Program Name : **Diploma in Plastic Engineering**

Program Code : **PS**

Semester : **Fourth**

Course Title : **Environmentally Sustainable Plastic Technologies**

Course Code : **22453**

1. RATIONALE

Plastics due to their advantages and wider applications are becoming more and more popular and its products are used almost everywhere. Plastics are replacing the materials being used today. On the other side the plastic wastes are imposing problems of environmental pollution, as they are not biodegradable. This indeed gives rise to another idea of recycling the plastic wastes and reuse for suitable applications. Recycling of waste plastics has a wider scope; hence this course will be of great use for applications in industries. This course will be extremely useful for plastic engineering technocrats who wish to become entrepreneur by establishing plastic recycling units.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Use relevant plastic recycling methods for implementing energy conservation and pollution reduction techniques for sustainable environment.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant skills associated with this course are to be taught and implemented, so that the student should perform the following industry oriented COs associated with the above mentioned competency:

a. Identify the areas of plastic waste management.
b. Select relevant methodology for plastic waste management.
c. Use relevant sorting and separation methods.
d. Use relevant recycling method.
e. Utilize relevant plastic waste for manufacturing recycled plastic products.
f. Justify the equitable use of resources for sustainable development.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

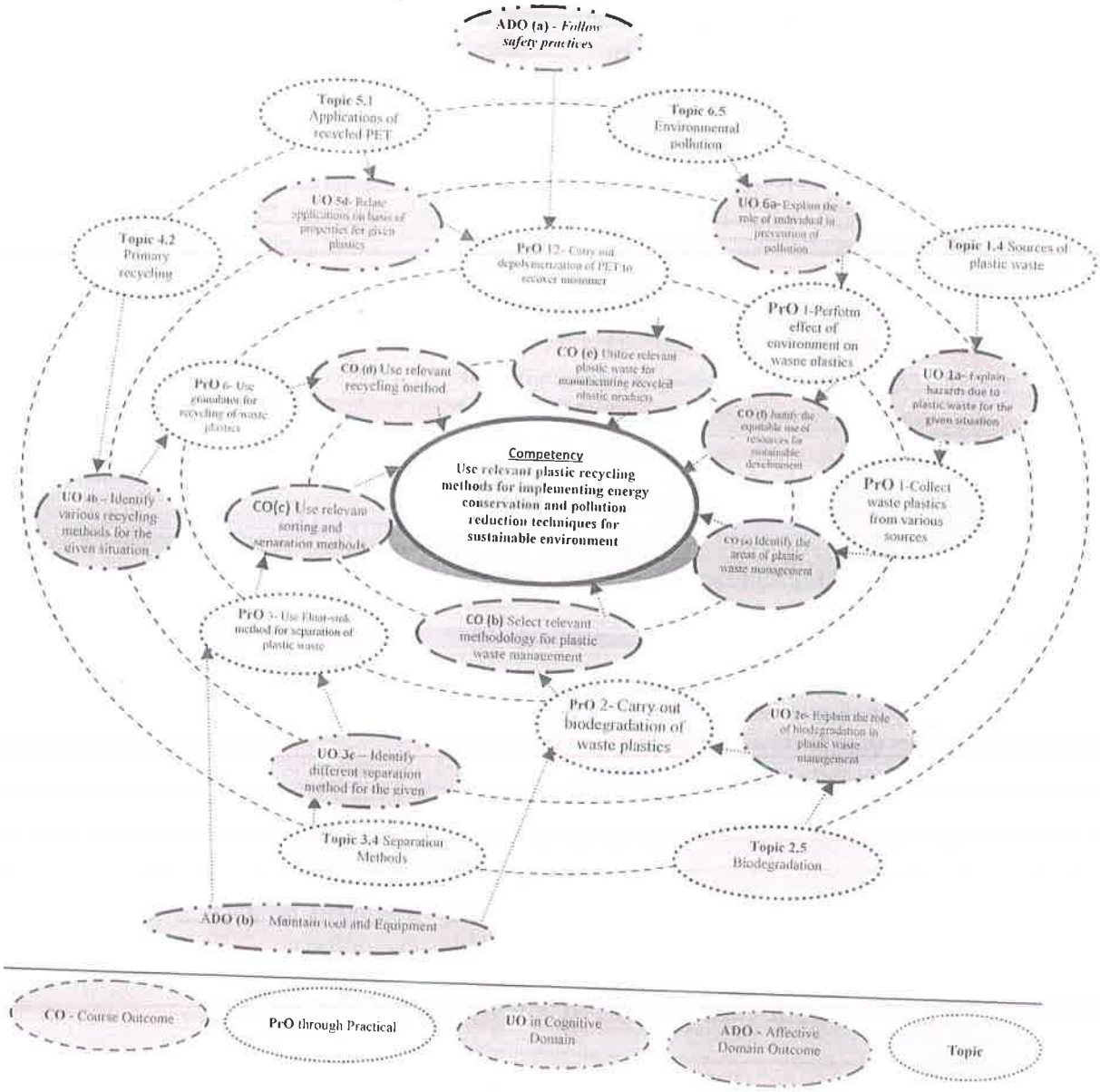

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Collect various types of plastic wastes.	I	02*
2	Carryout biodegradation of waste plastic by fungi/bacteria	II	02*

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	methods.		
3	Use float-sink method for separation of plastics.	III	02*
4	Use wet process for separation of paper from plastic products.	III	02*
5	Use shredder for size reduction of waste plastic.	IV	02
6	Use granulator for recycling of waste plastic.	IV	02*
7	Perform hydrolysis of waste plastic to recover value added products.	IV	02
8	Perform ammonolysis of waste plastic to recover value added products.	IV	02
9	Perform Pyrolysis method for conversion of waste plastic into useful products.	IV	02*
10	Perform Methanolysis of waste plastic to recover value added products.	IV	02
