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**CURRENT STATUS AND PROSPECTS OF  
PLASTIC AND PLASTIC BAG WASTE  
RECYCLING**

Bayarsaikhan Battsetseg · Saruul Sukhbaatar

Tugjjav Oyunchimeg

Mongolian National University



## CURRENT STATUS AND PROSPECTS OF PLASTIC AND PLASTIC BAG WASTE RECYCLING

Bayarsaikhan Battsetseg<sup>1</sup>, Saruul Sukhbaatar<sup>2</sup>, Tugjjav Oyunchimeg<sup>3\*</sup>

<sup>1,2</sup>*Department of Environmental Protection Technology, Mongolian National University, Mongolia*

<sup>2</sup>*Department of Ecology Mongolian University Life of Sciences, Mongolia*

<sup>1</sup>[bayarsaikhantsetseg@gmail.com](mailto:bayarsaikhantsetseg@gmail.com) , <sup>2</sup>[saruul.munhdul@gmail.com](mailto:saruul.munhdul@gmail.com),

<sup>3</sup>[T\\_oyunchimeg@mul.s.edu.mn](mailto:T_oyunchimeg@mul.s.edu.mn)

**Abstract**— In recent years, plastic and plastic bag policies have emerged around the world and have been introduced at many levels of government. The main reason for implementing policies to reduce the use of plastic and plastic bags is to fight environmental pollution. As of 2022, plastic bag bans have been implemented in varying degrees in 94 countries, with 32 countries charging per bag instead. In 2019, Mongolia issued a decree prohibiting the importation of single-use plastic bags with a thickness of 0.035 mm or less and their use in services. In many countries of the world, measures are still being taken to bury, burn and recycle plastic waste, and in recent years, developed countries have paid more attention to the production of liquid fuel by pyrolysis of plastic waste. As of 2021, our country has 40 waste recycling plants and more than 160 sorting points.

**Keywords**— Plastic Policies, Pyrolysis, Recycling

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\* Corresponding Author: Tugjjav Oyunchimeg

## 1. INTRODUCTION

Over the past few years, the production of disposable plastic packaging and products has expanded rapidly. This is because of its ease of operation, functionality, and low cost. However, the environmental impact of plastic waste has become one of the pressing environmental challenges worldwide. The World Bank's report estimates that the world generates 2.01 billion tons of waste a year which will increase to 3.40 billion tons by 2050.

To date, the problem of plastic waste has been addressed with both conventional and advanced technological methods. Conventional plastic waste processing technologies include landfilling and incineration, which do not effectively address the plastic problem and have their own set of which face bottlenecks [1]. Countries in the developing world rely solely on the landfill as their waste disposal strategy. Therefore, certain recycling schemes do not realize the advantages of increasing the value of the economic chain [2]. Landfilling waste without proper means of recovering raw materials and energy leads to groundwater pollution, increased greenhouse gas emissions, and major public health and environmental problems [3]. Therefore, landfilling is considered the least desirable management strategy and is regulated by a variety of provisions [4]. Incineration of plastic waste requires large amounts of energy and produces hazardous by-products [5].

According to the United Nations Environment Program, 8 million tons of plastics have been produced worldwide over the past 65 years, of which 9% were recycled, 12% incinerated, and the remaining 6.3 billion tons have not been recycled. In addition, the amount of plastic dumped 8 million pieces of plastic are thrown into the ocean every year. Therefore, in order to overcome the challenges of traditional technologies such as landfilling and incineration, considerable research has been done on advanced waste treatment technologies, and current review articles focus on specific techniques such as pyrolysis [6], photodegradation [7], thermodegradation [8], and biodegradation [9].

Treatment of plastic waste in various ways has been a major area of research and development, and is particularly important for obtaining energy and valuable products from waste. The purpose of this paper analyzes the global and Mongolian policies, measures, and future trends of plastic and plastic bag waste.

## **2. THE PLASTIC AND PLASTIC BAG PROBLEM**

### **2.1. CHARACTERISTICS OF WASTE**

Waste characteristics are materials that humans do not want or cannot use. Waste is a substance that is no longer needed or discarded after its initial use or is damaged or ineffective. Whereas in natural ecosystems waste (i.e. oxygen, carbon dioxide, and dead organic matter) is used as food or a reactant, waste materials resulting from human activities are often highly resilient and take a long time to decompose.

