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A Systems Approach to Recover Refuse Derived Fuels from Municipal Solid Waste - A Case Study

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Abstract: ***Solid wastes are increasing in urban areas. Characteristics of the solid wastes are dynamic and are changing with technology and cultural and living habits of the population. Conventional methods of Municipal Solid Waste (MSW) disposal on to the open lands are causing threat to soil-water and air. Also finding open lands within Municipal limits is difficult and huge amounts municipal budgets are spent on transportation of wastes to far of places. Removal of moisture content and non-combustible matter can be made use making Refuse Derived Fuel (RDF) pellets. In this technical paper, principles of making RDF pellets, calorific value associated with MSW-RDF pellets and their use as substitute conventional fossil fuels is examined, for which Jaipur City is taken as a case study.***

Keywords: MSW, Refused Derived Fuel (RDF), RDF Calorific Value, Energy Generation form MSW

1. Introduction

Cities are expanding geographically in size due to migration of population in search of employment opportunities. Municipal Solid Waste (MSW) is the material that arises from various human and economic activities. It is being produced since the beginning of civilization. Changing technology, living styles, cultural habits, consumption pattern resulted in increased generation of MSW in the present day. In the past they were conveniently disposed of on to open lands due to low population density and abundant availability. Lack of integrated solid waste management practice in fast-growing cities of developing countries is posing a threat to sustainable and green cities development. Increased waste generation and non-availability of dumping lands government lands within the Municipal Corporation limits, long distance of haul for safe disposal of MSW is of serious concern to the Municipal Administration. Despite spending 40-50 percent of Municipal service budget on solid waste disposal, most of the Indian Municipalities are unable to provide satisfactory solid waste management services. There is need to shift form conventional methods of MSW to MSW-Refused Derived Fuel(RDF) technology for the fast growing Jaipur, the Pink City in Rajasthan state requires up-to-date on waste quantification and characterization for planning and implementation of sound waste management options such as waster segregation at source, at local collection centers. The conventional methods available for solid waste disposal are land filling, incineration, and composting and bio-gas generation. Among the conventional methods, implementation of land filling method is affecting availability of lands in city limits, threating air and land and groundwater pollution. Hence there is need to explore innovative technologies(RDF) and cost effective-ecofriendly methods for disposal of Municipal Solid waste for the fast expanding cities for which Jaipur city is taken as case study for demonstration.

1.1 Jaipur City

Jaipur the "Pink City" capital of Rajasthan State occupies prominent place in North Western Region of India for its importance in tourism, trade commerce, education and marble industry. Jaipur rank's 7th fastest growing city in India and is in 24th position among 300 cities of the globe [City Mayor's foundation London ranked Jaipur based on various growth pointers, economic growth by National and International Statistics]. Jaipur City being located in a strategic location in North Western (NW) region, connecting to the sea ports Kandla, Adani, JNPT and also a gateway to National Capital Region (NCR) plays a significant role in socio economic development of the region and the country. Jaipur witnessed significant population growth rate (5%) during the period 1980-2001. Observed growth rate during the last decade was 2.83%. As per 2011 census population of the City was 30, 73,350 [Estimated population for Jaipur for the base year 2017 is about 36.5M], making it the tenth most populous city in the country

Population and employment would be the basic planning parameters, play crucial role in MSW demand estimation and requirements and there by the systems design for solid waste management Jaipur City is connected to the rest of the regions through the Gateway corridor namely to New Delhi in the North, Sikar-Bikaner in the North-Western, Agra in the East, Ajmer in the South-West and Tonk-Kota in the South respectively. These corridors dictate the directional growth and spatial expansion of the city. Spatial changes and land- use developments in Jaipur City during the last two decades resulted in, expansion of the city in North, South - Western and Southerly directions. Currently Jaipur City is organized into 91 Municipal wards and in 8 zones. Examination of decadal variation in populations reveal that the city underwent a Compound Annual Growth Rate (CAGR) of more than 5% prior to 2001 and observed a CAGR of 2.83% during the last decade. Observed trends in population is given in the table:1 below:

