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d-RDF (Refused Derived Fuel) for SMART-CITIES of INDIA

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Abstract: *Densified Refuse derived fuel (d-RDF) generally refers to the product of CHEMICAL plus MECHANICAL processing of Municipal Solid Waste (MSW) produce as per specific output. The current research work is the assessment of the energy available from the MSW and from the rural Village for the Self-Sustainable development of new (RDF), as a green fuel and development of the new site for MSW management. The study also entailed the Collection and Segregation of all the energy available in the villages as well as Municipal Corporations. From the study it is found that the green village as well as Municipal Corporation has considerable energy potential. The magnitude of the energy density will help in building a self, power generation villages. The energy & green fuel density will also help for the development of the green fuel at one particular village as well as at MC locations. A suitable sustainable renewable energy generation from the green fuel, system of (SITES) which was studied for the villages and for MC is also being recommended with STATE of the ART designs for sites as SMART-CITITIES projects of INDIA.*

Keywords: *Municipal Solid Waste, Smart Cities, Solid-blend, Green Fuel, Refused Derived Fuel (RDF).*

1. INTRODUCTION

The DENIFIED refuse-derived fuel (d-RDF) is the product of the mechanical compaction of some form of RDF to agglomerate pieces which are sufficiently cohesive to sustain storage and handling. The term ‘densified’ is used in the generic sense to include all forms of compaction, such as extrusion or rolling to produce BRIQUETTES, PELLETS, CUBLETES, etc. Generally, d-RDF is a fuel for stoker boiler analogous to lump coal. The concept of RDF & d-RDF can be extended to other waste derived or biomass fuel. The commercial preparation of d-RDF has been described. This paper is to update and expand the information and describe the objectives and operation of some of the unit processes used and properties of the d-RDF.[1 &2]

Presently the d-RDF is used for CEMENT Clinker which can also be fed into plasma gasification modulus, or pyrolysis plants as the d-RDF is capable of being combusted cleanly which in compliance with the KYOTO Protocol of Sustainable living and development. Importantly[3], waste management is collection, transportation, processing or disposal managing and monitoring of waste materials. All waste materials whether they are SOLID, LIQUID, GASEOUS or RADIOACTIVE fall within the dispatch of waste management. Apparently, the biodegradable waste could be processed by vermin composting, and land-filling should be restricted to non-biodegradable inert waste and compost rejects. A properly designed and well-managed land fill can be a hygienic and relatively inexpensive method of disposing of waste materials within towns, villages and cities. From the study it has been found that the cities have considerable green energy potential. The magnitude of the green energy density will help in building a self power generating smart cities inside INDIA at same time it could be used in industries.

Urban waste comprises of 3 different categories **wet waste** (vegetable peels, food waste etc.), **dry** (paper, plastic, metal etc.) waste and **toxic waste** (batteries, CFLs etc.).

- **Wet Waste:** Organic waste is segregated at the processing facility through the mechanical segregation process and it is then converted to compost through aerobic composting. Most of the organic waste is converted in compost and sold to farmers. Waste from permanent and temporary vegetable markets is collected and transported to the composting plant and reused as organic manure.
- **Dry Waste** such as glass, paper, metal, as substantial amount is collected by Ghantagadi workers and informal rag pickers and this is further handed over to scrap merchants in the city. The material of **Street Sweeping / Drain Cleaning is** collected by the safai karamcharis and transported to the Ghanta Gadis in the respective wards of the URBAN & CITY areas.
- **Hazardous or Toxic** waste as shown in Figure (1), is waste that poses substantial or potential threats to public health or the environment and which is ignitable (i.e., flammable), reactive, corrosive and toxic[4].

Figure 1. *Segregated Wet, Dry and Toxic Waste.*

The densities of solid wastes vary markedly with geographic location, season of the year, and length of time in storage. The moisture content of solid wastes is usually expressed as the mass of moisture per unit mass of wet or dry material. In the wet mass method of measurement, the moisture in a sample is expressed as a percentage of the wet mass of material; in the dry mass method, it is expressed as a percentage of the dry mass of the material. For the most industrial solid wastes, the moisture content will vary from 10 to 25 per cent. where ***a*** = Initial mass of sample as delivered, ***b*** is mass of samples after drying;

$$\left(\frac{a-b}{a}\right) * 100 \tag{1}$$

Information on the chemical composition of solid wastes is important in evaluating alternative processing and recovery options. If solid wastes are to be used as fuel, the four most important properties to be known are:-

