Pyrolysis/Gasification of waste plastic materials

Term Project

MastersofTechnology
In
ENVIRONMENTALENGINEERING

BY

Akansha Mishra(224104111)

Bwenyele Tep(224104114)

Supervisor: Prof. Ajay Kalamdhad

DEPARTMENTOFCIVILENGINEERINGI

NDIANINSTITUTEOF

TECHNOLOGY GUWAHATI

ASSAM, INDIA

ACKNOWLEDGEMENT

We are delighted to present the Term project report for CE525 (Solid and Hazardous Waste) course in the second semester of our post-graduation in Environmental Engineering from the Indian Institute of Technology, Guwahati. This project has provided us with practical exposure to the current conditions in the field and enabled us to evaluate the feasibility of the theories we have learned in the course.

We are extremely grateful to all the individuals who have contributed to making this project a rich experience. We would like to express our sincere appreciation and indebtedness to Prof. Ajay Kalamdhad for his valuable guidance and unwavering encouragement throughout the project.

Furthermore, we would like to extend our gratitude to Ms. Silvia, a Ph.D. scholar in the Civil Engineering Department at IIT Guwahati, for her continuous motivation and support during the project period.

We are privileged to have worked under the Civil Engineering Department, which provided us with inspiration, support, and meticulous attention during the project. We express our sincere acknowledgement to them with immense respect and deep gratitude.

thankherforher constantmotivationandsupportduringtheprojectperiod.

It was indeed a privilege to work under**Civil Engineering Department** who believed in us,inspiredus&providedcontinuoushelp&meticulousattentionduringthisproject.Withimmenserespect&deepgratitude,weexpressoursincereacknowledgementtothem.

TABLEOFCONTENT

TableofContents

INTRODUCTION

Municipal Solid Waste (MSW) has to be managed by technologies and methods that enablekeeping our cities clean, prevent pollution and protect the environment and at the same timeminimize the cost through recovery of resources and energy. As per CPCB report 2012-13municipal areas in the country generate 1, 33,760 metric tonnes per day of MSW, of which only91,152 TPD waste is collected and 25,884 TPD treated. The MSW, therefore, dumped in lowlying urban areas is a whopping 1,07,876 TPD, which needs 2,12,752 cubic meter space everydayand776hectareofprecious landperyear.

The Municipal Solid Waste (MSW), as submitted by the Ministry of New and Renewable Energy(MNRE),isaheterogeneousmixtureofpaper,plastic,cloth,metal,glass,organicmatter,construc tionanddemolitiondebris,dust,etc.,generatedfromhouseholds,commercialestablishments, markets and road cleaning activities. The Committee were apprised by theMNRE that India generates about 62 million tonnes of Municipal Solid Waste annually, out ofwhich,82% isbeingcollectedand theremaining18% islittered; out ofthe totalcollectedwaste, only28%isbeingtreated anddisposed.

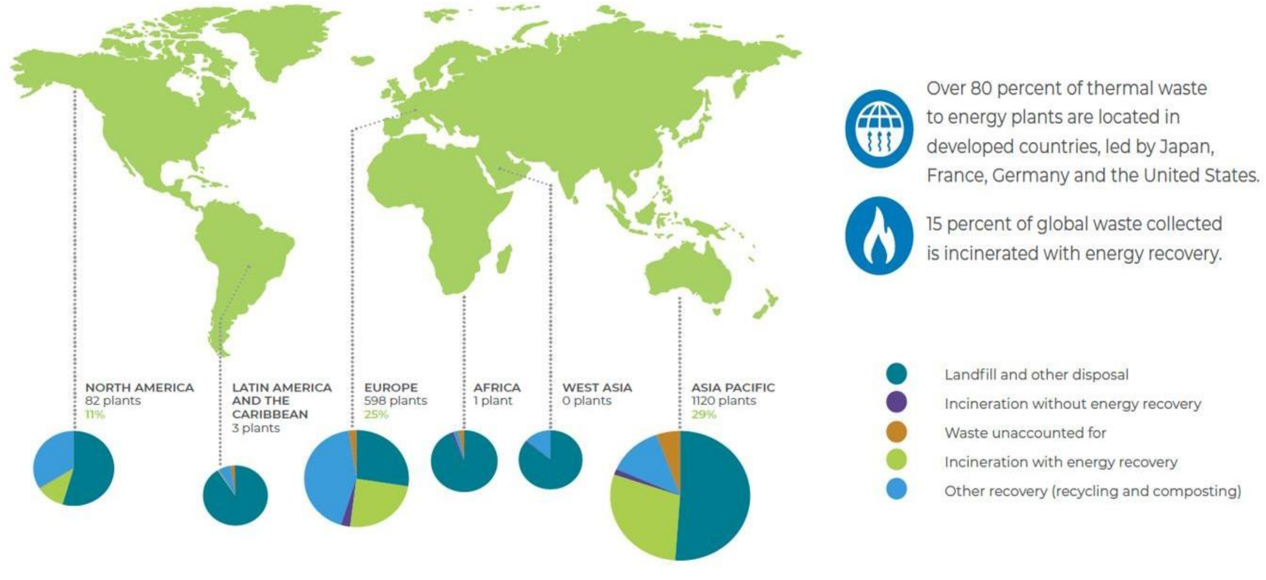


Fig.1:Currentstatusofwastetoenergy

However,theCommitteehaveobservedthatthereishardlyacityinthecountrywhereMunicipal Solid Waste is disposed off scientifically. Keeping in view that by 2031, the totalgeneration of Municipal Solid Waste in the country would be 165 million tonnes — an increaseof about 100 MillionTonnes in about 15 years, due to increasing industrialization, urbanizationand changes in the pattern of life, there is an urgent need to look into this subject and find outwaysandmethodsto copewiththisgargantuangarbageproblem.

TheCommitteehavebeeninformedthatindevelopedcountries,environmentalconcernsrather than energy recovery is the prime motivator for waste-to-energy projects, which helps intreating and disposing of wastes. However, the Committee fully conform to the view of theMinistry that in the Indian context, energy generation from MSW improves the viability of suchwastemanagementprojectsandthatthemajoradvantagesforadoptingtechnologiesforrecoveryofenergyfromMSWaretoreducethequantityofwasteandnetreductioninenvironmentalpollution,besides generation ofsubstantialquantityof energy.

