A STUDY ON PRODUCTION PROCESSES FOR SYNTHESIS OF ENERGY FUEL FROM WASTE PLASTIC

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ABSTRACT

The increasing demand of plastic with changing lifestyle has resulted in accumulation plastic waste in the environment.. Most of the developing countries are majorly concerned this issue of plastic waste the management and its disposal. The amount of waste plastic has been increased by an average of almost 10% every year on a global basis since 1950. Several methods are available for plastic waste management. Such as, land filling, mechanical recycling, biological recycling, thermal incineration, chemical recycling. Individual limitations of each of these processes make them less suitable for plastic management. Thermochemical conversion of waste plastic has becomes a prominent pathways for plastic management and energy extraction from the waste due to its higher energy content and increasing availability in local communities. In this thermochemical conversion, waste plastics are converted into valuable liquid hydrocarbon product (oil) that can be used as an energy source various applications. This work is focused on the extensive study on pyrolysis process, production of fuel oil from waste plastic and the characterization that are carried out for the pyrolytic oil .

Keyword : - *Fuel oil, Plastic recycling, Thermochemical Conversion*

1. STATISTICS CONSUMPTION OF PLASTICS AND GENERATION OF PLASTIC WASTE

Plastics are one of the greatest innovations of the millennium and have surely proved their reputation to be true. They belong to the category of are synthetic organic materials that can be produced by polymerization process. The fact that plastic is low weight, does not corrode or decompose, cost is low, recyclable and protects natural resources is the main reason for which plastic has gained much popularity with regard to its usage. Again, Plastics save energy and CO_2 release during their use.

Plastics production has increased day by day by an average of approximately 10% every year on a global basis since 1950[1]. The average Indian consumption of plastics per capita reached 3.2 kg in 2001 (here 5 kg if recycled material is also added) from a mere 0.8 kg in 1991 and 1.8 kg in 1998/1999. However, this is only one fourth of the consumption in China. It is 12 kg/capita in 1998 and one sixth of the world average that is 18 kg/capita.

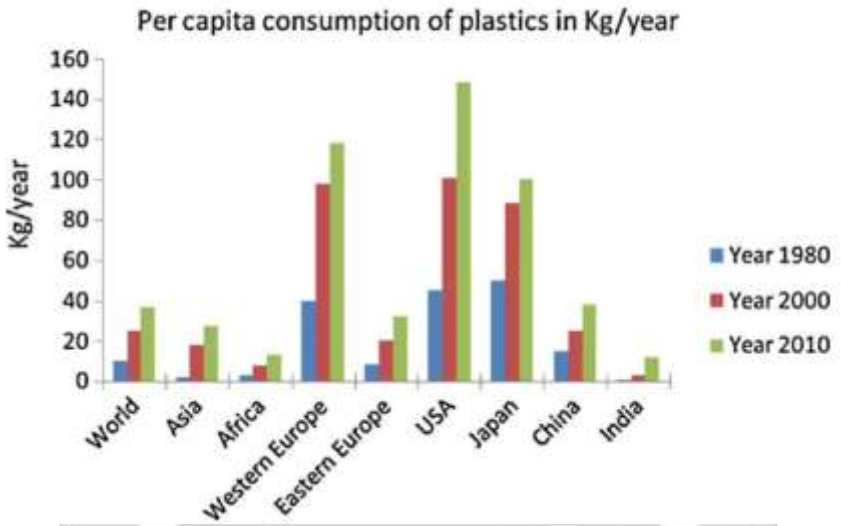

Chart -1: Comparison of per capita consumption of plastics over three different periods

2. DIFFERENT METHODS USED FOR PLASTIC WASTE MANAGEMENT

Due to high population growth, the demand for plastic products has steadily increased over the last 40 years. Since plastics materials are non-biodegradable in nature and they cannot be easily returned to the natural carbon cycle. Hence the life cycle of plastic materials ends at waste disposal facilities. There are various methods available for disposal of municipal and industrial plastic waste, like landfill, incineration true material recycling, and chemical recovery. The largest amount of plastic wastes is disposed of by land filling (65 to 70%), and incineration (20 to 25%). Recycling is only about 10% during early in 2000.[4].In mechanical recycling method ,we used plastic waste and convert into low quality plastics products. This is a primary and secondary types of recycling of plastic where the homogeneous waste plastics or mixed plastics are converted into useful products with closely same or less performance level than the original product.