11	Perform depolymerisation of PMMA to recover monomer.	IV	02
12	Perform depolymerisation of PET to recover monomer.	IV	02*
13	Perform depolymerisation of PVC to recover monomer.	IV	02
14	Perform depolymerization of HDPE to recover monomer	IV	02*
15	Perform depolymerisation of LDPE to recover monomer.	IV	02
16	Perform depolymerisation of PS to recover monomer.	IV	02*
17	Perform effect of environment on waste plastics.	VI	02*
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 10 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO are to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1	Setting of experimental set up	20
2	Operate equipment skillfully	30
3	Follow Safety measures	10
4	Work in team	10
5	Record Observations	10
6	Interpret Results to conclude	10
7	Answer to sample questions	5
8	Submit report in time	5
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment/Instruments/Other resources name with Broad Specifications	PrO No.
1	Float and sink separator(Interior width- 1500-2000 mm; Total Length- 4-6 meters; Interior material- Stainless still; Exterior frame- Carbon steel; Screw conveyer motors- 5.5 KW + 3.7 KW; Rotating Drum Motor- 0.37 KW + 2.2 KW)	3
2	Electrostatic separator (Batch type- maximum continuous treatment capacity of Class 300kg/h; Measuring 1.3m wide×1m long×2.1m; High in outside dissipations; Separator should be a space- and energy-saving type, with a separating voltage of 30kV or less and power dissipation of 1kW or less)	4
3	Washing Tank (Size wide-2m x long 4 m)	4,6
4	Shredder/scrap grinder (Power Required-3 HP; Grinding Capacity/hr-40 Kg; No. of Blades-5; Throat size- 8" x 8"; Length of blades-8"; L x W in mm-950 x 650; Weight of machine-275 Kg)	5
5	Magnetic Separator (Cylinder Dimension (mm)-600-900; Average value of dressing area and magnetic induction of the cylinder surface(mT)- 145-180; Cylinder Revolution (r.p.m)- 40; Feeding Particle Size (mm)- 0-0.2; Capacity (t/h) -8-18; Motor Power (kw)-1.5; Weight of machine (kg) – 981)	5
6	Granulator (Power Required-3 HP; Grinding Capacity/hr-30 Kg; No. of Blades-5; Throat size in mm- 200 x 200; Length of blades- 200 mm)	6
7	Pyrolysis reactor (Volume-100 litre; Pressure-350 bar; Temperature-500^{0}C)	9
8	Extruder (Screw Diameter-90 mm; Screw RPM-0-80; Plasticizing Capacity-80-90 Kg/Hr; Max. Article Wt-3000 GMS)	10
9	Required chemicals (NaOH, HCl, H_2SO_4, Acetone, Phenol etc.)	11
10	Glassware (Conical flask, Three necked round bottom flask, measuring cylinder, distillation assembly etc.)	11