WTETechnologies

Fig.2: Bio-medical waste incineration plant,Panikhaiti,Guwahati

Fig.3:Pyrolyser,IITGuwahati

Fig.4: Pyrolizer, School of Energy Science,IIT Guwahati

Fig.5:Gasifier,SchoolofEnergyScience,IITGuwahati

LITERATURE

The solid waste generated from the cities/towns in India has present potential to generatepower of approximately 500 MW, which can be enhanced to 1,075 MW by 2031 and further to2,780MWby 2050.

- 7functionalplantsof92.4MWcapacity
- 4non-functionalplantsof 40.6MW capacity
- 31underconstructionplantsof241.8MWcapacity
- 21plantsundertenderingstageof163.5MWCapacity

Wastegeneration,collectionandtreatmentoftop8statesofIndia:

ThedataisobtainedfromMNREreportonPowerGenerationfromMunicipalSolidWaste, India–2016andis plotted graphically(shownbelow).

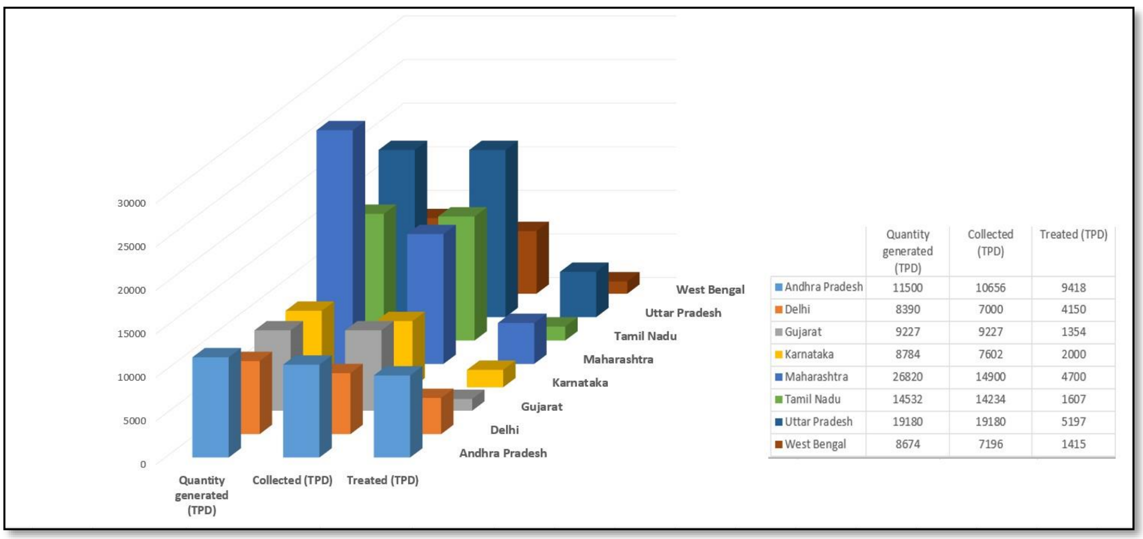


Fig.6: Graphicalrepresentationofwastedata byMNRE

WTEplantsinIndia:

Asdiscussedaboveaboutthenumberofplantsthatareindifferentphases,someofthemwhich arepopulararelisted belowin tables.

FunctionalPlants inIndia:

Location	Wasteintake (MT/day)	Powergeneration (MW)
Okhla,Delhi	2000	16
Ghazipur,Delhi	1300	12
Narela-Bawana,Delhi	2000	24
Jabalpur,MadhyaPradesh	600	11.4
Solapur,Maharashtra	400	3

Non-operationalPlantsinIndia:

Location	Wasteintake (MT/day)	Powergeneration (MW)
Kanpur, UP	1500	15
Elikkta(V),MahabubnagarDistt.,A.P.	200	6.6
Vijayawada	225	6
Rajahmundry,AndhraPradesh	1074	13

METHODOLOGY

1. Incineration:

Incineration is a waste treatment process that involves the combustion ofsubstances containedin waste materials. Industrial plants for waste incineration are commonly referred to as waste-to-energy facilities. Incineration and other high-temperature waste treatment systems are describedas "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas andheat. The ash is mostly formed by the inorganic constituents of the waste and may take the formof solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseousand particulate pollutants before they are dispersed into the atmosphere. In some cases, the heatthat is generated by incineration can be used to generate electric power. In several countries,there are still concerns from experts and local communities about the environmental effect ofincinerators.

In some countries, incinerators built just a few decades ago often did not include a materialsseparation to remove hazardous, bulky or recyclable materials before combustion. These facilitiestended to risk the health of the plant workers and the local environment due to inadequate levelsofgascleaningandcombustionprocesscontrol.Mostofthesefacilitiesdidnotgenerateelectricity.

Incinerators reduce the solid mass of the original waste by 80%–85% and the volume (alreadycompressed somewhat in garbage trucks) by 95%–96%, depending on composition and degree ofrecoveryofmaterialssuchasmetalsfromtheashforrecycling.Thismeansthatwhileincineration does not completely replace landfilling, it significantly reduces the necessary volumefor disposal. Garbage trucks often reduce the volume of waste in a built-in compressor beforedelivery to the incinerator. Alternatively, at landfills, the volume of the uncompressed garbagecan be reduced by approximately 70% by using a stationary steel compressor, albeit with asignificant energy cost. In many countries, simpler waste compaction is a common practice forcompaction atlandfills.

Incineration has particularly strong benefits for the treatment of certain waste types in nicheareassuchasclinicalwastesandcertainhazardouswasteswherepathogensandtoxinscanbe destroyed by high temperatures. Examples include chemical multi-product plants with diversetoxic or very toxic wastewater streams, which cannot be routed to a conventional wastewatertreatmentplant.

Wastecombustionisparticularlypopularincountriessuchas Japan,SingaporeandtheNetherlands, where land is a scarce resource. Denmark and Sweden have been leaders by usingthe energy generated from incineration for more than a century, in localized combined heat andpowerfacilitiessupportingdistrictheatingschemes.In2005,wasteincinerationproduced4.8%of the electricity consumption and 13.7% of the total domestic heat consumption in Denmark. Anumber of other European countries rely heavily on incineration for handling municipal waste, inparticular Luxembourg,theNetherlands,Germany, andFrance.