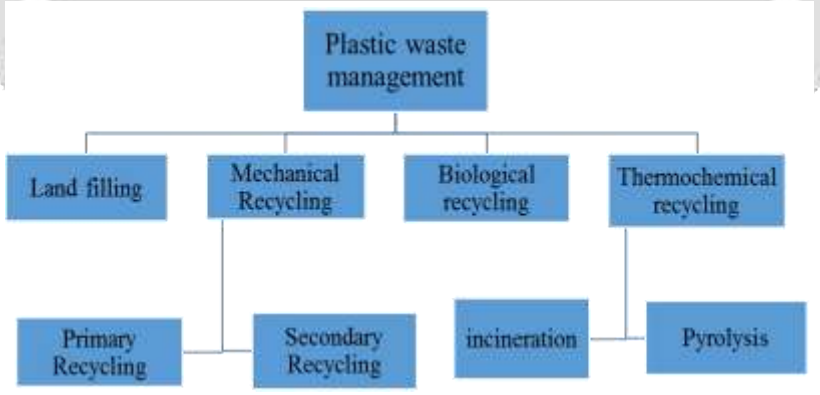

Chart 2. plastic waste management

In biological recycling synthetic and natural cis-poly (isoprene) converts highly resistant to biodegradation when prepared into industrial products (Ex. tyres) which is a direct importance of the presence of highly effective antioxidants additional during their manufacture .

In thermal recycling Energy produced by incineration of plastics waste is in principle a possible use for recovered waste polymers since hydrocarbon polymers exchange fossil fuels and thus reduce the CO2 burden on the environment. Incineration is the desired energy recovery choice of local authorities because there is financial increase by selling plastics waste as fuel.

Co-incineration of plastic wastes with other municipal solid wastes may be gradually practiced, because the high caloric value of plastics can improve the heating value of MSW and assist an effective incineration, while their energy content can also be recovered.

In chemical recycling feedstock recycling is also known as tertiary recycling or chemical recycling, purposes to convert waste polymer into original monomers or other valuable and useful chemicals. These products are useful as feedstock for a multiplicity of downstream industrial processes or as transportation fuels.

There are three main parts:
1. Depolymerisation
2. partial oxidation
3. cracking(thermal, catalytic and hydrocracking).

3. PYROLYSIS OF WASTE PLASTIC

Pyrolysis is generally defined as the controlled heating or burning of a material in the absence of oxygen. In plastics pyrolysis, the macromolecular structures of plastics are broken down into smaller molecules or oligomers and sometimes monomeric units.This process of thermal degradation is carried out in the absence of oxygen. The pyrolysis reaction can be take place with or without the presence of catalyst.

Plastic waste is treated in a cylindrical chamber and the pyrolytic vapour condensed in a especially designed condenser system to yield a hydrocarbon distillate including, cyclic aliphatics and aromatic hydrocarbon and straight and branched chain aliphatics. The resultant mixture is fundamentally equivalent to petroleum product. The plastic is pyrolised at 370ºC - 500ºC temperature and the pyrolysis vapor are condensed through a heat exchanger unit to produce the pyrolytic oil.

Feed :-Low-density polyethylene (LDPE)
Volume of oil = 10 ml
Density = 7.89/10
= 0.789 gram/ml
=789 gram/liter