Waste has been defined in most countries and is generally tied to the concept of disposal. Article 5 of the Basel Convention: Waste is any substance or object that has been disposed of, is intended to be disposed of, or is required to be disposed of by national law [10], OECD: ‘The term waste refers to substances or objects other than radioactive materials covered by other international agreements which are disposed of or recovered; are intended to be disposed of or recovered; or are required, by national law, to be disposed of or recovered’ [11]. Waste Framework Directive of the European Union, Article 3: The term ‘waste’ refers to any substance or object that is discarded, intended for disposal, or required for disposal by the holder. [12], Article 4 of the Mongolian Law on Waste states: "Waste" means items and materials that are no longer used by the owner" [13]. As shown in Figure 1, two main waste categories can be established based on the distinct legislation and policy instruments usually in place: non-hazardous or solid waste; and hazardous waste.

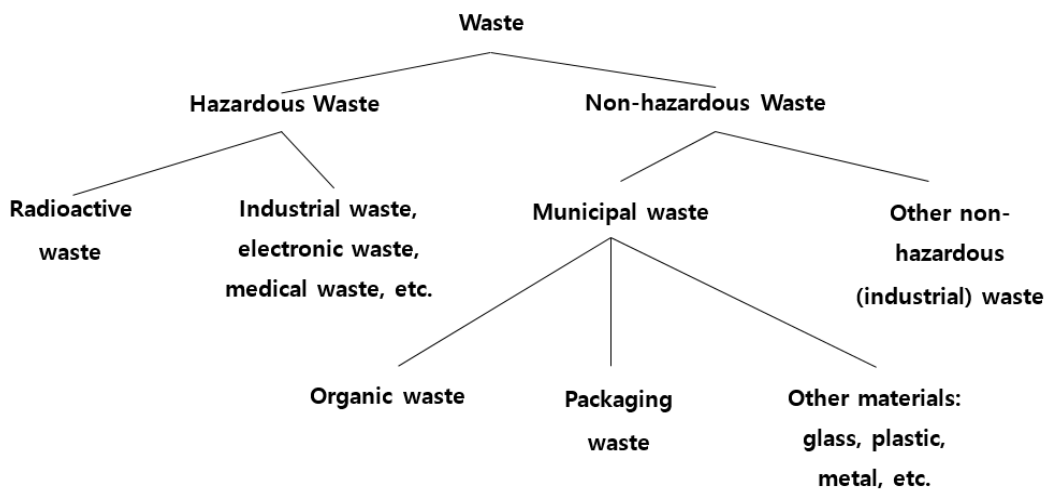


Figure 1. Fundamental Classification of Waste

## 2.2. WHAT IS PLASTIC?

Humankind has constantly strived to find materials that are beneficial to humans beyond those available in nature, such as stone, metal, glass, and wood. As a result of such efforts, organic polymer compounds were finally created by synthesizing substances extracted from fossil fuels, etc. They created a “dream material” that is light, hard, does not change easily, and can be easily molded into any desired shape. This new plastic product has all the properties that humankind desires. Bakelite was the first synthetic plastic to be produced in 1907, which marks the beginning of global plastics production [14]. The growth of global plastics production did not develop until the 1950s. After World War II, plastics entered industrial production and everyday life.

Plastics are an extremely useful material (e.g. lightweight, cheap, durable, tough, resistant, easy to manufacture, etc.), lending their use in a plethora of applications, such as in packaging, automotive, agriculture, construction, and healthcare industries, with undisputable benefits over other materials (e.g. metals, glass) [15]. The production of plastics has increased dramatically in recent years, from 1.5 million metric tonnes produced in 1950 to around 360 million metric tonnes in 2018, amounting to more than 8.3 billion metric tonnes of plastics produced worldwide [16].

