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"A- Review Of Related To Decomposition Of Municipal Solid Waste"

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Abstract
Disposal of municipal solid waste material is always considered as a problem and it adds a lot of matter to dump yards occupying vast areas of land. A lot of efforts have been made for getting rid of this so that energy from it can be utilized in a proper way. Researchers have suggested many techniques using experimental as well as numerical approaches. In the present paper, works done by various researchers have been discussed on the basis of the techniques used by the researchers. Overall it can be concluded that biomass conversion can be very beneficial and the techniques developed can prove to be worthy. Bio-oil obtained from biomass can be used for blending of fuels to reduce dependency on conventional fuels.

Keywords: Pyrolysis ,Biomass, Dump Yards, Residual Waste, Computational Fluid Dynamics, Garbage Combustion.

Introduction

Solid waste is any unwanted product which is not a liquid or gas in our surroundings and from our daily products. It can be household waste, Industrial waste or biomedical waste. In the current scenario the house hold waste i.e., garbage is collected from the city (societies, colonies, market, hat bazaar, hospitals, hotels restaurants street waste, schools offices etc) and not categorized or separated at home location, due to lack of human effort and logistics required which is time taking and expansive, as a result the recycling cost increases.

Vast land area is also been occupied by the dump yard which causes air pollution, soil toxicity, water pollution and never the less bad smell. Also, acres and acres of land have been wasted, which instead can be used for developing infrastructure. In recent years a lot of research

has been done for overcoming these kinds of shortcomings by extracting energy even from waste using biomass conversion techniques.

The collection process should be based upon already separated and bifurcated material (solid waste), composting, recycling, Mechanical biological treatment (MBT) of residual waste, WTE of combustible fraction and disposal of inert fraction from MBT. Into the process of thermal treatment also sewage sludge from regional waste water treatment plants can be induced.

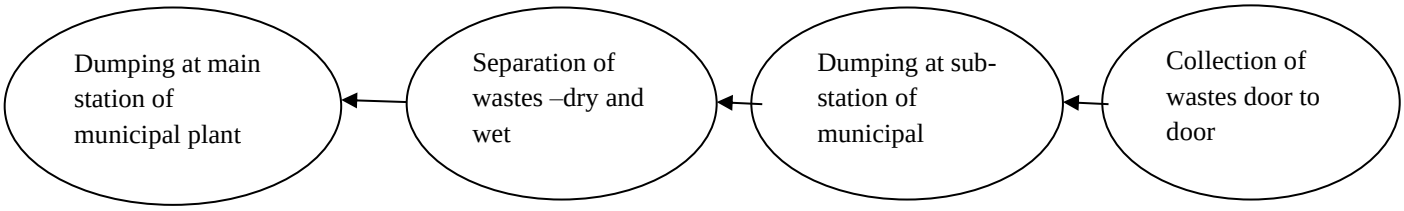

Fig. 1: Process of MSW

To reduce the waste amount on the landfill, in accordance with the concept mentioned, waste must first be collected separately and then re-used or treated. In such manner the amount of the waste residue to be deposited on the landfill is minimized. Separate collection ensures three collected waste stream of MSW and they are:

1. Biodegradable waste;
2. Recyclable sorted household waste (packaging waste);
3. Remains of the sorted household waste

Types of waste

There are many categories of MSW such as food waste, rubbish, commercial waste, institutional waste, street sweeping waste, industrial waste, construction and demolition waste, and sanitation waste. MSW contains recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), compostable organic matter (fruit and vegetable peels, food waste) and soiled waste (blood stained cotton, sanitary napkins, disposable syringes)

Types of disposal treatment system (MSW)

The two leading innovative mechanisms of waste disposal being adopted in India include composting (aerobic composting and vermi-composting) and waste-to-energy (WTE) (incineration, pelletisation, biomethanation).WTE projects for disposal of MSW are a relatively new concept in India. Although these have been tried and tested in developed countries with positive results, these are yet to get off the ground in India largely because of the fact that financial viability and sustainability is still being tested. Different methods for the disposal and treatment of MSW are -

1) Land filling
2) Recycling of organic waste

3) Thermal treatment techniques of MSW
4) Recovery of recyclable materials

Literature Review

A lot of work has been done by many researchers in the field of biomass conversion. In the present paper, the work done by various researchers has been categorised as research papers based on pyrolysis, research work based on waste material, numerical based research papers and numerical & experimental based research papers