F = Feed of plastic = 100gm
L = liquid oil collect = 42ml
R = Residue = 51 gm

Take overall material balance

F = V+L+R
$100 = V + (42*10^{-3}*769)+51$
V = 100-32.298-51.83
= 15.87gm

Vapor =15.87 gram
Liquid =32.298 gram
Residue =51.83 gram

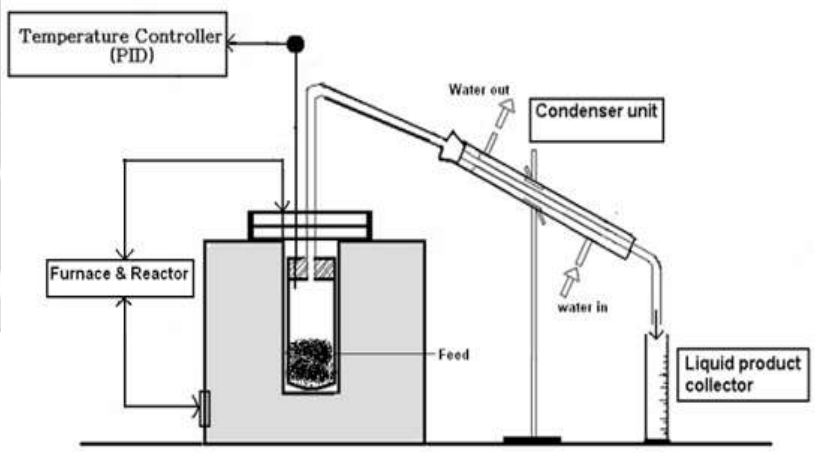

Fig 1 Pyrolysis of plastic waste to liquid fuel

%Area	M.W	BP	Formula	Compound name	Mole%	Mass	Mass%	Component gm
3.670	127	146	C9H18	1- nonene	3.810	483.84	0.025	2.160

4.520	129	146	C10H20	Nonane	4.692	605.29	0.031	2.703
4.820	140	170	C10H22	1-decene	5.004	700.50	0.036	3.128
4.770	143	151	C11H22	3,7 -dimethyl decane	4.952	708.09	0.036	3.161
5.130	155	196	C11H24	1 - undecane	5.325	825.44	0.042	3.685
5.300	156	220	C12H24	2,4,6- trimethyl undecane	5.502	858.3	0.044	3.832
4.590	168	214	C12H26	1-dodacene	4.765	800.49	0.041	3.574
5.660	170	200	C13H26	Octane	5.876	998.85	0.051	4.460
4.210	182	232	C13H28	6- tridecene	4.370	795.41	0.040	3.551
6.280	185	234	C14H28	2,4,- dimethyl octane	6.519	1,206.02	0.061	5.385
3.470	196	250	C14H28	4- tetradecene	3.602	706.01	0.036	3.152
6.340	198	234	C14H34	Tridecane/ hexadecane	6.582	1,303.45	0.066	5.818
2.290	210	268	C15H30	1- pentadecene	2.377	499.21	0.025	2.229
6.030	212	269	C15H32	Pentadecane	6.260	1,327.03	0.067	5.925
1.680	224	284	C16H32	1-hexadecene	1.744	390.67	0.020	1.744
5.950	226	268	C16H34	Pentadecene /	6.177	1,395.93	0.071	6.233
1.010	238	298	C16H30	7-hexadecene	1.048	249.53	0.013	1.114
4.910	240	302	C17H36	Heptadecane	5.097	1,223.29	0.062	5.462
0.470	252	314	C18H36	9-octadecene	0.488	122.95	0.006	0.549
4.270	254	315	C18H38	Octadecane	4.433	1,125.90	0.057	5.027
0.220	266	329	C19H38	1-nonadecene	0.228	60.75	0.003	0.271
3.020	268	330	C19H40	Nonadecane	3.135	840.19	0.043	3.751
2.470	282	342	C20H42	Eicosane	2.564	723.07	0.037	3.228
2.130	296	330	C21H44	Dodacane	2.211	654.5	0.033	2.922
1.540	324	253	C14H29	Tetradecene	1.599	517.96	0.026	2.313
0.910	338	391	C24H50	Tetracosane	0.945	319.29	0.016	1.426
0.670	366	412	C26H54	Hexacosane	0.696	254.56	0.013	1.137
96.330		6,734			100.000	19,696.408	1.000	87.940

Chart 3.Component present in pyrolytic oil

3.1 Laboratory Experiments for determination of order of pyrolysis reaction (Reaction kinetics)[3]

Non-isothermal kinetic study of weight loss under pyrolysis of oil is an extremely complex task because of the presence of numerous complex components and their parallel and consecutive reactions. The kinetics LDPE decomposition is carried out in order to calculate the activation energy, frequency factor and to determine order of reaction

The extent of conversion or the fraction of pyrolysed material α is defined by the expression

$$\alpha = \frac{w_0 - w_t}{w_0 - w_f}$$

Where w_0 is the initial weight,

w_t the weight at "*t*" minutes

w_f the weight after complete pyrolysis.