- Proximate Analysis; Moisture (loss at 105^0C for 1 h), Volatile matter (additional loss on ignition at 950^0C), Ash (residue after burning), & Fixed Carbon (remainder). & Flushing point of ASH.
- Ultimate analysis percentage of C (Carbon), H (Hydrogen), O (Oxygen), N (Nitrogen, S (Sulphur), & ash contains & Heating Values are shown in Table [1].
- d-RDF Compositions in (%) is Plastics (31%), Textiles (14%), Paper & Cardboards (13%), Wood Fractions (12%), and Others (30%).[5]

Table 1.*Properties of d-RDF.*

d-RDF TYPES	HEATING VALUE of received (J/g)	Moisture Content (%)	Ash Content (%)
RDF	12,000 to 16,000	15 to 25	11 to 22
Coal	21000 to 32000	3 to 10	5 to 10
MSW	11000 to 12000	30 to 40	25 to 35

2. Material & Methods to Characterize as a Fuel

2.1. Determination of Ignition and Combustion Behavior

To accurately determine the ignition and combustion behavior of fuels is to investigate a number of parameters. In detail these are the ignition temperature, thermal absorption rate, combustion air mass flow rate and temperature, flow rate in fuel bed and particle size. For these investigations, the equipment shown in Figure [2], could be used for; Ignition reactor, Laboratory Thermo Balance, Technical Thermo balance, & Batch reactor.[6]

❖ The **IGNITION REACTOR** is used to determine the ignition behavior of fuels. In which the equipment is powered with sample mass of approx 300mg, which is burnt in a pre-heated reactor up to a temperature of 1100°C. Through an optical sensor and an installed thermal element, in which the temperature distribution over the current flow is ascertained.

❖ The laboratory **THERMO BALANCE** which is shown in Figure [2], in which the ignition and combustion behavior under different Temperature-Time conditions, with varied gas atmosphere, kinetic reaction constant, where studied, for example max 1 g of sample was determined. Apparently, sample amount is small and homogenization is hence necessary it was very difficult for RDF to be simulated under given conditions.

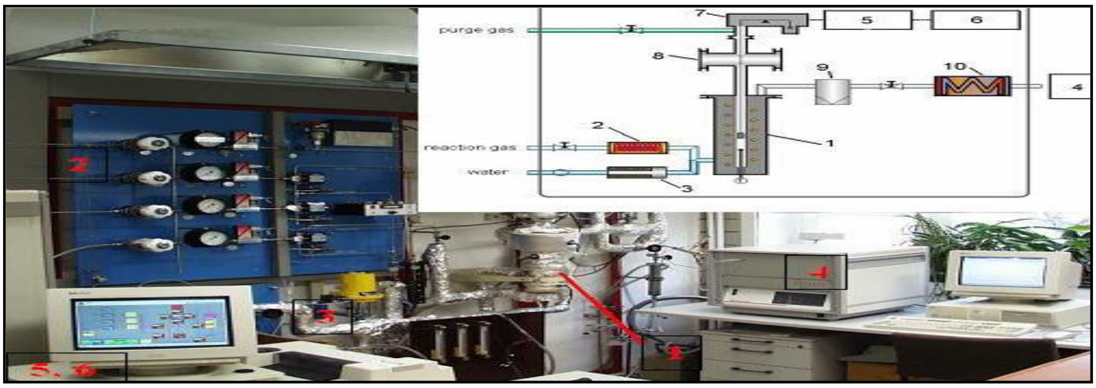


Figure 2. *Laboratory Thermo Balance*

❖ The **TECHNICAL THERMO-BALANCE** in which the sample can weigh up to a size of 3kg, & hence it was suitable for d- RDF as heterogeneous lumpy samples.

2.2. Technological Assumptions

It was assumed that the RDF production was carried out according to the best available technology in order to prevent strong environmental impacts. Similarly, the technologies chosen for RDF utilization are based on an average high standard and represent **BAT** (Best Available Technologies), in the sense of the **IPPC** (Integrated Pollution Prevention and Control) directives. Apparently, the IPPC directives stipulates that in order to meet a specific environmental quality standard, must include additional conditions in the environmental permits for specific large industrial production installations, if more stringent standards must apply than those feasible with the best available technologies (BAT). The specified standards for MSW incinerator in the module used for the environmental assessment are ensuring compliance with the new Waste Incineration Directive. For the cement works and power plants, a general compliance with the threshold value could be specified on the ratio of energy substitution for waste derived fuels. RDF fuels could be differentiat from fossil fuels by; a heterogeneous composition e.g. size, higher inert material composition of volatile matter, chlorine, alkali and heavy metal content with lower calorific value, lower bulk density and lower energy conversion’s density. These properties have an influences on the ignition, combustion behavior, slag formation corrosion potential and lastly on the corrosion efficiency. Combustion remains predominant; therefore technology for MSW conversion with realized improvements in emission. The projection of generation of the Municipalities wastes for next twenty years will be as shown in Table [2].