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Sources of Plastic Waste	1a. Explain hazards due to plastic waste for the given situation. 1b. Identify sources of plastic waste for the given situation. 1c. Identify different pollutants for the given situation. 1d. Select pollution control methods for the given situation. 1e. Justify the need of plastic waste management.	1.1 Waste and Waste Management. 1.2 Hazards to Environment due to accumulation of Plastic Waste. 1.3 Pollution and pollutant, Types of Pollutants. Ways to control the Pollution. 1.4 Sources of Plastic waste-Domestic, Industrial, Commercial and Medical 1.5 Need of Plastic waste management.
Unit– II Techniques of Plastic Waste Management	2a. Explain steps in plastic waste management for the given situation. 2b. Select proper waste disposal method for the given situation. 2c. Justify the use of Landfilling for the given plastic waste disposal. 2d. Analyze different methods of plastic waste recycling for the given situation. 2e. Explain the role of biodegradation in Plastic waste management. 2f. Justify the selection of methodology for plastic waste management for the given situation.	2.1 Steps in Plastic waste management 2.2 4 R terminologies of plastic waste management 2.3 Landfilling types 2.4 Recycling- Types of recycling such as primary, secondary, tertiary, and quaternary, Physical Recycling and Chemical recycling (Definitions only). 2.5 Biodegradation-Mechanism of biodegradation, Enzymes for biodegradation, Additives for biodegradation, Degree of biodegradability, Test to measure resistance of plastic to biodegradation (Resistance to fungi and bacteria), Properties and applications of PHA and PHB.
Unit– III Collection, Sorting, Separation of Waste Plastics and Additives	3a. Explain different collection methods for the given situation. 3b. Explain different sorting methods for the given situation. 3c. Identify different separation methods for the given situation.	3.1 Collection methods of waste plastics. 3.2 Sorting by size, shape, and color. 3.3 Separation by properties, recycling codes. 3.4 Separation Methods-Dry separation, Wet separation (Float-sink method). 3.5 Additives used for improving the Properties of plastic waste.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	3d. Select proper separation method for the given situation. 3e. Select suitable additive to improve properties of recycled products for the given situation. 3f. Justify the selection of sorting and separation methods for the given plastic waste management.	
Unit-IV Recycling of Waste Plastics	4a. Describe with sketches the process of size reduction for the given situation. 4b. Identify various recycling methods for the given situation. 4c. Analyze different recycling methods for the given situation. 4d. Distinguish tertiary and quaternary recycling methods for the given situation. 4e. Estimate the energy recovery from plastic waste for the given situation. 4f. Justify the selection of relevant recycling method for the given situation	4.1 Size reduction-cutting by impact and pressure, shredding by impact and shearing, Cryotechnical fine grinding 4.2 Primary Recycling- Granulation, 4.3 Secondary Recycling- Melt processing 4.4 Tertiary Recycling- Hydrolysis, Glycolysis, Methanolysis, Ammonolysis 4.5 Quaternary Recycling- Incineration, construction and working of Incinerator 4.6 Energy recovery from plastic waste - Pyrolysis (Fuel recovery), Gasification (Gas recovery)
Unit –V Applications of Recycled Plastics	5a. Select proper plastic for given applications. 5b. Maximize the utilization of recycled plastics for given situation. 5c. Compare applications of given plastics. 5d. Relate applications on basis of properties for given plastics. 5e. Justify the selection of relevant plastic waste for manufacturing recycled	**Applications of recycled plastics** 5.1 PET (Fiber, Packaging, others). 5.2 HDPE (Packaging, Lumbers, Pipes, injection moulded Products, Films) 5.3 PP (Automotive, other applications) 5.4 PVC (Building and construction products, packaging, clothing) 5.5 LDPE (Film products, other products) 5.6 PS (Building products, soil conditioners, packaging) 5.7 ABS (Automobile products) 5.8 Nylon (Film products)