In the case of developed countries, a waste management system has been established, but in for countries with low and middle, there is no waste management system, so the amount of waste that is dumped without permission, incinerated, or dumped into the amount is considerable [11]. Plastic production in Asia accounts for 50% of the world's production, and China accounts for 29% of the world's plastic production, making it the single country that produces the most plastics in the world [17]. The top 10 countries that produce the most plastic waste are shown in Table 1. The amount of plastic waste in Mongolia increased from 185.3 thousand tons in 2018 to 198.7 thousand tons in 2019, an increase of 7.2 percent [18].

Table 1. 10 Countries with the most plastic pollution

| <b>№</b> | <b>Counties</b> | <b>Unit</b>     |
|----------|-----------------|-----------------|
| 1        | Chine           | 59,079,741 tons |
| 2        | United States   | 37,825,550 tons |
| 3        | Germany         | 14,476,561 tons |
| 4        | Brazil          | 11,852,055 tons |
| 5        | Japan           | 7,993,489 tons  |
| 6        | Pakistan        | 6,412,210 tons  |
| 7        | Nigeria         | 5,961,750 tons  |
| 8        | Russia          | 5,839,685 tons  |
| 9        | Turkey          | 5,596,657 tons  |
| 10       | Egypt           | 5,464,471 tons  |

### **2.3. PLASTIC PROBLEM AND RECYCLING**

Many sources estimate it can take 500-1,000 years for plastic to decompose in a landfill. With the rate at which we use plastic bottles these days, the fact that they don't decompose quickly in landfills is an environmental concern. We are producing over 380 million tons of plastic every year, and some reports indicate that up to 50% of that is for single-use purposes. In addition to the environmental effects of plastics, there are three major health effects: 1) Like heavy metals such as lead, mercury, and cadmium, they are toxic to humans. 2) Causes cancer similar to diethyl hexyl phthalate (DEHP) 3) Cancer, fetal malformations, immunosuppression, and child development can all have serious consequences. In addition, the next big problem is the wide range of plastic pollution that affects the marine environment.

The four major effects on the marine environment are: 1) Physical effects on marine life: entanglement, ingestion, starvation, 2) Chemical effects: accumulation of persistent organic pollutants, 3) Aggressive nature of polluted rivers, transport of pollutants to remote areas of the ocean, 4) economic impact: damage to fisheries, shipping, and tourism. Therefore, we believe that recycling plastic waste can reduce the amount of waste dumped at landfills, this, in turn, saves energy costs and can effectively reduce the negative impact on the environment. For every ton of plastic that is recycled, 7.4 cubic yards of landfill space is saved. The main ingredient in most plastic materials is a derivative from crude oil and natural gas.

Plastic polymers fall into two main categories: thermoplastics and thermosets. Thermoset plastics are synthetic materials that harden when heated, but cannot be re-cast or reheated after molding. Thermoplastics are polymers that can be softened through heating before being processed and then left to cool and harden. Approximately, 80% of plastic wastes are thermoplastics that undergo repeated formation into novel products via heat application. According to Table 2, thermoplastics that can be recycled include polyolefins such as polyethylene terephthalate (PET), LDPE, HDPE, or PP. The structure of polyethylene is shown in figure 2.

Figure 3 shows the fundamental steps involved in recycling plastic waste. These stages involve collecting, sorting, and reprocessing the plastic ready to be used in new products. Plastic recycling includes both 1) chemical recycling (pyrolysis) and 2) incineration. The various methods proposed for recycling waste plastics include primary and mechanical recycling methods. Primary recycling is the reprocessing of waste materials into

industrial waste. Mechanical recycling involves separating plastics from contaminants by crushing, melting, or other similar methods. Plastics' mechanical recycling involves separating various plastic resins by their chemical orientation.