1. CFD based research papers:

Wang and Yan, 2008, discussed about the fundamentals which are involved in developing a CFD solution for thermo chemical conversion of biomass. Governing equations describing fluid flow, heat and mass transfer and chemical reactions have been presented. Work of various researchers regarding application of CFD in biomass thermo chemical process have also been discussed. Effect of various parameters has also been covered. Works of other authors such as modelling of gasifier to simulate the flow and reaction in it, vapour deposition flux, particle tracing have been discussed. It has been concluded that CFD modelling provides good results but it requires validation.

Shaohua et al., 2012, reviewed the numerical work done for biomass gasification. Results of two commercially available softwares: Aspen Plus and Fluent were analysed and compared for biomass conversion. It was found out that combination of Aspen Plus and Fluent gives best results for pyrolysis. Pyrolysis process is simple to simulate in Aspen Plus, then the obtained results can be fed to Fluent to simulate the left oxidation reactions. This is the best way to get temperature and gas distribution in the gasifier

Shiehnejadhesar et al., 2013, developed and tested a design tool for parametric study for optimisation of biomass combustion plant. CFD model has been developed for biomass grate furnaces. For testing and verification, the developed CFD model has been applied for optimisation of a 180 kW_{th} pilot scale grate furnace. For optimisation performance of the furnace diameter and angle of secondary air nozzle were varied for getting reduction in CO emissions and pressure loss. Several independent design parameters were found out and evaluated leading to conclusion that the completed work would be very helpful in design optimisation even in future. An empirical model was developed for the description of solid biomass combustion in grate. Mass and energy fluxes were described on the grate as boundary conditions. After that design parameters were selected as secondary nozzle is of utmost importance as it affects the CO emission and pressure losses over the secondary air. Optimisation function was developed for the two optimisation variables: CO emissions and pressure loss. Linear correlation to the weight function was considered for pressure drop whereas polynomial function was considered for CO emission. For investigation of the developed method, design optimisation for a pilot scale moving grate furnace with a hot water fire tube boiler which used Miscanthus as fuel was considered. Manual

optimisation run was also carried out as a reference for the developed method. Grid with 700000cells and computational cell of about one million were considered. Response surface plots of CO emissions and pressure losses were calculated. Effect of angle of secondary nozzle on the emission of CO was also calculated. Tetrahedral as well as polyhedral mesh was separately considered to study the effect of grid type. Optimisation using tetrahedral mesh took one month while it took only six days for polyhedral mesh. It was concluded that better results can be obtained for polyhedral mesh by considering local mesh refinement near nozzle area.

Brosch et al., 2014, discussed about the recent trends in treating municipal solid waste. The authors have developed discrete element method that is similar to CFD code for simulating grate firing in municipal waste incineration plants. Verification of the simulation method has been done using the experimental data for heat transfer and combustion processes. It has been found that the simulation results are in good agreement. The value of temperature differ by around 100°C. It has further been concluded that discrete element method developed is suitable for simulating static and agitated reacting packed beds.

Frank and Castaldi, 2014, incorporated GRI 3.0 mechanism as a detailed chemical kinetic model into a customised 3D CFD model to understand NO_x chemistry in burning municipal solid waste. CFD analysis of waste to energy boiler was carried out for understanding the same. The geometry was modelled in Unigraphics, meshing was done in ANSYS Workbench. Commercial CFD code FLUENT was used for further simulation. The obtained results were compared with existing data which verifies the CFD model. The simulations were carried out for four different inlet boundary conditions. Simulation results showed that the fuel nitrogen accounted for 92% of NO produced . It was concluded that presence of nitrogen in fuel leads to formation of NO and assumption of flues intermediate nitrogen is insignificant to find out final NO concentration for the considered case.

Couto et al., 2014, discussed the problems which arise due to increase in municipal solid waste because of economic growth. Incinerators which are commonly used for treating the solid waste have negative impact on the environment. Authors developed a 2 dimensional CFD model using ANSYS Fluent for municipal solid waste gasification and to describe the transportation of mass, momentum and energy for solid and gas phases, an Eulerian- Eulerian approach has been used. The obtained results have been validated against the available experimental data from the literature. Both are found to be in good agreement.

