to energy, disposal in all 110 urban local bodies (ULBs) in Andhra Pradesh& Telangana, which is in line with national objective of SWATCH BHARATH MISSION, a prestigious project of Govt. of India. Rapid economic growth has created a growing need for dependable and reliable supplies of electricity, gas and petroleum products. Due to the fast paced growth of India's economy, Country’s energy demand has grown an average of 3.6% per annum over the past 30 years. Rapid urbanization, industrialization and population growth have led to severe waste management problems in several cities of developing or under developed world like India, Malaysia, Nepal, Bangladesh etc. Although MSWs, a vital part of any society, does not have the disastrous potential of either global warming or ozone depletion, which threats to environmental quality and human health.

2. MATERIALS AND METHODS

2.1. Sampling

Firstly, the solid waste is collected from all the collection points then transported to receiving station. After this solid waste is fed to shredder, here solid waste is cut down into small pieces so that it can be managed easily at subsequent stages. Now this shredded solid waste is passed through dryers to remove extra moisture. After this process, air is blown on solid waste which blows out light materials and heavy materials like ferrous metal is separated and sent for recycle as these materials can’t be burned in incinerators. The light solid waste is again passed through the second stage shredder to cut them into smaller pieces. Now these small solid waste pieces are burned into an incinerator which reduces the solid waste into ash, produce heat energy and gases which is shown in fig 2.1. The gases are passed through air filters if needed and subsequently released into atmosphere through stacks. Heat energy is used to boil water in boilers to produce this steam in turn runs turbine which is attached with generators. As turbine runs, it led to rotate the generator and produces electricity. This electricity is exported to the grid and some of it is used for plant itself.

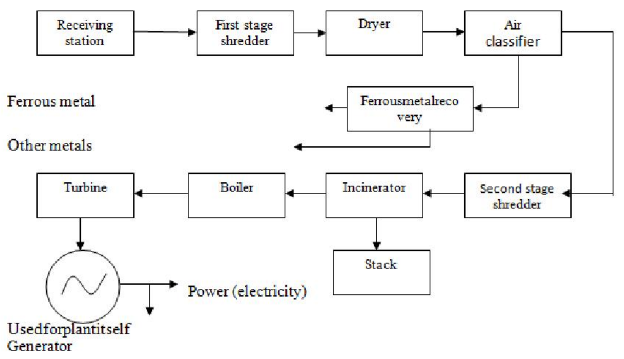

Fig 2.1. Power Generation from Dry Waste

2.2 Study Area

Bobbili city is famous for its fort, the legendary Venugopala Swami Temple and more famous for the "Battle of Bobbili" that was a major incident in the history of Andhra Pradesh. The Battle of Bobbili that took place in 1757 is considered one of the major incidents in the history of the state of Andhra Pradesh. The city is famous for manufacturing “Veena”, the south Indian musical instrument. Bobbili is situated at a distance of 60kms from Vizianagaram, Headquarters of Vizianagaram District. The Bobbili town is constituted as Municipality in the year 1956. Bobbili Municipality consists of 30 election wards. Bobbili town is spread over an extent of 25.6 Sq.Kms with a population of 50,096 in 2001 which increased to and 56,372 as per 2011 Census. The town has 40 slums with a population of 31,048 as per 2001 census. Interestingly, slum population of Bobbili Municipality constitutes more than 50% of the total population of the town (Table 2.1).

Table 2.1. Town population

Year	2001	2011
Total Population	50,096	56877
Male	25033(49.97%)	28234
Female	25063(50.03%)	28640
Literacy	NA	70%
Female Literacy	NA	63%
Male Literacy	NA	76%
No of.HH	11,389	14437

2.3 Rapidly Increasing Areastobe Served and Quantity of Waste

The solid wastes quantities are generated in urban areas are increasing due to the rise in population and increase in per capita waste generation rate. The increasing solid waste quantities and the areas to be served strain the existing SWM system.

2.3.1 Status of Solid Waste Management

Considering the average 450 gm/capita/day of solid waste, which increases 5% per year on account of increase in the population and change in lifestyle of the people, it is assumed that urban India will generate 2,76,342 TPD by 2021, 4,50,132 TPD by 2031 and 11,95,000 TPD by 2050. As per CPCB, only 68% of the MSW has generated in the country is collected of which, 28% is treated by the municipal authorities. In Andhra Pradesh & Telangana, 110 Municipalities and 15 corporations are generating 11500 TPD of MSW. In the above figure it appears that AP & TS is treating almost all the waste it is generating. But as per APPCB only 1595 TPD is being processed (Source, APPCB Website).This indicates a huge gap in the generation and treatment of solid waste which is matter of great concern. With rapid urbanization and improving in standards of living people, the waste generation is increasing day by day. Dumped waste and unscientific disposal of solid waste will ultimately lead to health hazard and pollution to environment.