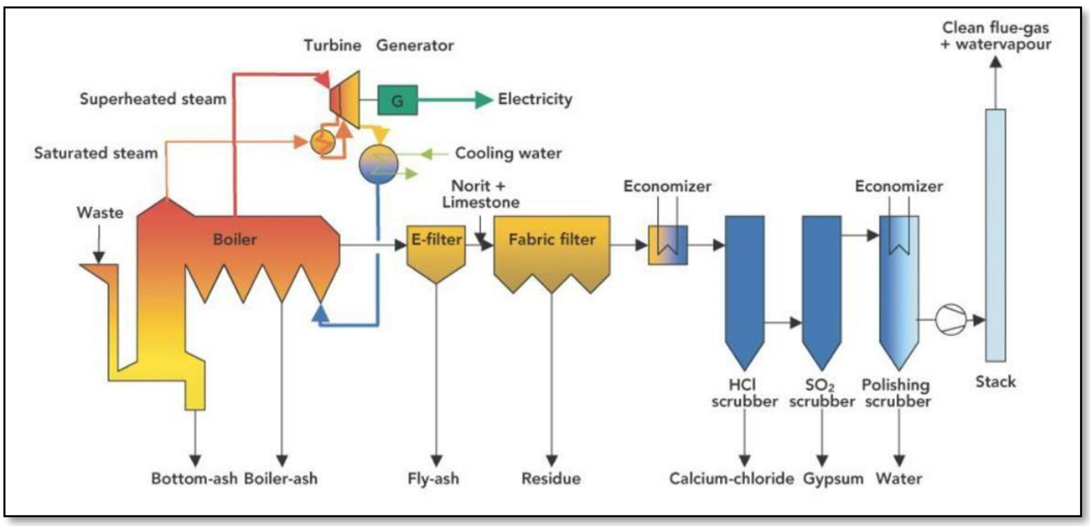


Fig.7:Incinerationdesignflowchart

TheWasteIncinerationProcess

Everyincineratorisunique,butthemostcommontechniqueiscalled“massburn.”Thegeneralprocessfollowed ina massburn incineratorincludesfivesteps.

Wastepreparation:Oversizeditemsareremovedandcertainrecyclableslikemetalsarerecovered.There mainingwasteisoftenshreddedbeforeitentersthe incinerator.

Combustion:Wasteisburnedinanoxygenatedsinglecombustionchamber.Materialsareburnedatextremelyhightemperaturesof1,800-2,200degreesFahrenheit.Atthosetemperatures,wasteshouldbecompletelycombusted,leavingnothingbutgasesandash.**Energy recovery**: The gases released during combustion are cooled with water, generating steamthroughheat recovery. The steam is used to power electrical generators.**Environmentalcontrol**:Thecooledgasistreatedbyscrubbers,precipitators,andfilterstoremove pollutants. The solids that form during treatment, called residuals, are disposed of in alandfill. **Environmental release**: The treated gas is released into the atmosphere. There should be novisible smoke from the smokestack because the remaining gases should be free from particulates.Because incineration utilizes such high temperatures, it can destroy many pathogens and sometoxic materials. For this reason, incineration is the preferred method of disposal for biomedicaland someother specialwastes, even incommunitieswhereMSW islandfilled.

2. Pyrolysis:

The pyrolysis process is the thermal decomposition of materials at elevated temperatures in aninertatmosphere.Itinvolvesachangeof chemicalcomposition.ThewordiscoinedfromtheGreek-derivedelementspyro "fire","heat","fever"andlysis"separating".

Pyrolysisismostcommonlyusedinthetreatmentof organic materials.Itisoneoftheprocessesinvolvedin charring wood. Ingeneral,pyrolysisoforganicsubstancesproducesvolatile products and leaves char, a carbon-rich solid residue. Extreme pyrolysis, which leavesmostly carbon as the residue, is called carbonization. Pyrolysis is considered the first step in theprocesses ofgasificationorcombustion.

The process is used heavily in the chemical industry, for example, to produce ethylene, manyformsof carbon,andotherchemicalsfrompetroleum, coal, and even wood, toproduce coke from coal. It is used also in the conversion of natural gas (primarily methane) intonon-polluting hydrogen gasandnon-pollutingsolid carbon char,recentlyonanindustrialscale.[]Aspirational applications of pyrolysis would convert biomass into syngas and bio char,waste plasticsbackintousableoil,or wasteintosafely disposable substances.

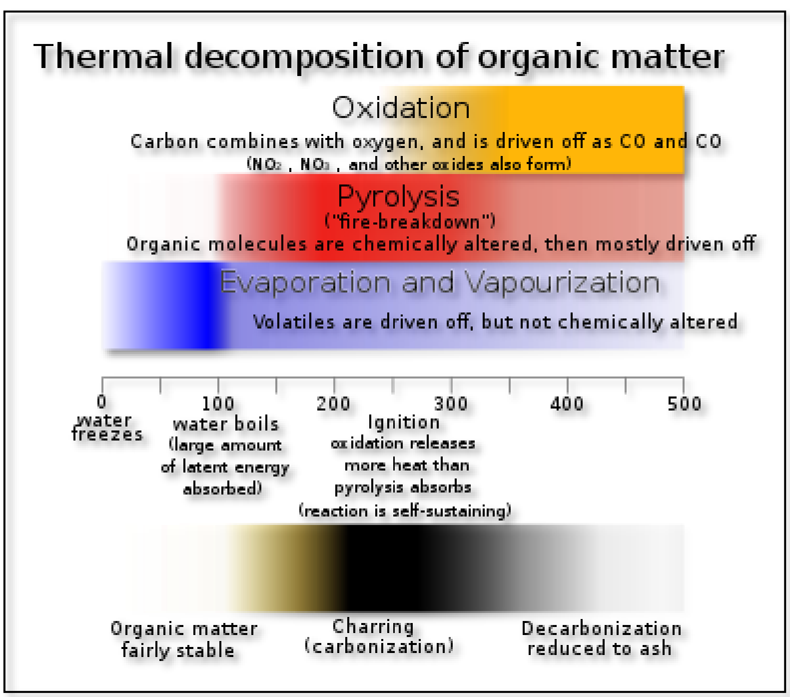


Fig.11:Temperaturevariationinpyrolizer

Pyrolysis has many applications in food preparation. Caramelization is the pyrolysis of sugars infood (often after the sugars have been produced by the breakdown of polysaccharides). Thefood goes brown and changes flavour. The distinctive flavours are used in many dishes; forinstance,caramelizedonionisusedin Frenchonionsoup.Thetemperaturesneededforcaramelization lie above the boiling point of water. Frying oil can easily rise above the boilingpoint. Putting a lid on the frying pan keeps the water in, and some of it re-condenses, keepingthetemperaturetoocooltobrownforlongertime.