Sun et al. 2015, established a Computational Fluid Dynamics (CFD) model to disclose the description of combustion process in fixed porous bed of Municipal Solid Waste (MSW). All the equations and pre conditions were modelled to understand the incineration process as per the actual local conditions and waste matter. κ-ε turbulence model was used to model turbulence of gaseous phase and for particle phases, kinetic theory of granular flow was used to model turbulence.

Arrhenius eddy dissipation and the Arrhenius-diffusion reaction rates were used to determine the heterogeneous reaction rates. The work has been done experimentally as well as numerically and both bear close resemblance in results. Detailed information is obtained which is very hard to get experimentally. It is further concluded that the average concentration of carbon mono oxide and the conversion of carbon to it are inversely proportional to primary air flow rate. A little increase in primary air flow leads to faster increase in flame front near the grate.

Gonzalez et al. 2017, developed a CFD model for performance prediction of industrial boiler furnace which was running on sugarcane baggase. ANSYS FLUENT, a commercially available CFD code was used and user defined codes were written in C language for devolatization phenomenon and combustion on the grate. Physical and gasification properties of sugarcane baggase were obtained using experimentation. State equation for incompressible ideal gas was employed as the density of gas was function of temperature. Eddy dissipation model was considered for species transport. κ- ε model was considered for turbulence. The pressure drop was predicted by Gan and Riffat using CFD and the performance using this technique was compared with the experimental data. Using ANSYS FLUENT, geometry of furnace was modelled, meshed and boundary conditions were specified to obtain temperature contours, contours of oxygen mass fraction, particle trajectories. It was found out that the drying process takes at the lower zones of the furnace. It was concluded that devolatization is leading occurrence and is the important factor in predicting hot regions. Using CFD analysis, performance of such type of boilers is possible.

Silva et al.,2017, analysed an industrial biomass boiler using computational fluid dynamics approach. CFD model was used for analysing volatile gases which were released from the combustion of biomass in a grate. ANSYS Fluent has been used for the analysis. Turbulence was modelled using Realizable κ-ε model. Obtained results for temperature distribution, air velocity and concentration of species fields are well presented pictorially. It has been concluded that secondary air flow affects the operating conditions of a boiler whose optimisation leads to lower values of emissions.

Pour et. al., 2020, proposed a computational fluid dynamics approach for numerically simulating combustion process for domestic portable incinerator. Critical parameters were investigated so that the incinerator suits Iranian food and waste culture. Natural gas which is available in abundance in Iran has been used as fossil fuel. The parameters of design which are investigated include place of primary burner, flow rate of primary air. Validation has been carried out for mesh quality. Error of 5% was observed between experimental and numerical approaches. It has been concluded that on increasing the flow rate of cooling air, the combustion process is improved as the hot spots inside the combustion chamber reduced. Also, on increasing more cooling air, evacuation of hazardous gases is increases because of negative pressure created.

2. Experimental work done

Palanichamy et al., 2002 conducted a feasibility study for Tamil Nadu state for electricity generation from municipal solid waste. The results have been compared with the power obtained, limitations, and advantages of wind power generation. It was concluded that power generation using municipal solid waste has a lot of benefits over wind power generation such as by products generation, recycling opportunities, economic benefits, and economic solution to municipal solid waste problems. It is further concluded that the study is beneficial for the investors of energy sectors.

Sharholy et al., 2008 did survey on Municipal Solid Waste Management as a major problem in India by reviewing various research papers. Current status for handling municipal solid waste in India, problems related to management of municipal solid waste, public health and environment have been covered. Characteristics, generation, collection and transportation, disposal and treatment technologies follower in India have been discussed. Few suggestions such as aerobic composting, vermin-composting, anaerobic digestion and various thermal techniques have been suggested so that the municipal solid waste management system is improved in the country. For proper handling of the waste, modifications are needed from collection point to the end point of waste have been stressed upon.

Mohammad et al., 2012 highlighted the projection of pyrolysis of solid waste as a source of energy and its role in solid waste management. Using pyrolysis the solid waste can be segregated into solid, liquid and gaseous components which can further be utilised for energy extraction on need. Pyrolysis f biomass, its products, temperature and heating rate, biomass composition have been discussed. It has been concluded that bio-oil is superior most among all three: solid, liquid and gaseous products obtained from pyrolysis of biomass.