Table 1: Demographic Trends in Jaipur

Sl. No	Year	Population	CAGR %
1	1951	304380	
2	1961	410376	3.03%
3	1971	636768	4.49%
4	1981	1015160	4.77%
5	1991	1518235	4.11%
6	2001	2324319	4.35%
7	2011	3073350	2.83%
Source: Compiled from Statistical Census GOI			

After reviewing the past population growth rates, population projection for the next thirty years is carried using the available conventional methods. While carrying the future projections population growth rates of similar size cities [[1] Similar cities, like Nagpur, Bhopal, Indore, Lucknow, and Kanpur are examined for population growth over the last few decades] in India are given due consideration and growth rates for Jaipur city for the next thirty years is suggested judiciously. Population projections and suggested growth rates are given in the table 2. Characterization of waste also depends upon the source of generation. In Jaipur City there are about 240 slum locations (2011census) with 59476 households [[1] As per survey findings of Rajeev Awaas Yojana, 2011 and JMC & JDA] with a population of 6.9 lakh constituting about 22.5% of total population. Population in 91 wards of Jaipur city varies from a high value of more than one lakh per km^2 at city core(Pink City) to less than 10,000 per km^2 at the city periphery. Population density variations and Jaipur city regional is shown in the figures 1 and 2

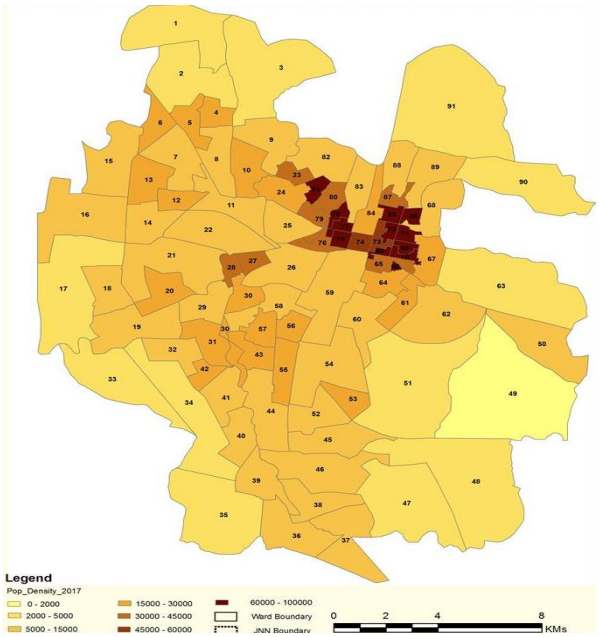

Figure 1: Population Density Variation in Jaipur City

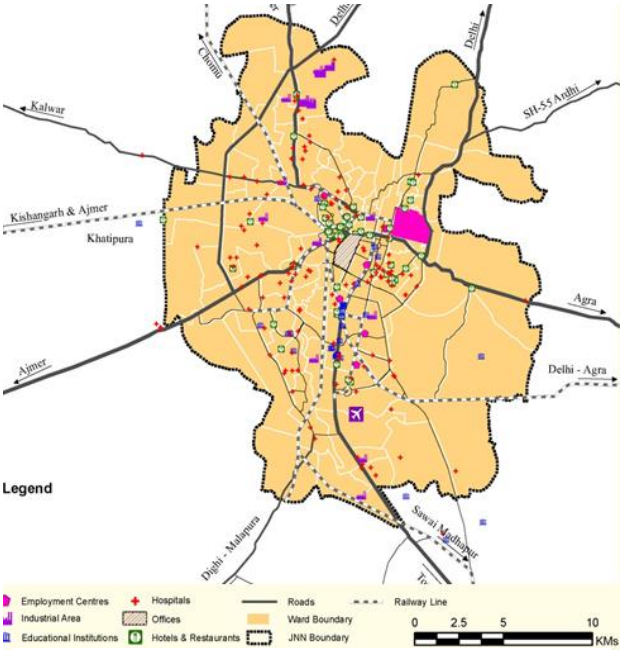

Figure 2: Work Places and Regional Linkages at Jaipur City

Table 2: Population projection and suggested Growth rates at Jaipur City

Year	2001-2011	2011-2021		2021-31	2031-41	2041-51
CAGR (%)	2.83	2.83		2.5	2	1.5
Year	2011	2019	2021	2026	2031	2041
Author's Population Estimate	3073350	3812854	4081343	4622465	5118458	6134586

Source: Compelled and estimated by Authors

1.2 MSW Generation in Jaipur City

In Jaipur per capita generation of solid wastes varies across different land uses and wards average production of waste is about 0.45 kg/person/day. Generation of waste for the next 30 years is quantified and is furnished in the following table.

Table 3: MSW projections in Jaipur City

Year	2019	2021	2026	2031	2041
Population Estimate	3812854	4081343	4622465	5118458	6134586
MSW Per capita per day in Kg	0.45	0.45	0.44	0.43	0.40
MSW Generation at City Level Tons/day	1716	1837	2022	2175	2454

(Source: Authors Estimation)

From the table it can be seen that MSW generation is increasing from 1700 tons/day to 2400 tons/day by the year 2041. While carrying projections it is assumed that per capita MSW factor would stabilize at 0.40kg/person/day, due to technological changes, policy regulations and government regulations.