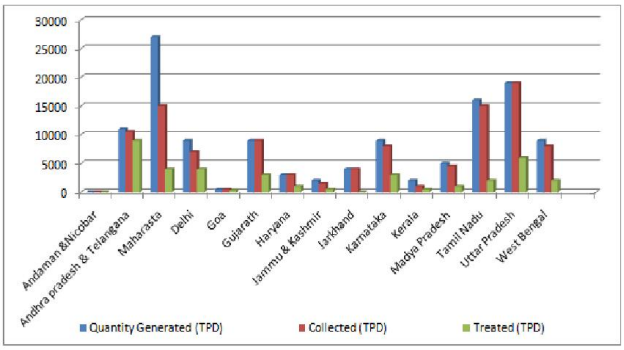

Fig. 2.2. Comparison of waste in various states.

2.4 Sources of Solid Wastein Bobbili

This study was carried out in the different places in bobbili city

Source1: Domestic Origin
Source2: Street side Waste
Source3: Market Origin
Source4: Industrial Solid waste
Source5: Hospitals/Medical solid waste
Source6: Commercial Institutional Waste
Source7: Agricultural and Animal Waste

2.4.2 Waste composition in municipal solid waste

The total waste is classified as 2 types they are

Type1: Wet waste 30%
Type2: Dry waste 70%

2.4.3 Chemical Characterization of waste

Mainly Chemical characteristics are considered for municipal wastes are moisture, nitrogen, phosphorous, potassium, C/N ratio etc. Indian characteristics of waste are presented below: MSW sample was collected from the dumping yard of Bobbili Municipality and analyzed for various chemical characteristics. Below table shows Bobbili chemical characteristics results.

2.3 Future Generation Trends

Based on Geometric progression projections and the percapita survey results of waste quantification, calculations were carried for the year 2030. The quantification details are tabulated below.