Bio char is the residue of incomplete organic pyrolysis, e.g., from cooking fires. It is a keycomponent of the terra preta soils associated with ancient indigenous communities of theAmazon basin.

Fig.12:Char

Charcoal is a less smoky fuel than pyrolyzed wood. Some cities ban, or used to ban, wood fires;when residents only use charcoal (and similarly-treated rock coal, called coke) air pollution issignificantly reduced. In cities where people do not generally cook or heat with fires, this is notneeded. In the mid-20th century, "smokeless" legislation in Europe required cleaner-burningtechniques,suchascokefuelandsmoke-burningincineratorsasaneffectivemeasuretoreduceairpollution

Fig.13:Bituminous coal

A blacksmith's forge, with a blower forcing air through a bed of fuel to raise the temperature ofthe fire. On the periphery, coal is pyrolyzed, absorbing heat; the coke at the center is almostpurecarbon, andreleasesa lotofheatwhen thecarbonoxidizes.

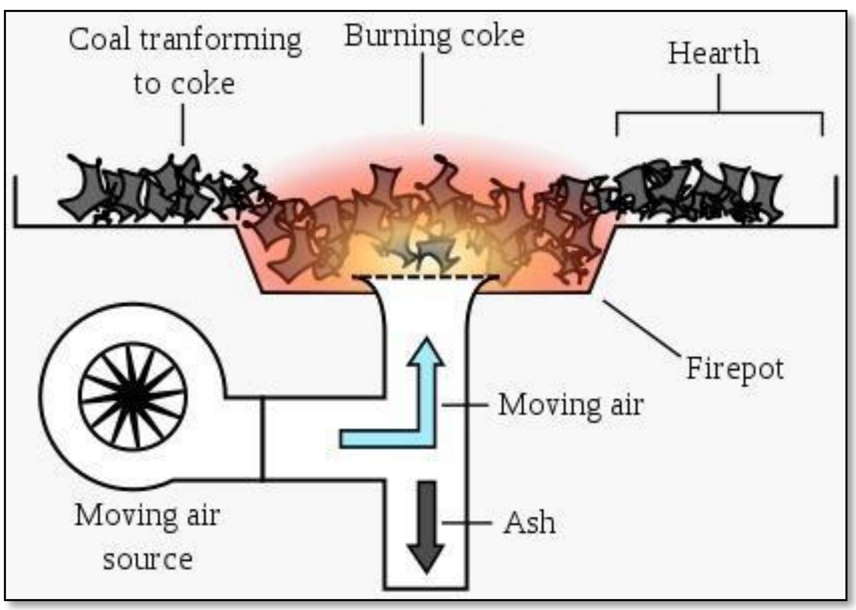


Fig.14:blacksmith'sforge

Carbonfibers produced bypyrolyzing a silk cocoon.Electronmicrograph,scale bar at bottomleftshows100µm.

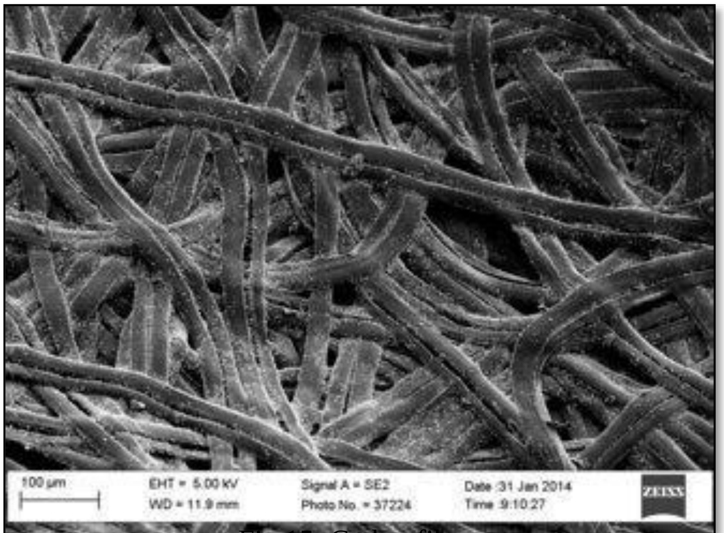


Fig.15: Carbonfibers

3. Gasification:

Gasification converts MSW to a usable synthesis gas, or syngas. Gasification is a unique processthat transforms a carbon-based material, such as MSW or biomass, into other forms of energywithout actually burning it. Instead, gasification converts the solid and liquid waste materialsinto a gas through a chemical reaction. This reaction combines those carbon-based materials(knownasfeedstock's) withsmallamounts of airor oxygen(but not enough to burn thematerials), breaking them down into simple molecules, primarily a mixture of carbon monoxideandhydrogen.