1.3 RDF from MSW

In the recent decades, much research has been carried for the safe disposal of waste and energy recovery from the waste. One such latest technology is Refuse Derived Fuel (RDF), in this method the MSW is processed through Mechanical and Biological treatment methods to make pellets using the solid waste. Municipal Solid Waste collected from the urban areas contain significant portion of carbon, noncombustible material and moisture. After removal of moisture and noncombustible matter, the MSW can be used as an alternate fuel to replace conventional fuels like coal and petroleum products. In this technical review, manufacturing principles of RDF, its performance and Coal-RDF-co firing issues are comprehensively examined for which Jaipur is taken as case study.

1.4 Current MSW disposal Practices in Jaipur

From the statistical records of Jaipur Nagar Nigam about 1700-1800 tons of waste is being collected from the Municipal wards of Jaipur City. Out of which very small quantity of waste (150-200TPD) is being processed. Most of the waste is dumped onto open lands located at Sewapura and Langariawa.

Figure: Disposal of MSW on Road Side open lands Within Neighborhood of Jaipur City

Currently MSW is disposed onto 859 Bighas (537 acres) of municipal landfills located at Mathuradaspura, Sewapura and Langariawas. Description of the sites and their handling capacity is given in the table below 4.

Table 4: Jaipur City MSW Management practices

SL. No	MSW Disposal Site	Area in Bhigas	Amount of MSW Disposed Tons/day	Remarks
1	Sewapura	176	300-350	Oldest Site 17Km from City
2	Mathuradas	200	350-400	Site 20 Km from City
3	Langariawas	483	950-1000	Site 20 Km from City
		859	1700-1750	

(Source: compiled by the author)

Of all the waste generated only 25-30% is treated and the remaining is disposed on to open lands and 600 tons/day is converted in to compost, remaining goes to RDF. RDF pellets produced are sold at INR 66/ton to cement plants [1]. There are plans to generate power from MSW by Jaipur Municipal Corporation. From the Table 4 it can be seen that, amount of MSW generated expected to increase from 1700 TPD to 2400 TPD in the next 20 years. Conventional methods of MSW disposal would be difficult to handle such large quantities of MSW and there is a need to shift to energy recovery methods, to curb threats of pollution. Systems approach followed for the disposal of the waste is given in the figure: 3 below.