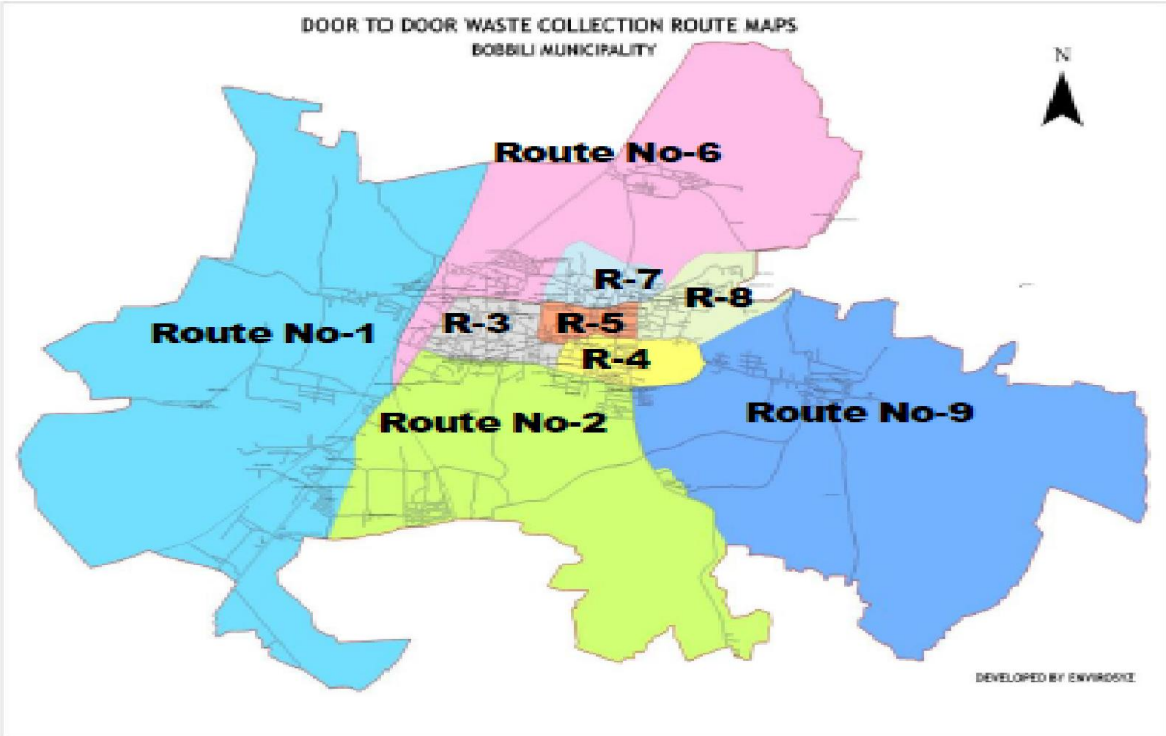

Fig 2.3. Route map for collection of waste

Total Waste Generation in Bobbili municipality

Table 2.2: Total Waste Generation in Bobbili municipality

Sl. No	Type of Waste	Waste generated (Tons/day)	% ofWaste Generation
1	Residential and commercial area	11.6	64.2
2	Market Waste	0.9	5.0
3	Street sweepings and Drain cleaning	1.5	8.4
4	Hotels & restaurants	1.1	6.0
5	Marriage/Function halls	0.4	2.1
6	Commercial Establishments	1.3	7.1
7	Hospitals/Health centers	0.3	1.7
8	Construction waste	0.1	0.7
9	Institutions	0.4	2.2
10	Temples	0.2	1.1
11	Meat Stalls	0.3	1.4
	Total	18.00	100.0