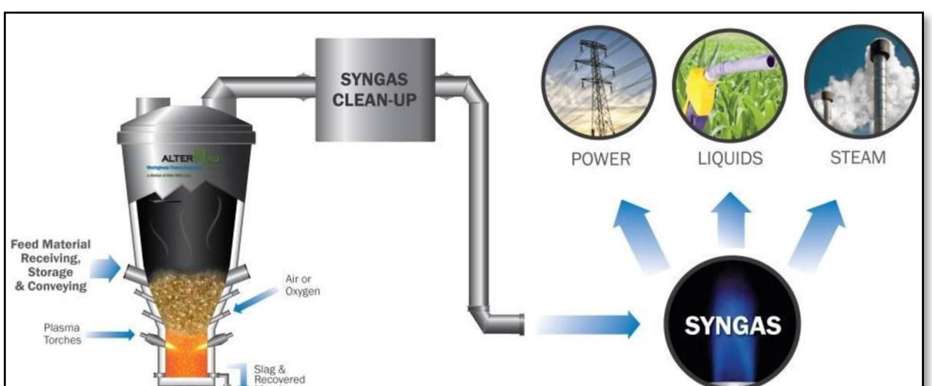


Fig.16:Gasificationdesignanduses

PlasmaGasification

Plasma is an ionized gas that is formed when an electrical discharge passes through a gas. Theresultant flash from lightning is an example of plasma found in nature. Plasma torches and arcsconvertelectricalenergyintointensethermal(heat)energy.Plasmatorchesandarcscangeneratetem peraturesupto10,000ºF (5,500ºC).

Use of plasma technology for gasification is much newer. While other gasifier feedstock's, suchas coal and biomass, are relatively homogeneous and easily gasified, MSW and other wastes aretypicallyheterogeneousandmaybedifficulttogasify.Thehightemperatureofaplasmagasifier initiates and supplements the gasification reactions, and can even increase the rate ofthose reactions, making gasification more efficient. The high energy input from the plasma arcsor torches can be easily increased or decreased as the quantity and quality of the MSW fed intothe gasifier changes. The high temperature maintains the gasification reactions, which breakapartthechemicalbondsofthefeedstockandconvertsthemintosyngas.SomeMSWgasification systems use conventional gasification technology to convert the feedstock intosyngas, and then treat the syngas stream with plasma arcs or torches to ensure the efficientbreakdown of any unconverted compounds into syngas. The syngas consists primarily of carbonmonoxide and hydrogen—the basic building blocks for chemicals, fertilizers, substitute naturalgas, and liquid transportation fuels. The syngas can also be sent to gas turbines or reciprocatingenginestoproduceelectricity,orcombustedtoproducesteamforasteamturbine-generator.

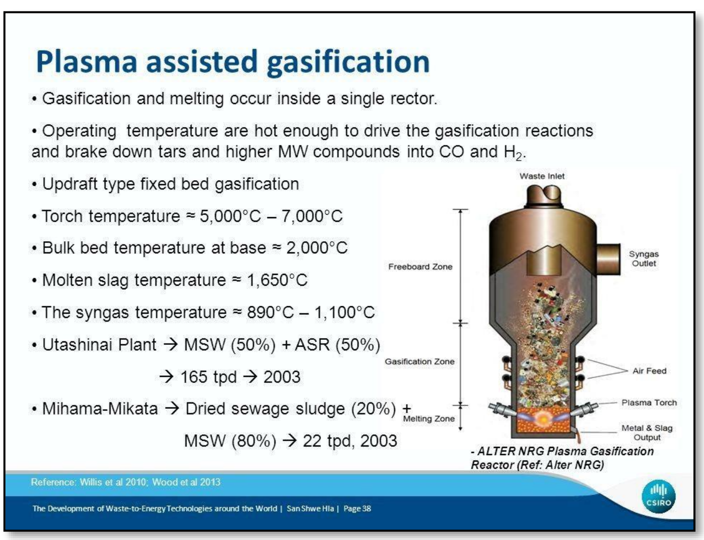


Fig.17:Plasmaassistedgasification

Pyrolysis of plastic wastes:

1. **Sanitary napkins**
2. **PET bottles**

1. **Sanitary Napkins**

Introduction:

Sanitary pads are one of the essential items for women's hygiene during menstruation. The production and disposal of sanitary pads have raised environmental concerns, especially in developing countries. Most of the sanitary pads are made up of plastic, which takes several years to decompose, causing damage to the environment. Thus, an eco-friendly approach for sanitary pad disposal is the need of the hour.

Pyrolysis is a thermal decomposition process that involves the conversion of organic matter into energy-rich products in the absence of oxygen. In this project, we aim to produce energy-rich products from used sanitary pads by pyrolysis.

Methodology:

The pyrolysis of used sanitary pads was carried out at different temperatures ranging from 250°C to 550°C for a residence time of 180 minutes. The resulting product was biochar, which was analyzed for its properties.Before pyrolysis, proximate analysis was performed on the raw sample of used sanitary pads to determine its composition. Proximate analysis is a technique used to determine the amount of moisture, volatile matter, fixed carbon, and ash content in a sampleAfter pyrolysis, the resulting biochar was subjected to proximate analysis to determine its properties. The results of the proximate analysis on the raw sample and the char sample were compared to evaluate the effectiveness of pyrolysis as a method for converting used sanitary pads into biochar.

The results showed that the moisture content of the raw sample was 3.5%, while the moisture content of the char sample decreased to 0.6% at 550°C. The volatile matter content of the raw sample was 86.9%, while the volatile matter content of the char sample decreased to 16.5% at 550°C. The fixed carbon content of the raw sample was 9.1%, while the fixed carbon content of the char sample increased to 79.2% at 550°C. The ash content of the raw sample was 0.5%, while the ash content of the char sample increased to 3.7% at 550°C.

The results of the proximate analysis indicate that the pyrolysis of used sanitary pads is an effective method for converting them into biochar. The biochar produced has a low moisture and volatile matter content, high fixed carbon content, and a moderate ash content.

In conclusion, the pyrolysis of used sanitary pads is a promising method for converting them into biochar. The biochar produced can be used as a soil amendment, a carbon sequestration agent, and a source of renewable energy. Further research is needed to optimize the process parameters and to evaluate the economic feasibility of pyrolysis as a method for sanitary pad waste management.