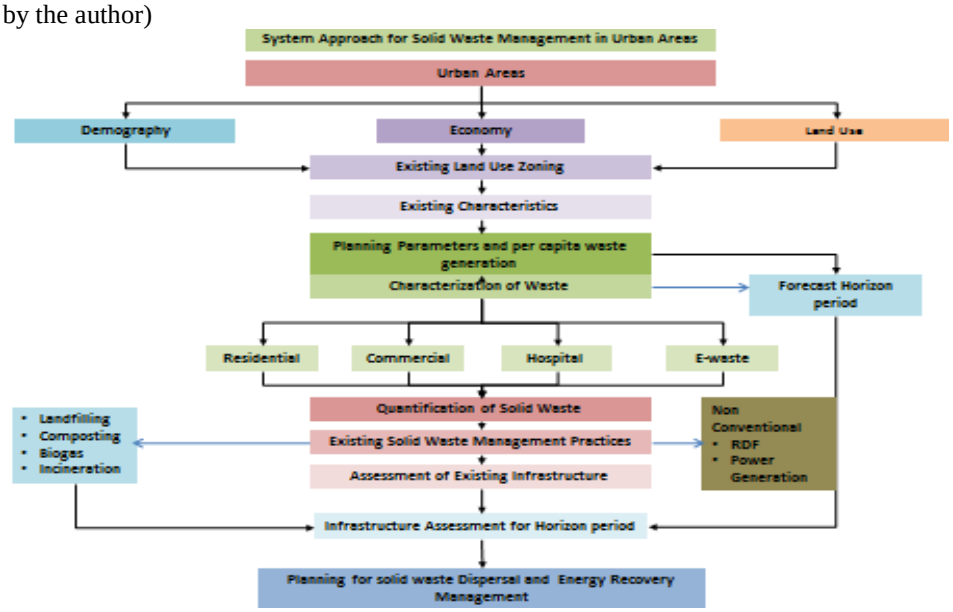

Figure 3: Systems Approach for MSW Management

2. Literature Review

2.1 Guidelines on Usage of Refuse Derived Fuel in Various Industries (2018)

To achieve the mission of Swatch Bharat, GOI prepared draft guide lines for the usage of MSW-RDF for its usage in cement plants located within 400Km of urban areas[2].Industrial coal is having a calorific value(kcal/kg) of 3000-4200, based on this RDF pellets are classified in to different grades 1500-4500. Guide lines also recommended that transportation cost of RDF for the first 100km, to be borne by the cement plants beyond this ULB or the plants would born for which the cement plants agreed. As per Depending on waste characteristics and waste hierarchy, the potential treatment options and segregation required for segregation of non -combustible matter are summarized in SWM Rules 2016[3]. Method for MSW collection and their analysis need to be in accordance with the BIS and ASTM standards. Many of the recommendations are yet to be adopted by Urban Local Bodies (ULB).

Waste generation in Indian cities is ranging from 0.3-0.55 Kg/capita/day. The MSW contain 25-35% of moisture content, large amounts (65%-70%) of Waste generated from these cities are dumping onto the open lands causing infiltration of leachate in to ground water. Characteristics-composition of MSW varies marginally from city to city. Many researchers worked for effective utilization of MSW and energy recovery methods, one such method is Refuse Derived Fuel (RDF).

2.2 Manufacture of RDF Pellets

2.2.1 Principle involved in Making of MSW Pellets.

Municipal waste collected from the source, the residential and commercial areas contain large quantities of non-combustible matter, like street sweepings, soil, silt , glass, metal, etc,. Such MSW would be difficult to shredding and also upon burning they release large amounts non-combustible material and affect the efficacy of furnace. Hence there is a need to segregate for the combustible matter and made them ready for shredding. As the MSW is having considerable amount of moisture (25%- 30%), they need to be removed through air drying. For air drying, hot air at a temperature of 60^0 C is blown in to shredded and segregated waste in a closed container for a period of one week. The process of removal of moisture content from MSW is termed as densification. Prolonged blowing of air involve aerobic digestion may likely to volatile methanol and formaldehyde from MSW and may refuse the calorific value. Hence there is a need to conserve the volatile gases during densification and aerobic digestion through modified and innovative methods. To refuse the costs involved in palletization process, solar drying is recommended.