Assuming that the reaction order is close to unity, kinetics of no isothermal pyrolysis may be described by the following equation

$$\frac{d\alpha}{dt} = kf\alpha$$

Where *k* (the rate constant) is given by the Arrhenius expression

$$k = A.exp\left(-\frac{E}{RT}\right)$$

where A is the frequency factor (s^{-1})

E is activation energy ($kJ \cdot mol^{-1}$)

R is gas constant ($8.314 \cdot 10^{-3}$ kJ/(mol·K));

T is absolute temperature (K). According to the uniform kinetics of reaction

$f(\alpha)$ Can be defined as f (α) = $(1-\alpha)^n$, where n is the reaction order.

For a non-isothermal kinetic experiment with a linear heating rate of β ($K \cdot min^{-1}$), β = dT/dt

1st trial calculation

w_0 initial weight = 100.37

w_t = weight at "*t*" minutes = 99.728

w_f = weight after complete pyrolysis.= 0.25

$$\alpha = \frac{w_o - w_t}{w_o - w_f} = \frac{100.37 - 99.728}{100.37 - 0.025} = 0.006398$$

$$M = \frac{d\alpha}{dt} = \frac{(0.006398 - 0.006378}{(27 - 26.5)} = 3.98 * 10^{-5}$$

$$N = \frac{1}{((1-x)^n)} = \frac{1}{((1-0.006398)^{0.37})} = 1.0023$$

$$M \times N = 3.99 \times 10^{-5}$$

$$Y = \ln(M \times N) = -10.12$$

$$X = \frac{1}{T} = 0.001745$$

Temperature(°C)	Weight (%)	time, min	X (alpha)	da/dt	1/((1X)^n)	M x N	ln (MN)	1/T
300	99.728	27	0.006398	0.000040	1.00238	4E-05	-10.1277	0.00175

305	99.724	27.5	0.006438	0.000080	1.00239	7.99E-05	-9.43454	0.00173
310	99.703	28	0.006647	0.000419	1.00247	0.00042	-7.77623	0.00172
315	99.673	28.5	0.006946	0.000598	1.00258	0.000599	-7.41945	0.00170
320	99.659	29	0.007086	0.000279	1.00263	0.00028	-8.18153	0.00169
325	99.636	29.5	0.007315	0.000458	1.00272	0.00046	-7.68501	0.00167
330	99.598	30	0.007693	0.000757	1.00286	0.00076	-7.18278	0.00166
335	99.565	30.5	0.008022	0.000658	1.00298	0.00066	-7.32373	0.00164
340	99.516	31	0.008511	0.000977	1.00317	0.00098	-6.92824	0.00163
345	99.466	31.5	0.009009	0.000997	1.00335	0.001	-6.90785	0.00162
350	99.424	32	0.009427	0.000837	1.00351	0.00084	-7.08205	0.00161
355	99.369	32.5	0.009976	0.001096	1.00372	0.0011	-6.81218	0.00159
360	99.301	33	0.010653	0.001355	1.00397	0.001361	-6.59975	0.00158
365	99.231	33.5	0.011351	0.001395	1.00423	0.001401	-6.5705	0.00157
370	99.148	34	0.012178	0.001654	1.00454	0.001662	-6.39985	0.00156
375	99.041	34.5	0.013244	0.002133	1.00495	0.002143	-6.14546	0.00154
380	98.902	35	0.01463	0.002770	1.00547	0.002786	-5.8833	0.00153
385	98.635	35.5	0.01729	0.005322	1.00647	0.005356	-5.22952	0.00152
390	98.35	36	0.020131	0.005680	1.00755	0.005723	-5.16321	0.00151
395	98.012	36.5	0.023499	0.006737	1.00884	0.006796	-4.99138	0.00150
400	97.6	37	0.027605	0.008212	1.01041	0.008297	-4.79184	0.00149
405	97.073	37.5	0.032857	0.010504	1.01244	0.010634	-4.54366	0.00147
410	96.434	38	0.039225	0.012736	1.01492	0.012926	-4.34851	0.00146
415	95.766	38.5	0.045882	0.013314	1.01753	0.013547	-4.30156	0.00145
420	94.892	39	0.054592	0.017420	1.02099	0.017786	-4.02937	0.00144
425	93.846	39.5	0.065016	0.020848	1.02519	0.021373	-3.84562	0.00143
430	92.488	40	0.078549	0.027067	1.03073	0.027898	-3.57919	0.00142
435	90.743	40.5	0.095939	0.034780	1.03802	0.036102	-3.32139	0.00141
440	88.497	41	0.118322	0.044766	1.04770	0.046901	-3.05972	0.00140
445	85.675	41.5	0.146445	0.056246	1.06034	0.05964	-2.81943	0.00139
450	82.042	42	0.18265	0.072410	1.07748	0.07802	-2.55078	0.00138
455	77.275	42.5	0.230156	0.095012	1.10162	0.104667	-2.25697	0.00137
460	71.097	43	0.291724	0.123135	1.13612	0.139897	-1.96685	0.00136
465	61.86	43.5	0.383776	0.184105	1.19618	0.220223	-1.51312	0.00136
470	49.589	44	0.506064	0.244576	1.29820	0.317509	-1.14725	0.00135
475	38.325	44.5	0.618317	0.224505	1.42814	0.320625	-1.13748	0.00134
480	28.821	45	0.71303	0.189426	1.58709	0.300636	-1.20185	0.00133
485	19.178	45.5	0.809129	0.192197	1.84555	0.354709	-1.03646	0.00132
500	1.283	47	0.987463	0.065016	5.05442	0.328617	-1.11286	0.00129