Preparation of sample:

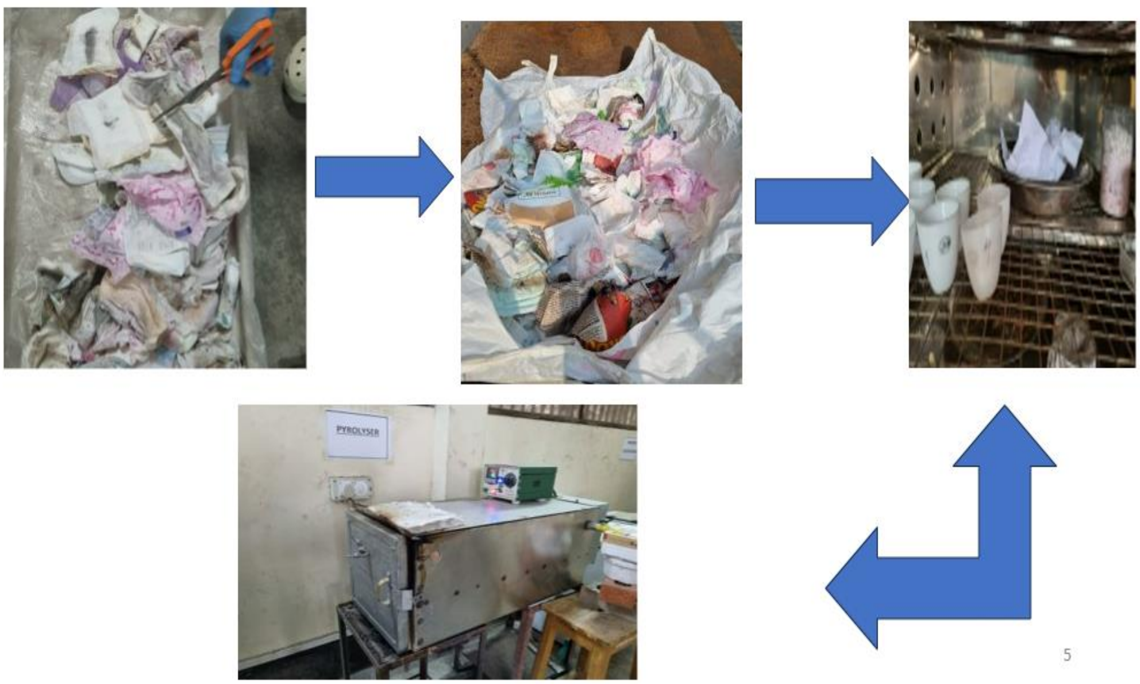


Fig: reduction of size->drying in the sun->drying in the hot oven->pyrolysis

Results and discussions:

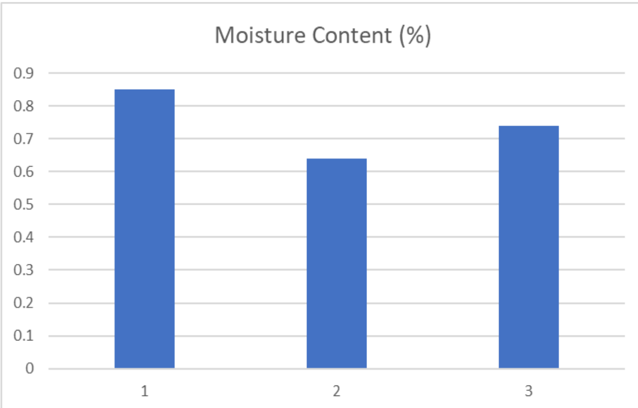
Holding time of the sample= 180 mins(after reaching the desired temperature)

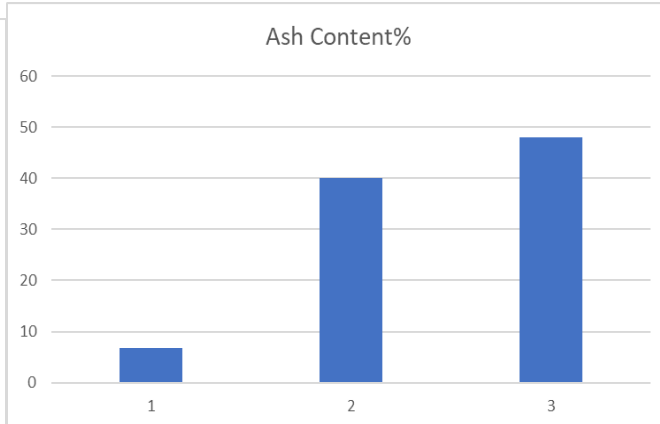
Heating rate = 10 ^{0} C/min

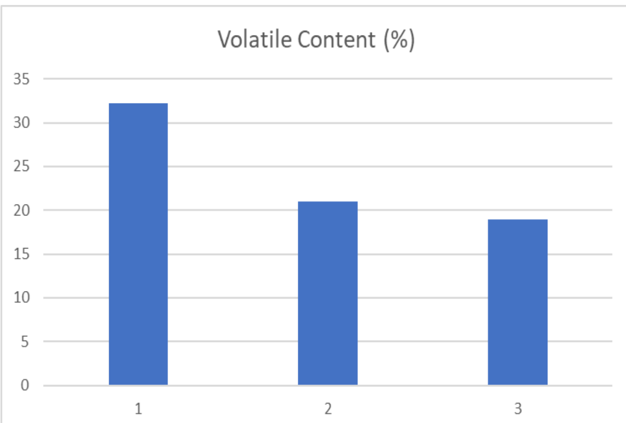
Temperature	Initial weight (gm)	Final weight(gm)	Percentage of Char(%)
250	100	75	-----
350	75	29	38.6
450	100	15	15
550	100	11	11

- **Proximate Analysis: Char Sample**

Sl no	Temperature	Moisture Content(%)	Ash Content (%)	Volatile content(%)
1	350 ^{0} C	0.85	6.8	32.27
2	450 ^{0} C	0.64	40	21
3	550 ^{0} C	0.74	48	19