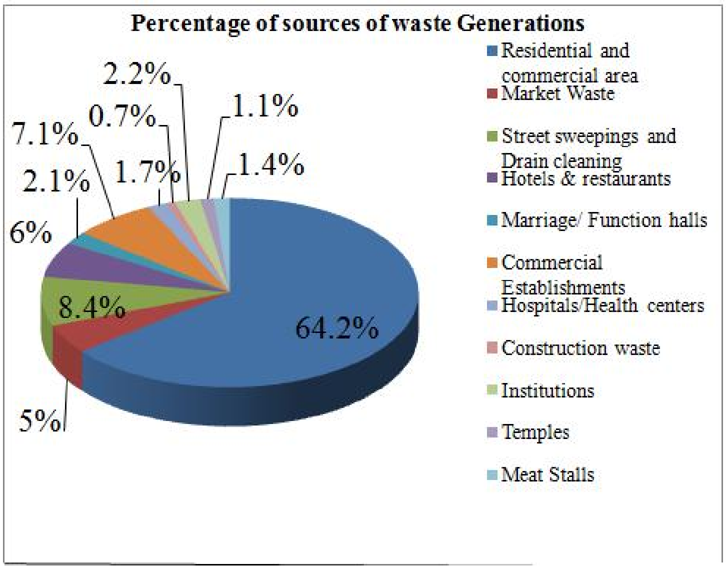

Fig.2.4. Percentage of sources of waste Generations

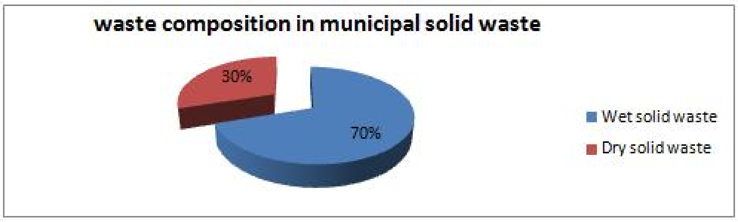

Fig 2.5. Waste composition in municipal solid waste

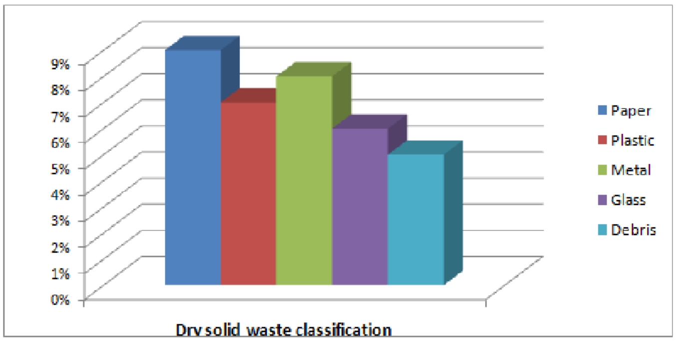

Fig.2.6. Dry solid waste classification

Table 2.3. Chemical composition

S.No.	Item	Unit	Result
1	pH (5% solution)	-	6.12
2	EC(5% solution)	µSiemens/cm	1908
3	Total Waste Soluble	mg/gm	5.8
4	Moisture content	%	39.0
5	Total organic Carbon	%	18.3
6	C/N Ratio(Dry)	-	25.0
7	Calorific Value	Kcal/kg	919
8	Total Phosphorus	%	0.68
9	Total Potassium as K	mg/gm	0.77
10	Total Nitrogen as N	%	0.73
11	ArsenicasAs$_2$O$_3$	mg/kg	BDL
12	Cadmium as Cd	mg/kg	BDL
13	Chromium as Cr	mg/kg	10.3
14	Nickel as Ni	mg/kg	BDL
15	Lead as Pb	mg/kg	13.3

Table 2.4. BobbiliTownWasteGenerationCalculationSheetforProspectivePopulation

BOBBILITOWNWASTEGENERATIONCALCULATIONSHEETFORPROSPECTIVEPOPULATION								
Sl. No.	Year	Population by Geometric method	Waste Generation Rate (Kg/c/day).	Total Waste for One day (in M.T.)	Waste generated from HH per day. @ 30%	Commercial Waste @ 60% (in M.T.)	Street Sweeping @ 10% (in M.T.)	Waste Generation per Annum (in M.T.)
1	2012	57643	0.28	16	10	5	2	5,891
2	2013	58427	0.28	16	10	5	2	5,971
3	2014	59222	0.30	17	10	5	2	6,052
4	2015	60027	0.30	18	11	5	2	6,573
5	2016	60843	0.31	18	11	5	2	6,662
6	2017	61670	0.31	19	11	6	2	6,978
7	2018	62509	0.31	19	12	6	2	7,073
8	2019	63359	0.32	20	12	6	2	7,169
9	2020	64221	0.32	21	12	6	2	7,501
10	2021	65094	0.32	21	12	6	2	7,603
11	2022	65979	0.33	21	13	6	2	7,706
12	2023	66876	0.33	22	13	7	2	8,055
13	2024	67785	0.33	22	13	7	2	8,165
14	2025	68707	0.33	23	14	7	2	8,276
15	2026	69641	0.34	23	14	7	2	8,388
16	2027	70588	0.34	24	14	7	2	8,760
17	2028	71548	0.34	24	15	7	2	8,879
18	2029	72521	0.34	25	15	7	2	9,000
19	2030	73507	0.34	25	15	7	2	9,122

3. Estimation of Power generation and utilization

3.1 Generation of Power

Generally, there are two types of MSW incineration ash, which are the remaining residues after burning: bottom ash (IBA) that remains after combustion on the grate and fly ash (IFA) that is removed from exhaust flue gases (Alec Liu *et al.*, 2015). In Bangkok, the waste-to-energy scheme has been implemented by using incineration technology with a capacity of 500 tons per day to produce 9 MWe followed by the second phase of 2,000 tons per day with 26 MWe. However, this accounts for only one-fifth of the waste generated in Bangkok. Nevertheless, incineration is not the ultimate solution for the treatment of megacity waste. Public participation is required, including reduce, reuse and recycle (3Rs) method, together with the separation of garbage at the source for sustainable development (Krongkaew Laohalidanond *et al.*, 2015).

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 (Shubham Gupta, 2015). Incineration remained to be the most integral part of MSW management in many countries.

In the incineration process, waste feedstock is mixed thoroughly to maintain a more constant heating value and then loaded into a large hopper, bunker, or other delivery system. Feedstock is then delivered along a conveyor or other mechanism into the furnace, typically onto a graded stoker or other bed for combustion. This consists of directly burning the waste in excess oxygen with temperatures in excess of 800^0C. As the waste is incinerated, released heat travels upward and heatswater in a boiler system, which in turn drives a steam cycle and steam turbine. The most important byproduct of incineration is the bottom ash which consists of silicon, iron, calcium, aluminum, sodium and potassium in their oxide state. Considering the amount of solid waste generated in the study area, the amount of power that can be generated has been calculated. According to the data provided by the Bobbili

Municipality, the composition of the solid wastes is as follows.