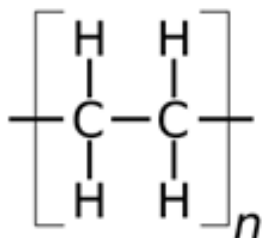


Figure 2. Polyethylene structure (Shutterstock, 2022)

Table 2. Type of plastic materials

| № | Type of plastic materials  | Abbreviation                       |
|---|--|------------------------------------|
| 1 | Acrylic or Polymethyl Methacrylate   | PMMA                               |
| 2 | Polycarbonate  | PC                                 |
| 3 | Polyethylene<br>— Low Density Polyethylene<br>— Medium Density Polyethylene<br>— High Density Polyethylene<br>— Ultra High Molecular Weight Polyethylene | PE<br>LDPE<br>MD<br>HDPE<br>UHMWPE |
| 4 | Polypropylene  | PP                                 |
| 5 | Polyethylene Terephthalate   | PETE or PET                        |
| 6 | Polyvinyl Chloride   | PVC                                |
| 7 | Acrylonitrile-Butadiene-Styrene  | ABS                                |

#### 2.4. WHAT IS A PLASTIC BAG? PLASTIC BAG PROBLEM!

Plastic bags are non-woven poly-grade containers for storing, transporting, and packaging a wide range of items and materials. The production of Plastic bags is made from an ever-available polymer known as polyethylene. The polymer starts with ethylene commonly extracted from natural gases. To make a polymer, the gases are treated to form long chains of hydrogen and carbon atoms. Table 3 shows the types of plastic bags and types of plastic bags. Plastic bags are made of high-density polyethylene-HDPE, but thin bags are made of low-density polyethylene - LDPE. The main environmental impact of plastic bags is that they take longer to decompose in nature.

Table 3. Plastic Bag materials and type of plastic bag

| No | Plastic Bag Materials                   | No | Types of Plastic Bag                 |
|----|---|----|--------------------------------------|
| 1  | High-Density Polyethylene (HDPE)        | 1  | Flat Plastic Bags                    |
| 2  | Low-Density Polyethylene (LDPE)         | 2  | Markable Plastic Bags                |
| 3  | Linear Low-Density Polyethylene (LLDPE) | 3  | Resalable Plastic Bags               |
| 4  | Medium Density Polyethylene (MDPE)      | 4  | Gusseted Plastic Bags                |
| 5  | Metallocene (mPE)                       | 5  | Anti-Static Plastic Bags             |
| 6  | Vinyl                                   | 6  | Postal Approved Plastic Bags         |
| 7  | Polypropylene                           | 7  | Biohazard Plastic Bags               |
| -  |   | 8  | Cleanroom Plastic Bags               |
| -  |   | 9  | Wicketed Plastic Bags                |
| -  |   | 10 | Shrink Plastic Bags                  |
| -  |   | 11 | Vapor Corrosion Inhibitor Bags (VCI) |
| -  |   | 12 | Tamper Evident Plastic Bags          |

It takes approximately 15-1000 years for a plastic bag to decompose in the environment. When plastic bags in nature are destroyed by sunlight, they release toxic substances into the soil, and during combustion, large amounts of toxic substances are released into the atmosphere, causing air pollution. We use 5 trillion plastic bags... per year! That's 160,000 a second! Also estimated 300 million plastic bags every year end up in the Atlantic Ocean alone. And fewer than 3 percent are recycled. Most recycling bags are blue, and biodegradable bags are usually green. Other non-recyclable bags are usually dark gray or black. Approximately 450,000 bags are equivalent to one ton of plastic bags, and recycling them will save 11 barrels of oil.

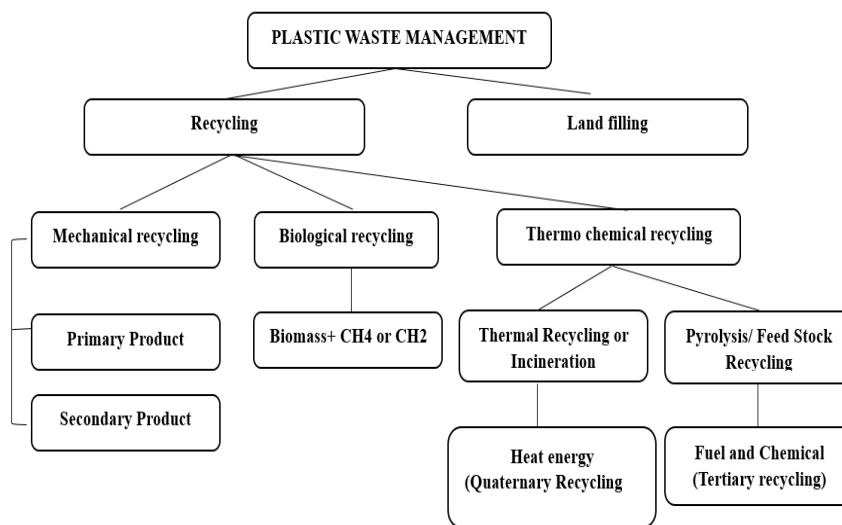


Figure 3. Fundamental plastics recycling techniques  
 (Centre for Science and Environment, 2020)