Chart 4. Component present in pyrolytic oil

Prepared X vs Y Plote

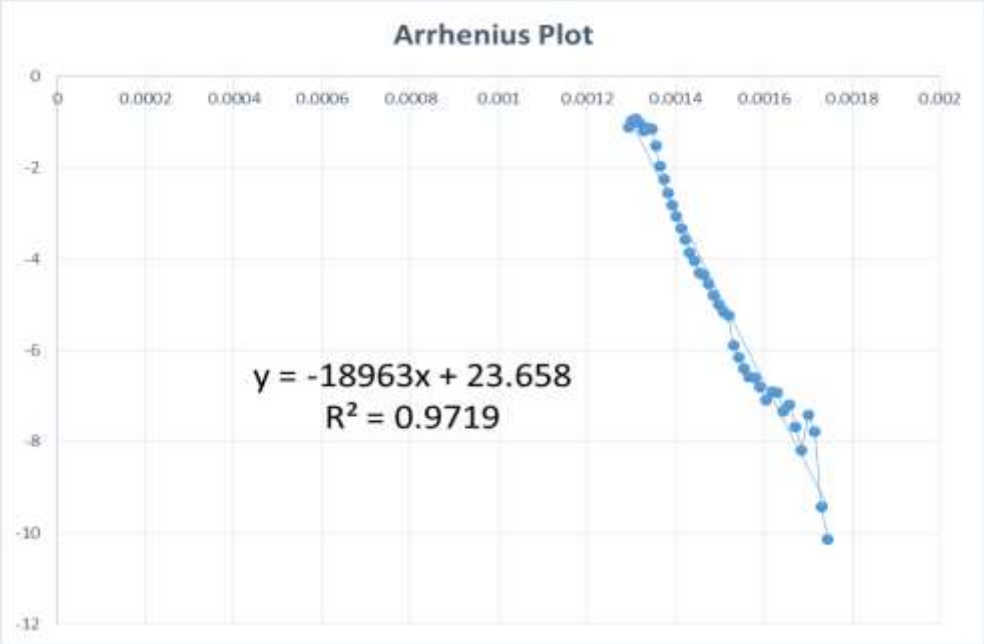

Chart 5. Arrhenius plot

Result

KINETICS RESULT			
SR NO	PARAMETERS	UNIT	RESULTS
1	R	J/mol K	8.314
2	Slope	-	18963
3	E	J/mol	157658.382
4	Intercept	-	23.66
5	Order	-	0.37
6	A (F.F)	S^{-1}	3.14E+09
PROXIMATE ANALYSIS			
SR.NO.	PARAMETERS	UNIT	RESULTS
1	Moisture	%	0.035
2	Ash Content	%	0.015
3	Volatile Matter	%	99.94
4	Fixed Carbon	%	0.010
ULTIMATE ANALYSIS			
SR.NO.	PARAMETERS	UNIT	RESULTS
1	Carbon	%	84.1
2	Hydrogen	%	7.42
3	Nitrogen	%	6.62
4	Sulphur	%	BDL
Energy Requirement			
SR.NO.	PARAMETERS	UNIT	RESULTS
1	Energy Require	watt	75.45

4. CONCLUSIONS

From this studies we conclude that the order of pyrolysis reaction is 0.38 and due large amount of volatile matter present it is a single stage decomposition .if we take 50gm LDPE plastic than we get approximate 42ml pyrolytic oil.

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