Patil et al., 2014, explained the role of incineration for energy extraction from Municipal Solid Waste. The heat obtained from same can be converted into energy form and it also reduces the problem of landfills in crowded cities. The environmental conditions for incineration, volume/quantity of waste produced, heat of combustions, facilities available, operation and maintenance cost needs to be taken into account for burning waste effectively. The study has been done in contrast to India. Advantages, disadvantages, limitations, problems for operation of incineration plant have been discussed by considering case study.

Dube et. al., 2014 stressed on the Municipal Solid Waste Management with reference to Urban Indian context. Academic and political factors of Urban Waste sector have been discussed and the results have been compared with those of Germany and Europe. The problems of proper incineration plants in India have been discussed. Lack of proper planning, energy recovery from waste, waste segregation, data transparency, lack of monitoring and regulatory bodies have been

stressed upon. Problems due to Green House Gas emissions as a result of incineration have also been focussed upon.

Sarkar et. al., 2015 used pyrolysis technique for newspaper waste in a reactor at specified conditions. Similar kinds of conditions were created for pyrolysis of newspaper waste in thermo-gravimetric analyser. The temperature range was kept from 573 K to 1173 K. And it was found that pyrolysis was high at 773 K which led to weight loss. Same has been explained with the help of graph between temperature and weight of residue. Chemical characterisation of product has also been carried out. Mathematical model has also been developed for the same. It has been concluded that the study is very beneficial to study reaction engineering behaviour of similar systems.

Lach et al., 2016, stressed on properties and detailed characteristics for thermal treatment of waste as it produces undesirable by-products which are not desired. Combined techniques of thermal analysis have been used for determining properties of by-products. The examination were conducted on dust from the boiler, bottom slag and ash, and solid waste from the exhaust gas cleaning obtained from incineration plant in Poland. SEM was used to study the morphology of waste material and laser diffraction was used to determine the size of waste by-product particle. Three samples were taken for experimentation. Curves for coupled techniques: TG and DSC were obtained and it was concluded that thermal stability of samples was highly dependent on their type.

Czajczyn´ska et al., 2017, stressed upon energy extraction from the residues left after pyrolysis. Linkage between type of residue and their chemical & mineralogical conditions, pyrolysis conditions, advantages of pyrolysis in waste management have been investigated. Household waste has been stressed upon for the further research work as its quantity is increasing with time. The temperature range in pyrolysis is 400°C - 500 °C. It has been concluded that addition of organic waste results in better product (gas) quality. It has been further proposed that there is need to develop more efficient method for waste treatment.

Chowdhury at el., 2017, discussed about lignocellulosic biomass as potential source of renewable energy. Energy obtained form it can be used for cooking which would reduce production of electricity, heat, bio-fuels and solid fuels. The residue left after can be reused and can replace non-renewable sources such as coal and oil. In the chapter various ways to extract energy, chemical reactions involved, process of pyrolysis are expressed in detail especially for lignocellulosic biomass. The chapter also focuses on types of reactors, bio products and current technologies for pyrolysis. It has been further concluded that technology further needs to be developed to obtain high efficiency.

Gour & Gupta, 2018, reviewed articles on blended fuels. It was concluded that bio-fuel obtained from the pyrolysis can reduce loads on conventional fuel. Also not many modifications in engines

are required. Blending of conventional fuel with bio fuel (which is obtained from pyrolysis) even reduces environmental hazards.

Table 1 The specific analysis performed in the different areas as discussed by this review paper

Name of Researchers	Year	Contribution	Input Material	Parameters Studied	Output Obtained
Shiehnejadhesar et al.	2013	Optimised biomass combustion plant	biomass	CO emissions and pressure loss	Work done would be beneficial for design optimisation
Gonzalez et al.	2017	Industrial boiler furnace	Sugarcane baggase	pressure drop and devolatization	devolatization is leading occurrence and is the important factor
Frank and Castaldi	2014	Explained in detail the NO_x chemistry in burning municipal solid waste	municipal solid waste	NO_x emissions	customised 3D CFD model
Wang and Yan	2008	Studied fundamentals of thermo chemical conversion of biomass	Available literature	modelling of gasifier to simulate the flow and reaction in it, vapour deposition flux, particle tracing	CFD is good tool to simulate thermo-chemical reactions
Brosch et al	2014	developed discrete element method for simulating grate firing	municipal solid waste	heat transfer and combustion processes	The developed code is successfully validated