### 3. THE PLASTIC AND PLASTIC BAG POLICIES

#### 3.1. THE PLASTIC POLICIES

The solutions to plastic pollution are complex, transboundary, and multilateral. Because of the diversity of plastic resources, the global response needs to be comprehensive and dynamic, requiring coordinated action by multilateral stakeholders at the national, regional, and international levels. Increasing awareness of plastic pollution, which has become ubiquitous in recent years, has guided public opinion and created stronger policy involvement in this area. The OECD's Global Plastic Product Outlook: Economic Incentives, Environmental Impacts, and Policy Choices aim to inform and support these efforts. Briefly describe the global legislation related to the use and recycling of plastics:

- United Kingdom - In 2015, a tax was levied on plastic bags.
- Canada - In May 2021, plastics were declared "toxic" and most disposable plastics were banned by the end of the year.
- Rwanda - In 2009, 10 years after the ban on all plastic bags and packaging, it became the world's first "plastic-free" country. The law provides for up to six months in prison for carrying plastic items.
- India - In 2017, it announced the complete elimination of disposable plastics by 2022. A total of three phases are planned.
  - The first phase of the ban, which begins on September 30, 2021, will focus on thin plastic bags (the most difficult to recycle).
  - From January 1, 2022, six types of disposable plastics are prohibited, including plastic headsets, plastic balls, plastic flags, candy sticks, ice cream sticks, and decorative polystyrene (PS).
  - In the third or final phase, which will take effect on July 1, 2022, plastic plates, bottles, cutlery, plastic spatulas, candy wrappers, invitations, cigarette packs, and thin plastic advertisements are prohibited.
- Kenya - In August 2017, for anyone found to have produced or sold plastic bags in Kenya a fine of up to \$40,000 or four years in prison could be imposed (£ 31,000).
- Germany - In July 2021, Germany banned the sale of disposable plastic straws, cutlery, cotton buds, and food containers by EU guidelines to reduce plastic waste.

- Norway - Under the recycling law, which came into force in 2014, 97 percent of all plastic containers are recycled.
- France - In 2016, bans for the first time in the world production and sale of disposable plastic cups, knives, plates, and food boxes. By law, 50 percent of disposable dishes must be made from bio-sources that can be used as fertilizer at home. This will reach 60 percent by 2025.
- Chile - In 2018, Chile became the first South American country to ban plastic bags other than trash. The first bill was intended to cover only the southern part of Patagonia, but a year later it covered the entire country.
- Sweden - "Instead of banning plastics, we are pursuing a policy of recycling plastics."
- Peru - Since November 2018, 76 nature and cultural protected areas in Peru's Machu Picchu, Manu, and Huascarán, as well as the National Museum, have banned disposable plastic.

### **3.2. THE PLASTIC BAG POLICIES**

In the last few years, plastic bag policies have emerged around the world and have been introduced at many levels of government. The main reason for reducing the use of plastic bags and implementing plastic bag policies is to combat environmental pollution. The number of government policies has tripled in the last nine years (2010-2019) as part of the plastic bag rejection policy. As of July 2018, 127 countries (192 countries) have enacted legislation to regulate plastic bags, according to the United Nations Environment and WRI. As of 2022, such bans have been introduced in 94 countries, with varying degrees of enforcement, and 32 countries instead impose a charge per bag [19]. Some countries have outright banned non-compostable plastic bags, but their severity varies from country to country. Plastic bags that are stronger and easier to reuse are often exempt from bans in many countries, but they are also subject to a fee. The production and import of plastic bags can also be restricted as part of a ban.