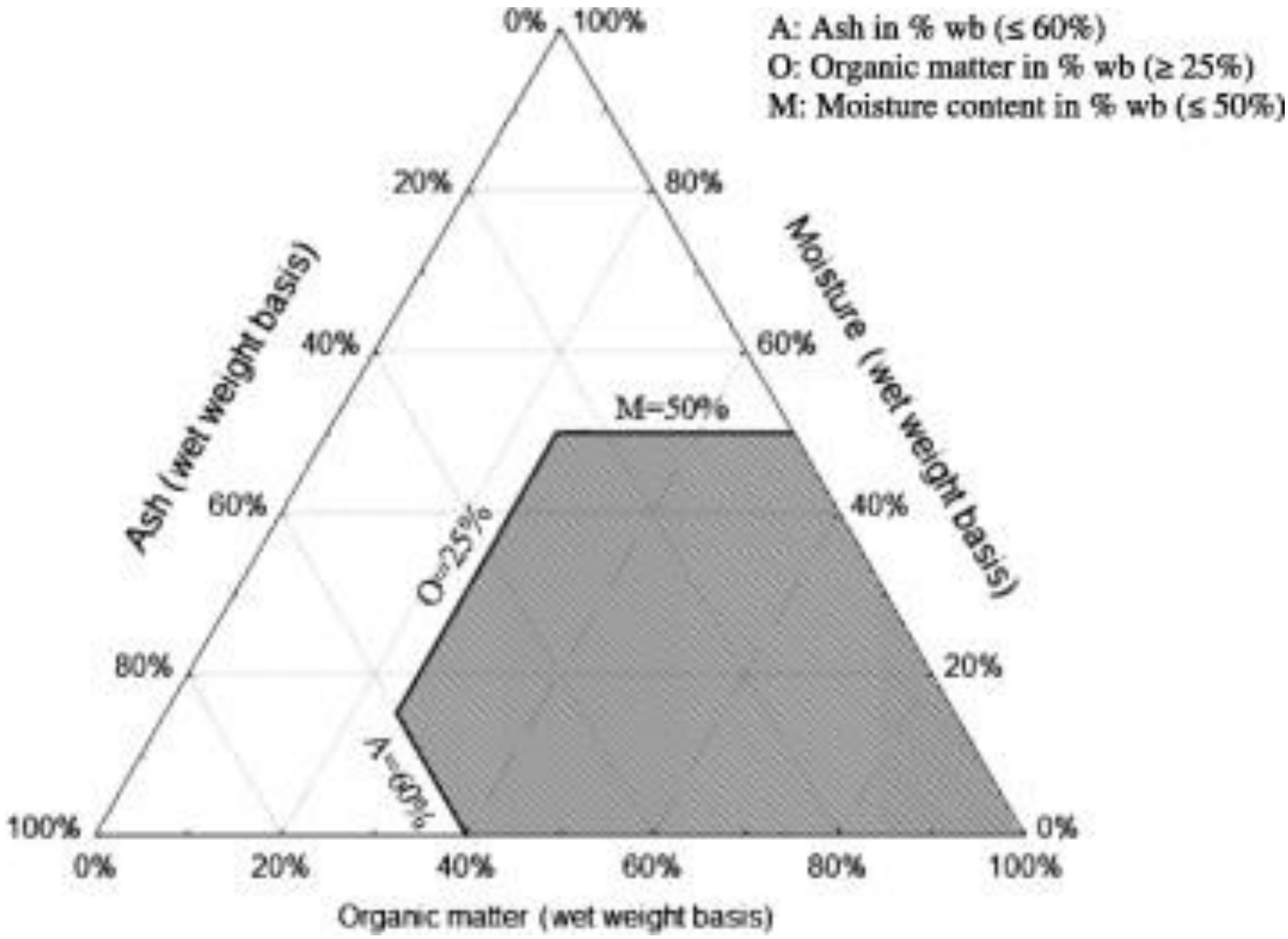
- **Proximate analysis of fresh sample**

Sample	**Moisture content(%)**	**Ash content (%)**	**Volatile content(%)**	**Fixed Carbon**
Fresh Sample	**6%**	**0.79%**	**92.6%**	**0.61%**

pH at 14 day = 7.12

pH at 28 day = 7.22

- **Tanner's diagram:**



Conclusion:

The pyrolysis of used sanitary pads is an effective way of producing energy-rich products from waste. The bio-oil obtained from the pyrolysis has the potential to replace fossil fuels, thus contributing towards sustainable development. The gas and char obtained can also be utilized as a fuel and soil conditioner, respectively, making the pyrolysis of sanitary pads a sustainable waste management solution.Pyrolysingat the household level is a good alternative to dumping because while pyrolyzing it doesn’t produce much harmful gases plus it uses less energy as compared to other alternatives such as incineratoing the sanitary napkins.

2. PET bottles

Introduction:

PET (Polyethylene Terephthalate) is a commonly used plastic material for packaging of food, beverages, and personal care products. However, the disposal of PET bottles after use is a major environmental concern due to their non-biodegradability and poor recycling rates. Pyrolysis is a thermal process that can convert PET waste into valuable products such as fuel, chemicals, and carbon black.

Objective: The objective of this project is to investigate the feasibility of using pyrolysis as a method for recycling PET bottles and to evaluate the properties of the products obtained from the process.

Methodology: PET bottles were collected and shredded into small pieces. The PET waste was then subjected to pyrolysis in a fixed-bed reactor at a temperature range of 400-500°C and a heating rate of 10°C/min. The pyrolysis products were collected and analyzed using various techniques such as Gas Chromatography-Mass Spectrometry (GC-MS), Fourier Transform Infrared Spectroscopy (FTIR), and Thermogravimetric Analysis (TGA).

Work flow:

Laboratory analysis:

After 350 °C

After 450 °C

At 550 °C

Raw Sample

2-2 Sample Each

Muffle Furnace

Experimental Data During Pyrolysing the Sample

Sl.no.	Temperature	Initial weight(gram)	Final Weight(gram)	Weight loss(%)
1	250°C	0.093	0.089(not degraded)	4.3
2	350°C	0.089	0.066	25.84
3	450 °C	0.063	0.001	**98.41**
4	550°C	0.079	0.008	89.87

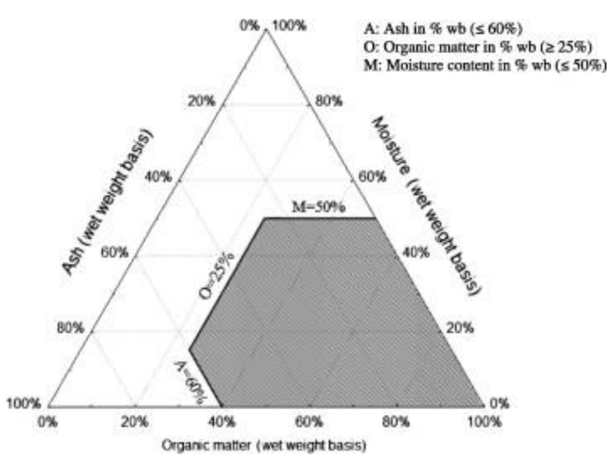
Data obtained from hot air oven and muffle furnace :