Table 2. *Generation of Municipal Solid Waste (Projections)*

S. No.	Year	MSW Mt. / Day	Quantity Mt. / Year	Volume of SLF.
1	2006	800	1,09,500	16,425
6	2011	421	1,53,665	23,050
16	2021	827	3,01,855	45,278
26	2031	1628	5,94,220	89,133
Remnants @15% MT Sanitary Landfill.			75,20,095	11,28,015

- Volume of SLF (Sanitary Landfill) at Compaction Density of 0.8 = 14,10,018M^3.

The high calorific energy containing materials present in MSW are to be handled separately from the slag of receiving at the tipping, floor onwards. RDF plant with different capacity should be installed for generation of fuel pallets from high calorific value material. Woody materials, paper products, textile, jute etc., forms the main constituents of RDF, which are a valuable source of alternate energy. The technology for RDF primarily focuses on refinement of MSW through material re-combinations, segregation, drying, size reduction, blending and homogenization. These material are further refined for separation of sand, dust, metals, glass, etc, before grinding or shredding. The shredded material are obtained as ***fluff*** (< 2CM size) which are further processed into pellets, briquettes or baiting. Here, we could set up the benchmarks for the cities in India, apparently TABLE [3] is explain the benchmark, states of service and the reliability of the levels in which; **A** is HIGHEST, **B** is PREFERRED, **C** is INTERMEDIATE & **D** is the LOWEST level.[7]

Table 3. *Benchmarks for Chemical Industries in the Cities*

Performance	**Bench Mark**	**Status**	**Reliable**
Household level Coverage	100 %	86.88%	B
Efficiency in Collection of MSW	100 %	86.50%	B
Extent of Segregation of MSW	100 %	34.68%	C
Extent of MSW renewal	80 %	100 %	A
Extent of Scientific Disposal	100 %	0.00 %	D
Extent of COST Recovery	100 %	33.10 %	C
Effic. in Reduction of CUSTMOER's Complains	80 %	100 %	C
Efficiency in COLLECTION of SWM Charges	90 %	35.05 %	D

2.3. RDF Characteristics

Calorific Value is 2500 – 3000 Kcal /Kg. High Volatile Matter (60%). Emission Characteristics d-RDF is Superior Compared to COAL with less NOX, SOX, CO & CO_2. Bio fertilizer and the FLY ash are the useful by products. Analysis of City Waste was carried out recently, reveals 37.8% easily compostable (short-term biodegradable) materials, in which 19.5% hard lignite and long-term biodegradables, and 16.20% textiles. The plastics and rubber components having 35.70% content in the MSW which become a major cause of concern. These materials are a negative contributor to the processing plant efficiency and rapidly exhaust available land for land filling. Refuse derived fuel (d-RDF) is a kind of alternative solid fuel which is derived from domestic or insulated solid wastes, recyclable materials such as plastic, glass, metal, etc or after decomposition burnable hard to recycle materials.

Table 4.*Quantity of RDF from Household and Industrial Sources*

S. No.	**d-RDF Source**	**Calorific Value**	**Ash Residue**	**Chlorine Content**	**Sulphur Content**	**Water Content**
		(MJ / K)	**(% W)**	**(% W)**	**(% W)**	**(% W)**
1	Household Dry Waste	12 – 16	15 – 20	0.5 – 1	---	10 - 35
2	Household Wet Waste	13 – 16	5 – 10	0.3 – 1	01 – 0.0	25 - 35
3	Commercial Waste	16 – 20	5 – 7	<0.1– 0.2	< 0.1	10 - 20
4	Industrial Waste	18 – 21	10 – 15	0.2 – 1	---	30 - 10
5	Demolition Waste	14 – 15	1 – 5	< 0.1	< 0.1	15 - 25

Therefore, this fuel having high calorific value of d-RDF is about 4000 Kcal / kg. The reason of high calorific value is due to plastic, paper or cardboard contents. In addition RDF has also high-bio mass value. Thus technology is generally applied only at very large MSW (Municipal Solid Waste) facilities. d-RDF is commonly prepared by shredding, sorting and separating out metals to create a dense MSW fuel in a pelletized form of Uniform size. The composition of d-RDF Varies significantly from cities to city and state to state within India. This is due to cultural differences and to the level of source, separation and other recycling and processing of wastes carried out in different countries.