Table 2.5. Waste composition

Component	Percentage
Dry waste	30 %
Wet waste	70%

The components of dry wastes can be further classified as

Table 2.6. Components of dry wastes

Dry waste component	Percentage
Paper	9%
Plastic	7%
Metal	8%
Glass	6%
Debris/Sand	5%

The following two models can be used for energy conversion

- From dry solid waste
- From wet solid waste.

Since, Overall waste generated is18.00 Tons or18000 Kg

- Dry solid waste contributes to 30% of the total solid waste

Hence, dry solid waste = 0.3 x 18000 Kg = 5400 Kg

- Wet solid waste contributes to 70% of the total solid waste

Hence, wet solid waste = 0.7 x 18000 Kg = 12600 Kg

3.1.1 Power generation from dry solid wastes

In Bobbili, net calorific value or the amount of heat released during combustion value is 940 kcal / Kg.In India, the average net calorific value or the amount of heat released during combustion ranges from 800 kcal / kg to 1000 kcal / kg, with average value of 900 kcal / Kg.

Total solid waste generated (W)= 5400 Kg
Net Calorific value (NCV) = 900 kcal / kg
Energy recovery potential (kWh) = NCV x W x1.16 $x10^{-3}$
Power generation potential (KW) = (1.16 x NCV x $Wx10^{-3}$)/24
= 0.048 x NCV x W $x10^{-3}$
Considering the conversion efficiency to be 25%,
Net Power generation = (0.25 x 0.048) x NCV x W $x10^{-3}$
= 0.012 x NCV x W $x10^{-3}$
= 0.012 x 900 x 5400 x 10^{-3}
= 58.32 KW

3.1.2 Power generation from wet solid wastes

Total waste quantity organic / volatile solids = 12600 Kg
Few assumptions are made,

Organic biodegradable fraction (33%) = 4158 Kg
Typical digestion efficiency (60%) = 2494.80 Kg
Typical biogas efficiency (B) = 0.8 x fraction destroyed
= 0.8m 3 /kg of 1739
= 1995.84 m 3

Net Calorific value (NCV) of biogas = 5000 Kcal/ m 3
Energy recovery Potential (KWh) = NCV x B x 1.16 $x10^{-3}$
= NCV x 1995.84 x 1.16 $x10^{-3}$
= 11575.87 KWh
Power generation potential = NCV x B x 1.16 x 10^{-3}/24
= 5000 x 1995.84 x 1.16 x 10^{-3}/24

= 482.33 kW
Conversion efficiency = 30%
Net power generation = 144.70 kW
Total power generated from both dry and wet wastes (KW) = 58.32 + 144.70
= 203.02 kW
Total energy generated = (Total Power Generated X 24)
= 203.02 x 24= 4872.48 kWh

3.2 Energy utilized for street lamps

Road network for the study area was created and the total length of the roads was calculated in GIS environment. Total road length of the area is 16000 m (16 Km) considering the street lights to be at an average distance of 18 meters away from each other, the number of street lamps required for the area will be 16000 m / 18 = 889 lamps on one side of the road. Sooverall, 1778 lamps are required for the study area.

Also, considering the lamps used for street lighting to be 250W and being utilized for 12

Hours per day, the energy consumed by one lamp will be:
Energy consumed by unit lamp = 250 x 12

= 3000wh or 3kwh
Total energy generated = 4872.48 kWh
Therefore, total no. of street lamps supported for generated power = 4872.48 / 3
= 1625 street lamps
Remaining lamps = total lamps- lamps supported for generated power
= 1778-1625
= 153 lamps

Required power for remaining lamps = 153 x 3 = 459kwh Overall approx. 1625 street lamps can be used for 12 hours with the help of generated energy from solid wastes of the study area, this can satisfy about 91.33 % of the energy requirement.

4. RESULTS

From the analysis the contribution of solid waste for generating the energy by the various economic strata of the society. From the study, it can be attributed that the slum and non-slum areas contribute the maximum amount of solid waste (18000kg/day) respectively. Apart from this, it has been observed that 91.33% of energy has been generated by the municipal solid waste.

5. Conclusion

It has been observed that the energy generated from the solid waste will reduced the energy requirement to some extent. So, if the similar approach to be applied in the developing countries for improving the power assumption. Apart from this, it has been observed that the energy consumed by the lamp will be more than LED's. By using, LED's we can reduce energy consumption nearly 40% to 50% by which lot of power will be saved in country if it has been done everywhere.

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