Pour	2020	Found out place of primary burner and flow rate of primary air	Iranian food and waste culture	combustion process for domestic portable incinerator	on increasing more cooling air, evacuation of hazardous gases increases
Silva et al.	2017	analysed an industrial biomass boiler using CFD	biomass	temperature distribution, air velocity and concentration of species fields	secondary air flow affects the operating conditions of a boiler
Couto et al.,	2017	Developed 2 D CFD model	municipal solid waste	transportation of mass, momentum and energy for solid and gas phases	CFD results are in good agreement with available literature
Sun et al.	2015	Numerically simulated incineration and did its experimental validation	municipal solid waste	Level of carbon monoxide	average concentration of carbon mono oxide and the conversion of carbon to it are inversely proportional to primary air flow rate
Shaohua et al.	2012	Reviewed the work of other authors	biomass	Compared results of two softwares used for simulation	Pyrolysis process is simple to simulate in Aspen Plus, then the obtained results can be fed to Fluent

					to simulate the left oxidation reactions
Czajczyn´ska et al.	2017	Linkage between type of residue and their chemical & mineralogical conditions, pyrolysis conditions, advantages of pyrolysis	Household waste	chemical & mineralogical conditions	addition of organic waste results in better product (gas) quality
Chowdhury at el.	2017	various ways to extract energy from biomass have been discussed	lignocellulosic biomass	chemical reactions involved, process of pyrolysis, types of reactors, by products and current technologies	technology further needs to be developed to obtain high efficiency
Lach et al.	2016	Combined techniques of thermal analysis have been used for determining properties of by-products	Waste	dust from the boiler, bottom slag and ash, and solid waste from the exhaust gas cleaning	Thermal stability is highly dependent on type of waste
Sarkar et al.	2015	pyrolysis technique for newspaper waste in a reactor	Newspaper waste	temperature and weight of residue	study is beneficial to study reaction engineering behaviour of similar systems
Patil et al.	2014	Explained incineration for energy extraction	Municipal Solid Waste	environmental conditions for incineration,	Advantages, disadvantages, limitations,

		from Municipal Solid Waste		volume/quantity of waste produced, heat of combustions, facilities available, operation and maintenance cost	problems for operation of incineration plant
Dube et al.	2014	Discussed problems of proper incineration plants in India	Municipal Solid Waste	Academic and political factors of Urban Waste sector	Lack of proper planning, energy recovery from waste, waste segregation, data transparency, lack of monitoring and regulatory bodies
Mohamma d et al.	2012	projection of pyrolysis of solid waste	Solid waste	Pyrolysis of biomass, its products, temperature and heating rate, biomass composition	bio-oil is superior most
Sharholy et al.	2008	Reviewed Municipal Solid Waste Management in India	Municipal solid waste	problems related to management of municipal solid waste, public health and environment Characteristics, generation, collection and transportation,	aerobic composting, vermin-composting, anaerobic digestion and various thermal techniques

				disposal and treatment technologies	have been suggested
Palanichamy et al	2002	feasibility study for electricity generation from municipal solid waste	municipal solid waste	power obtained, limitations, and advantages	power generation using municipal solid waste has a lot of benefits
Gour & Gupta	2018	Reviewed articles in bio-fuel obtained from pyrolysis	Waste from various sources	Power obtained, oxides of nitrogen and carbon	bio-fuel obtained from the pyrolysis can reduce loads on conventional fuel

Conclusions

Municipal solid waste is one of the problems in India. Treatment of MSW is a hectic task but is must required. A lot of work has been done for extraction of energy from MSW. Pyrolysis and incineration are few of the ways to get dispose off of MSW. Heat liberated from biomass can be used for power production. The analysis for MSW treatment can also be carried out numerically using various available commercial codes or by developing own code. But both of these need validation. Analysis using Computational Fluid Dynamics technique saves time as well as resources. Furnaces can be easily analysed using these techniques and reactions can also be understood in detail.

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