3. RESULT AND DISCUSSIONS

Refused derived fuel facility as shown in Figure [3], is also for Crushing, Drying and Solidifying combustible refuse. The facility converts domestic combustible refuse into solid fuel and enables to consolidated incineration with improved transportation preventing the generation of Dioxins.

Apparently, the waste receiving and burning of processes through improved waste storage enabling utilization of solid fuel at the most suitable time. The conversion of waste into solid fuel improves refuse transportation and storability as well as makes it possible to consolidate small incineration facilities, for which taking measures to prevent the generation of dioxins is difficult and to incinerate facilities in response to power demand. Consolidation of incineration with improved waste transportation and prevention of generation of dioxins. Refuse is dried and solidified at small facilities, making it possible to improve refuse transportability, which is in turns makes it possible to consolidate incineration at a large facility. Continuous incineration prevents the generated during small-scale batch incineration, and its Optimized timing of incineration provide improved storability. Solidifying and Drying refuse prevents corrosion and reduces the volume providing improved storability. The refuse can be incinerated at the convenience of those incinerations and utilizing the refuse.

The perspective of a co-incineration plant, the use of d-RDF by a given facility may or may not be worthwhile. Let us assume that the material is technically acceptable from the perspective of the plant's operation (as opposed to limit values etc.).

- Let the cost of the waste to the plant be ***pw*** per tone (and this may be negative),
- Let the net calorific value of the material be ***cw*** MJ per tone,
- Let the cost of the fuel being replaced be ***pf*** per tone,
- Let the net calorific value of the fuel be ***cf*** MJ per tone

In this case, the quantity of waste used to displace one tone of fuel is :- (**cf/cw**) tones.

The cost of this is**:- (cf/cw)*pw**

Implying a net saving of: ***-pf - [(cf/cw)*pw]*** per cf MJ generated (2)

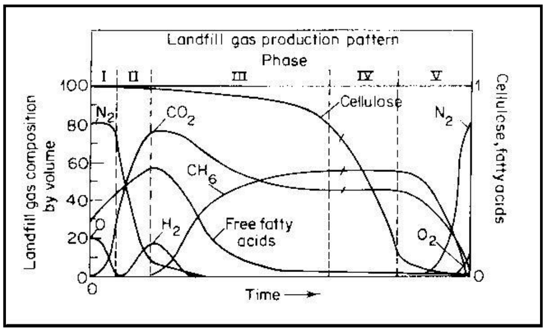
Clearly, in generating this quantity of energy, it is necessary to run the plant. Suppose the running costs of the plant are O(f) when using (**cf/cw**) tones of waste fuel and O(w) when using cf tones of waste, where O is a function relating operating costs to the nature of the fuel itself, then the total saving is:- **{pf – [(cf/cw)*pw]} + [O(f) – O(w)]** (3)

It is clear from this that the saving increases as:

- Conventional fuel prices rise (and fuel taxes may increase in future, and Greenhouse Gas abatement measures may have a similar effect)

The ratio (**pw/cw**) becomes smaller (or large if negative). In other words:

1. If the price paid for the waste is negative (a gate fee is charged), the operator may, subject to other constraints, become relatively indifferent to the calorific value as long as the operating costs do not increase unduly (higher the calorific value, the better);
2. If the price paid for the waste is positive, the calorific value is rather more important since net losses will occur if the lower price is not offset by calorific value.



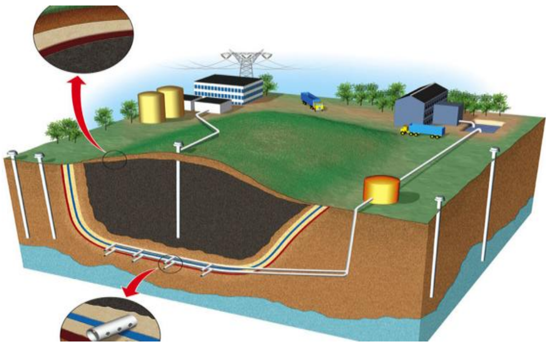


Figure 3. *Landfill gas emission patterns per phases & State of arts Municipal.*[8]

All this suggests that from the point of view of co-incineration plants, there may be significant benefits to making use of substitute fuels. This will be especially true where the facility is able to charge a gate fee. This situation is likely to prevail where there is no strong competition (competing outlets) for the wastes being combusted and where alternative waste treatments are non-zero in price (though the gate fee charge has to take into account what may be additional transport costs to the co-incineration facility). The solid waste which is not suitable for any processing is transported to the sanitary landfill site as shown in Figure [3]. For this purpose, a sanitary landfill in an area of 2 hector has been developed. All the necessary aspects of scientific land filling were considered during creation of sanitary landfill. Proper arrangement for leachate is also provided and this is connected to the leachate treatment plant for further processing. Then the aerobic decomposition of waste could be starts for a short period until trapped air is consumed. When this occurs anaerobic micro-organism becomes dominant and these initially break down organic compounds, principally carbohydrates to form fatty acids e.g. acetic, propionic, and butyric acids.