The unevenness of plastic bag policies around the world is one of the reasons why plastic pollution continues. Few countries in the world regulate the use, production, distribution, trade, and destruction of plastic bags. Countries favor partial bans over full bans. Of these, 89 countries have opted for a partial ban or restriction instead of a complete ban on plastic bags. No country restricts the production of plastic bags. One of

the most effective ways to limit the introduction of plastic products into the market is to limit production. However, it is the least used regulatory mechanism.

In the case of Mongolia, Government Resolution 189, which prohibits the import of plastic bags and their use in trade and services, came into force on March 1, 2019. The resolution specifies that disposable plastic bags with a thickness of 0.035 mm or less shall be prohibited. For example, it is prohibited to use thin, plastic bags of the above sizes in trade and services, and to sell products and services together. In case of non-compliance or violation of the decree, Article 6.1 of the Law on Violations stipulates a fine of 300 units for individuals and 3,000 units for legal entities or 300 thousand to 3 million MNT.

### **3.3. POLICIES AND MEASURES IMPLEMENTED BY MONGOLIA REGARDING PLASTIC WASTE**

According to a study, 2.4 million tons of waste is generated in Mongolia annually, of which 1.4 million tons are from the capital city, and 500 tons of it are plastic bags. Mongolia recycles only 8% of its used plastic and plastic bags. Therefore, the remaining 92 are dumped directly into nature. In 2018, the City of Capital Specialized Inspection Agency's Central Laboratory of Mongolia took 132 samples and analyzed them in waste plastic food bags. These include chemical 58, Twenty-seven samples of heavy metals and 72 samples of bacteria showed 10 percent bacteriological analysis and five times the number of microorganisms. The toxicological analysis also showed high levels of formaldehyde in 16 samples. Therefore, there is an urgent need to eliminate plastic bags or increase the recycling rate.

According to the Mongolian Constitution, citizens have a right to live in a healthy and safe environment and to be protected from environmental pollution. Within the framework of this concept, to improve waste management; i) increase the waste recycling rate to 30% by 2025 and 40% by 2030; ii) the goal of reducing the amount of waste dumped in the environment by 30% by 2024 and by 40% by 2030 [20]. As part of this policy, as of 2021, there are 40 waste recycling plants and more than 160 sorting points in Mongolia. All kinds of plastic, plastic bags, cans, aluminum alloys, metals, bones, ashes, cardboard, books, newspapers, stationery, animal skins, leather processing plant waste, forest waste market, sawdust, wood Processing plant waste, sawdust from cedar nuts, sewage sludge, thermal power plant ash, and food waste are recycled to produce value-added products and exported to China. The recycling industry is statistically considered to be the production of rubber and plastic products. In addition, July 2021, a large Italian

standard plant for the production of Italian plastic waste recycling products was launched in Mongolia. The plant can fully process 20-50 thousand tons of plastic waste per year.

#### **4. PROSPECTS OUTLOOK**

Plastic waste is recycled in three types: mechanical recycling, incineration, and chemical recycling. Mechanical recycling is the most widely used option for recycling, in which plastic waste is mechanically ground or combined to be recycled into similar products. However, these recycled products are not widely used in factories due to the deteriorating plasticity of the process. Incineration converts plastic waste into heat and electricity, but the process also releases toxic pollutants such as acid gases and heavy metals. Therefore, chemical recycling, the last option to convert plastics into fuels, is considered to be the most promising process for recycling low-impact plastic waste. Chemical recycling technologies use heat, chemical reactions, or both, to break down used plastics into raw materials for new plastic, fuel, or other chemicals. The process of converting plastic waste into fuel is pyrolysis.

Pyrolysis is one of the processes that convert plastic waste into fuel. The pyrolysis process can realize the conversion of plastic wastes into fuel by anaerobic heating at 350–600°C [21]. The materials are isolated, which allows them to be reused in an environmentally friendly way. Approximately 39,000 jobs and \$9 billion in economic output are predicted to be generated by plastic-to-fuel facilities in the US alone, according to the American Chemistry Council. It can improve the economy as well as create new ways to recycle plastics and protect the environment.