Temperature (Degree celcius)	Initial weight W1	Final weight at 104 Degree celcius W2	Final weight at 550 Degree celcius W3	Final weight at 700 Degree celcius W4
350 Sample	31.298	31.258	31.151	31.150
	32.752	32.699	32.607	32.602
450 Sample	35.928	35.875	35.800	35.797
	37.597	37.544	37.471	37.468
550 Sample	39.277	39.244	38.735	38.731
	39.576	39.545	38.179	38.174
Raw Sample	34.320	34.294	33.749	33.740
	33.748	33.697	33.456	33.455

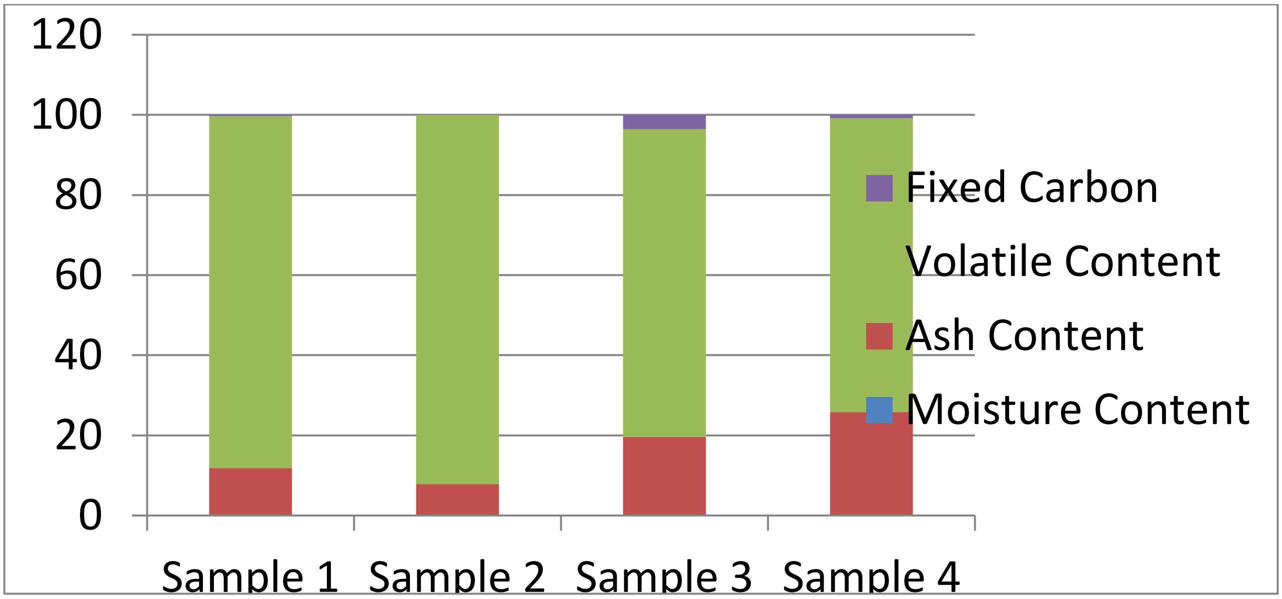
Result and Discussion: Using Tanner's diagram to check whether the sample needs auxiliary fuel.

Sl.no.	Sample pyrolysed at temperature	Moisture Content (%)	Ash Content(%)	Volatile content(%)	Fixed Carbon (%)	Auxiliary Fuel requirement
Sample 1	350°C	0.14	11.7	87.87	0.29	Not Required
Sample 2	450°C	0.16	7.69	**92.14**	0.01	Not Required
Sample 3	550°C	0.14	19.45	76.86	3.55	Not Required
Sample 4	Raw Sample	0.12	25.72	73.29	0.87	Not Required

Tanner's diagram:



Graphical representation of Result Data



Conclusion:

That plastic bottle has the lowest percentage moisture of 0.12% .

Highest volatile matter of 92.14% was found in 450°C heated sample.

The minimum percentage of fixed carbon in these samples 0.01% which is found in Sample pyrolysed at 450°C.

Pyrolysis is a promising method for recycling PET bottles and converting them into valuable products. The liquid products obtained from pyrolysis can be used as a source of fuel and chemicals, while the solid product can be used as a filler in various industrial applications. However, further research is required to optimize the process parameters and to evaluate the economic feasibility of pyrolysis as a method for PET bottle recycling.

CONCLUSION

Keypointsconcludedduringthisprojectare:

1) Fromourpointofview,incinerationplantsshouldbeinstalledinIndia, baecause for reduction of waste incineration is the best method.
2) Incineration plants should be located nearby to the industries which can take up theenergygenerated bythese plantsfortheiroperation purpose.
3) Proper provisions should be regulated by MNRE for the installation of these incinerationplants.
4) A major reason for the failure of these plants is also “Social Acceptance”. Awarenesscampaignsshouldbeheldto awarepeopleaboutthebenefitsof them.
5) Large amount of volume is reduced from the landfill sites due to the incineration forexample hazardous waste can also be incinerated instead of disposing to the landfills ordeepintoearth.
6) For sanitary pads ,pyrolysis is feasible as along with preventing the napkins to reach dumpsite it can be used as a source of energy.
7) Segregation is the major reason for the failure of such projects as the daily waste qualityisdifferentwhichhinders intheproductivity.
8) Inpyrolysis,fluegasisnotgeneratedsoit’sanadvantageofusingpyrolyser for PET bottles and it also gives useful products.
9) Weshouldoptforplasmagasificationbecauseitcangasifyalltypeofwasteinit.

REFERENCES

1) *UNEP(2019).Waste-to-Energy:ConsiderationsforInformedDecision-Making*

2) *MNREReportonPowerGenerationFromMunicipalSolidWaste,India–2016*

3) *ManualofMunicipalSolidWasteManagement,India–2016*