After oxygen has disappeared, methanegenic bacteria become active; they decompose organic acids into methane, carbon dioxide and water is shown in Figure [3] these gases as in phase patterns. This compost is also called as Bio-Organic fertilizer which could be used at the time of Transplanting as drilling or broadcast. It should be applied along with the rows or encircling around the plants. Since it is a fully DIGESTED material it can be applied at the time of Crop feeding Stage. Frequent analysis of material tests for moisture content, density, pH, soluble salts, and particle size distribution need to carry out. This could also aims at informing the public about current and future services, its environment and health benefits as well as the costs it incurs, In conclusions these project will help common man as well as government in protecting the environment, facilitation of energy efficiency, may represent the most economically sound waste treatment for the industry as ENERGY incineration and the State-of-the art MUNICIPAL LANDFILL site described in Figure [4].[9] Same time will help in securing supply of fuel of HIGH calorific value, also securing the employment and growth of the country. Apparently, as representation in Figure [4] the roots of plants such as ***Sunflower*** with dangling roots on ponds or in greenhouses can absorb pollutants such as radioactive strontium 90 and cesium 137 and various organic chemicals. Simultaneously phytostabilization plants such as ***Willo Trees*** and ***Poplars*** can absorb chemicals and keep them from reaching ground water or nearby surface water. Plants such as ***Poplars*** can absorb toxic organic chemicals and break them down into less harmful compounds which they store or release slowly into the air. Roots of plants such as ***Indian Mustard*** and ***Brake Ferns*** can absorb toxic metals such as lead, arsenic, and others and store them in their leaves.

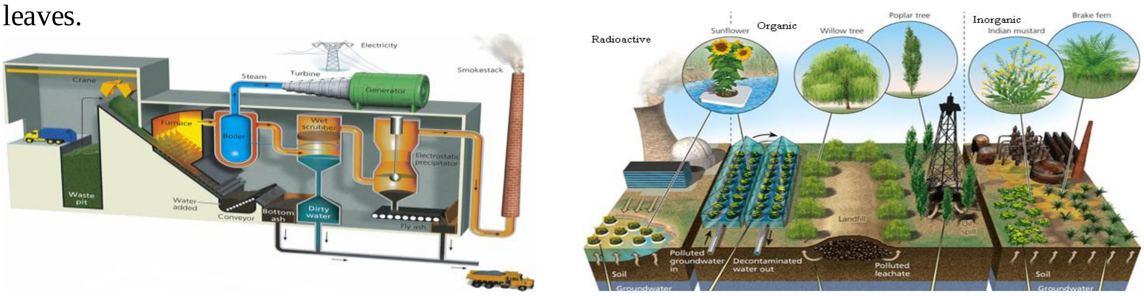


Figure 4. *Waste to ENERGY incinerator (Left) & State-of-the-art Municipal landfill.*

This meets the objective of the CLEAN INDIA by 2019 of our PM Narendra MODI's dream of Clean India by 2019, while protecting the environment in a safe sustainable secure and co-efficient way. In addition it creates employment and growth within the INDIA. Therefore these points should their's applications must get reflected in the INDIA's policies and regulatory initiatives.

4. Conclusion

Waste conversion systems, including both the mass burn and d-RDF technologies, have the potential to provide as much as 3% of the nations annual energy demand. Furthermore, the recycling of inorganic such as ferrous metals, glass and aluminum would further reduce our total energy use by an additional 1%. Beneficiation of d-RDF is given as; (1) Cement Production using d-RDF as a supplemental fuel is an economically viable option to reduce fuel costs and reduce landfill disposal. (2) Produces beneficial effects on air emission and ash residue when used as a fuel. (3) Produces a more homogeneous fuel which burns more evenly at a higher temperature thereby making combustion control easier. (4) Has a higher calorific value content, lower ash and moisture content. (5) Allows recovery of saleable materials. (6) Can be processed at one site and transported to other location for combustion. (7) Can be burned in a wide range of existing boilers, fluidized bed combustors, gasifies and cement kilns with no, or only minimal modifications required. (8) Can be co-fired in existing boilers with other fuels such as coal, wood or sewage sludge. (9) Achievers 50% greater power generation efficiencies than mass burn power plant, when blends of d-RDF and Coal are co-fired.

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