The MSW, after removal of moisture becomes puffy can be used as a fuel without pillarization, but its density and calorific value will be low. The shredded puffy material will be compressed in to cylindrical or cubical pellets under a compressive force of 50KN.

In the process of pellet making a marginal percentage of binding/additive material would be used to make MSW as in the form of briquettes. Most commonly used binding materials in pellet making are:

- Calcium hydroxide
- Magnesium hydroxide
- Petroleum Residue.

The type of additive material and its quantity requirement would be based on composition of MSW and PVC content in the MSW.

2.2.2 Calorific Value of RDF Pellets:

Calorific value of RDF pellets range from 10 to 20 MJ/kg, it largely depends on following parameters:

- Density of RDF-MSW pellets
- Composition of the MSW
- Moisture content
- Organic –combustible matter in MSW

To increase the calorific value of the MSW –pellets, combustible organic waste like rice husk, agricultural waste, coconut shells, peanut shells, saw dust, water hyacinth etc. can be added. The composite shredded MSW waste under high pressure in presence of additive material can be densified to raise the calorific value. Laboratory experimentation and research need to be initiated for better utilization and RDF briquettes as a substitute to conventional fuels and for ecofriendly disposal of MSW in Indian context.

2.3 Carbon Neutrality Issues

Many countries across the globe depend on nonrenewable resources like coal and petroleum products for generation of energy. Consumption of large quantities these fuel is releasing carbon dioxide. The objective of promoting RDF pellets use is to refuse release of Carbon dioxide, into atmosphere, which are generated from fossil fuels. Developed countries like UK and Japan already refused their dependency on coal consumption to refuse carbon dioxide generation from fossil fuels. Also the aim of promoting RDF is to achieve no net increase in contribution of CO_2 into atmosphere, this led to the concept of Coal-RDF –Co firing technology.

2.4 Performance Issues

One ton of MSW is capable of generating 400-500Kg of RDF pellets after removal of non-combustible matter and moisture. Performance of RDF pellets is largely depends on moisture content and other chemical constituents, which will determine its calorific value. For the parametric evaluation of RDF factors, analysis carried in previous research are directly taken from the reference [4]. Generic values of the composition of RDF is furnished below in the table:4

Table 4: MSW –RDF Composition

Sl .No	Constituent/Property	Value
1	Calorific Value/MJ Kg^{-1}	18
2	Moisture content (%)	11.1
3	Sulphur Content % d.b	46.9
4	Hydrogen Content % d.b	6.75

Sl .No	Constituent/Property	Value
5	Oxygen Content % d.b	40.8
6	Nitrogen Content % d.b	0.84
7	Carbon Content % d.b	0.19

With the inputs furnished in the table further analysis is carried by the researchers [5] to examine for the amount of air required for burning and the flue gases released upon burning. Summary of the analysis of combustion of RDF is furnished in the table 5 below:

Table 5: Combustion of RDF Air requirements and Emission of Gases

Sl No	Parameter	Measurement	Remarks
1	Air Requirement on Burning of RDF	One Kg of RDF requires 6Kg of air for complete combustion	
2	Volume of the flue gases produced on complete combustion	one Kg of RDF release 6.6 m^3 of flue gases in to the air	Composition of the flue gases are $C0_2$(13%), H_2O(13%), N_2(70%), 0_2(13%),
3	Harmful Emissions during complete combustion of RDF	SO_x and NO_x	Sulphur and Nitrogen are released into air in oxide forms. Even though their PPM levels are low, when they dispersed in to the air, they need to be removed using fluid bed technology