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	plastic products for given situation.	5.9 PU (Foam products) 5.10 Mixed Plastics (Injection moulded products)
Unit –VI Environmental studies	6.1 Elucidate the role of environmental studies. 6.2 Explain the role of individual in conservation of the given natural resources. 6.3 Explain characteristic feature, structure and function of the given eco system. 6.4 Explain different threats to biodiversity and measures of conservation. 6.5 Explain the role of individual in prevention of pollution. 6.6 Explain the effects of social issues on environment. 6.7 Explain the effect of population on the environment. 6.8 Justify the equitable use of resources for sustainable development.	6.1 The multidisciplinary nature of environmental studies-Definition, scope and importance 6.2 Natural Resources and associated problems- Water resources: Use and over-utilization of surface and ground water. Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources. Energy resources: Growing energy needs, renewable and non-renewable energy sources, use of alternate energy sources. 6.3 Ecosystems- Characteristic feature, structure and function of the eco system. 6.4 Biodiversity and its conservation-Definition of genetic, species and ecosystem diversity, threats to biodiversity, In-situ and Ex-situ conservation of biodiversity 6.5 Environmental Pollution- Causes, effects and control measures of Air, water, soil, noise and marine pollution. 6.6 Social Issues and the Environment-Causes of climate change, global warming, acid rain, ozone layer depletion, air and water (prevention and control of pollution) Act. 6.7 Human Population and the Environment-Population growth and explosion, environment and human health.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Sources of Plastic Waste	04	02	02	04	08
II	Techniques of Plastic Waste Management	10	02	04	06	12
III	Collection, Sorting, Separation of Waste Plastics and Additives	12	02	04	06	12
IV	Recycling of Waste Plastics	12	02	06	06	14
V	Applications of Recycled Plastics	12	02	06	06	14
VI	Environmental studies	14	02	04	04	10
Total		64	12	**26**	**32**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of LOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Collect various waste plastic products with recycling codes
b. Prepare flow chart of plastic products to its disposal.
c. Prepare chart of plastic waste recycling process.
d. Gather information of plastic waste collection agencies and recycling industries.
e. Visit an existing recycling unit/industry and collect information of registration procedure, plant layout, machinery specifications and price, electrical load, manpower requirement, rate list, annual turnover, major clients and terms and conditions. Make a report of it.
f. Prepared the chart for eco system.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various learning outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).

d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.
f. Demonstrate students thoroughly before they start doing the practice.
g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in Lab.
i. Demonstrate students thoroughly before they start doing the practice.
j. Encourage students to refer different websites to have deeper understanding of the subject.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty:

a. **Waste collection and separation**: Collect the plastic waste from houses, shops and sort them according to their size, color, codes and shape.
b. **Product recovery:** Depolymerize the collected waste for monomer recovery.
c. **Energy Recovery:** Pyrolysis of mixed waste plastic to produce fuel.
d. **Product Preparation**: Prepare different products from waste plastics.
e. **Recycling machine making:** Make recycling machine.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1.	Handbook of Plastic Recycling	Francesco La Mantia	Rapra Technology Ltd., UK 2015 ISBN:1- 85957-325-8
2.	Plastics Waste Management (Disposal, Recycling, and Reuse)	Mustafa, N.	Marcel Dekker, Inc, New York, 2015 ISBN: 0-8247-8920-2
3.	Plastic Fabrication and Recycling	Chanda M; Roy S. K.	CRC Press, London, 2015, ISBN: 978-1-4200-8062-9
4.	Plastic Waste Recycling Technology	EIRI Board	Engineers India Research Institute, New Delhi, 2016, ISBN: 9788189765309
5.	Concept of	Sugandha Mishra;	Rajesh Publication, New Delhi, 2017,

S. No.	Title of Book	Author	Publication
	Environmental Science	Dhirendra Kumar	ISBN: 978-938384397
6.	Textbook for Environmental Studies for Undergraduate Courses	Erach Bharucha	Orient BlackSwan, Pune, 2013, ISBN: 978-8173718625

14. SOFTWARE/LEARNING WEBSITES

a. https://www.youtube.com/watch?v=rTxXLNrwaNs- for plastic recycling
b. https://www.youtube.com/watch?v=ZwAvP2lb1sU- for waste plastic bottle recycling
c. https://www.youtube.com/watch?v=BlIdZTfDMwU- for plastic recycling
d. https://www.youtube.com/watch?v=k58pw040kGM- for successful story for plastic recycling business
e. https://www.youtube.com/watch?v=qb_Upfhnhb0- for mini plastic recycling machine
f. https://www.youtube.com/watch?v=5333MgaSatk- for Pyrolysis plant
g. http://www.unep.or.jp/Ietc/Publications/spc/WastePlasticsEST_Compendium.pdf- for converting waste plastic into a resource
h. http://www.researchtrend.net/ijet/ijet61/24%20NCRIET.pdf- for Fuel from Plastic Waste by Vijaykumar B. Chanashetty and B.M. Patil
i. http://gpcb.gov.in/Final%20Speaker%20PPTS/Day%202/Session%202x/Mr%20Ramkrishna%20Iyer.pdf- for thermal depolymerisation technology for converting waste plastics to diesel and gasoline blendstock
j. http://www.iosrjen.org/Papers/vol2_issue9%20(part-2)/F0293849.pdf- for First Simple and Easy Process of Thermal Degrading Municipal Waste Plastics into Fuel Resource by Moinuddin Sarker and Mohammad Mamunor Rashid
k. https://www.omicsonline.org/open-access/diesel-fuel-from-plastic-waste-2471-2698-1000e105.pdf- Diesel Fuel from Plastic Waste by Maceiras R