Advantages of using pyrolysis technology to convert plastic to oil:

- 1) **High efficiency:** Pyrolysis technology is suitable for almost all kinds of waste plastic, no matter it is clean or unwashed and unsorted. For a batch waste plastic pyrolysis plant, even no need to do the shredding work. All the processes from plastic to fuel oil is carried out inside the waste pyrolysis reactor together with its accessory system, very convenient and man-power saving.
- 2) **High profit:** Waste plastic such as PE(polyethylene)、PP(polypropylene)、PS(polystyrene) and ABS, etc. has a higher oil yield above 50%, which means from the above 10ton waste plastic, you can extract at least  $10\text{ton} \times 50\% = 5\text{ton}$  pyrolysis fuel oil. It is a process to convert waste into new energy, so this project is absolutely profitable.
- 3) **High using:** The fuel oil from plastic waste is a kind of heavy oil that has heating valu

e > 10000kcal/L, even higher than some diesel, so you can well take the advantage of its high heating value, and use it for boilers, cement factories, steel mill and glass factory, etc as the diesel, coal as well as wood substitute.

The main advantage of a plastic pyrolysis plant is that it is not only environmentally friendly but also can produce renewable energy sources such as plastic pyrolysis oil, carbon black, and combustible gas. In addition, it has the characteristics of high efficiency, low consumption, and high oil yield.

Disadvantages of using pyrolysis technology to convert plastic to oil:

- 1) Fuel oil from plastic waste has higher sulfur content than normal diesel.
- 2) Fuel oil from plastic waste is the lower flashpoint. The flashpoint of fuel oil from plastic waste is < 40 degrees, and the flashpoint of normal diesel is about 50 degrees.

In addition to being a promising way to recycle plastic waste to produce liquid fuels, one way that is planned to be addressed under international law is to end plastic pollution. At the UN Environment Summit in Nairobi in March 2022, heads of state and government, environmental ministers, and other delegates from 175 countries adopted a resolution calling for an end to plastic pollution by the end of 2024 and a legally binding international agreement.

## 5. CONCLUSION

Firstly. Countries around the world are dealing with plastic waste and plastic bag management and reuse at different levels. Within the framework of the issue of plastic waste recycling, more political policies and measures are being implemented in the direction of extracting energy and new raw material resources that are environmentally friendly.

Second. Pyrolysis is one of the main advances in recycling technology in developed countries. This method has more advantages in solving the problem of plastic pollution, reducing the carbon footprint of plastic products by reducing environmental pollution and carbon monoxide emissions, and is an important way to extract valuable energy and products such as oil and gas.

Third. In recent years, Mongolia has been working towards reducing plastic waste and increasing the amount of recycling in line with the measures taken by countries around the world. By adopting pyrolysis technology in its waste recycling measures, Mongolia

has the advantage of being able to simultaneously solve several problems such as energy production and fuel processing, in addition to recycling waste with environmentally friendly technologies.

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### AUTHOR'S INTRODUCTION


#### 1. First Author

|   |  |
|---|--|
|  | Bayarsaikhan Battsetseg <a href="mailto:Bayarsaikhantsetseg@gmail.com">Bayarsaikhantsetseg@gmail.com</a>   |
|   | The author is lecture at the Department of Environmental protection technology of the Mongolian National University and his research interests are environmental law, environmental impact assessment, environmental economics, and environmental chemistry. |

#### 2. Corresponding Author

|  |  |
|--|--|
|  | Tugjav Oyunchimeg <a href="mailto:T_oyunchimeg@mul.s.edu.mn">T_oyunchimeg@mul.s.edu.mn</a>   |
|  | Professor Mongolian University of life sciences (MULS) conducts research in the field of natural resource management and environmental technology. We are working to increase the participation of stakeholders in ensuring the implementation of environmental legislation by monitoring the use of natural resources in accordance with the carrying capacity of natural resources |

#### 3. Co-Author

|   |  |
|---|--|
|  | Sukhbaatar Saruul <a href="mailto:saruul.munhdul@gmail.com">saruul.munhdul@gmail.com</a>   |
|   | The author is a lecturer at the Department of Environmental protection technology of the Mongolian National University and his research interests are Geographic information system, Remote sensing, Soil pollution, Soil erosion and Land evaluation. |