2.5 Coal –RDF-Co Firing

Calorific value of RDF pellets- briquettes ranges from 20MJ/kg to 25MJ/kg. High calorific value of the RDF is attributed to low moisture content (<10%) and high carbon content (Paper/Plastic). Many investigations are carried for the cocktail coal –RDF –co fairing for the generation of electricity. In England at Slough cocktail combination is used [6]. From the investigative studies the following inferences are drawn:

- On burning of RDF pellets Sulphur dioxide levels of 200PPM are observed [6].
- NOx measured levels are observed at 80PPM.
- Sulphur dioxide released at the bed can be removed using lime stone fluidized
- Calcium carbonate is used to trap chlorine from the burning of plastic content in MSW. The ash collected indicate high level of chlorine content.

2.6 MSW-RDF Technology Implantation across the Globe

Finding open lands in urban areas and metro cities has become increasingly difficult to continue conventional methods of open land disposal of municipal solid waste disposal. To curb the practices many developed countries are switching on to on to energy recovery methods "Energy Return on Energy Invested"(EROEI)[7]. References of the MSW –RDF pellets operational plants are discussed below.

Table 6: MSW-RDF Pellet Use in different cities

S. No	MSW-RDF Plant Location	Description
1	Andhra Pradesh India	RDF Pellet as fuel for electricity generation, with calorific value 12to 13 MJ/Kg and ash content 20%.
2	Herof Plant Dresden Germany	Pretreatment by aerobic digestion before palletization with calorific value 15-18MJ/kg
3	Kahada –Okuise RDF plan Japan	Calcium Hydroxide as binding agent. Pellets with calorific value 18-20MJ/Kg
4	Istanbul, Turkey	Pilot study into pelletized RDF production
5	Greve in Chianti Italy	RDF Pellet of Calorific value 17 MJ/kg
6	Stockholm Sweden	CHP from fuels including RDF pellets

The information given in the above table limited, many other cites which are not following listed here due to space limitations. In India about 29 RDF – pellets plants were commenced, some of them are not working because of operational and MSW processing and segregation issues. MSW –RDF-Pellet feed to small power plants were commenced in Hyderabad, Vijayawada on operational basis. There is need to commercialize the technology for large scale implementation [9]. In Jaipur, Rajasthan, an Indian City RDF pellets use encouraged to supply them for power generation under private participation [10, 11].

Moisture content is one of the main parameter that determines the quality of RDF. Lower moisture content implies higher calorific values; otherwise material will burn at lower temperatures and thus increasing likelihood of harmful gas emissions (EPA, 2010). Produced RDF had moisture less than 10 % wt. which corroborate with reports from similar findings (Koukouzas et al., 2008; Park et al., 200; and Kara et al., 2009). With respect to ash content, T5 reported maximum value of 7.9 % wt. which might have been contributed by the nature of the additive (water hyacinth) which agrees with (Park et al., 2008, Poespowati and Mustiadi 2012)

3. Summary and Concluding Remarks

Increased generation of Municipal Solid Waste (MSW) has become major challenge for the Municipal Authorities due to the paucity of funds and non-availability of open lands for disposal. Utilizing MSW-RDF-pellets as an alternate fuel for energy generation and also address the problem of MSW management and disposal. Health hazards caused due to unscientific methods of disposal of solid waste [12] can be refused to a great extent by adopting RDF technology. The flue gases and hazardous emissions can be controlled by using fluidized beds. RDF technology would refuse the use of natural fossil fuels to refuse net addition of CO_2 in to the atmosphere. At the moment Jaipur is generating 1700 Tons of waste a day and there is a huge potential for the conversion of waste into MSW –RDF pellets. There is a need for the ULB authorities, to explore the possibilities of making MSW into RDF pellets.

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