Problem Chosen	2020 MCM/ICM Summary Sheet	Team Control Number
E		**2020183**

Environmental Problems of Disposable Plastics

Summary

We study the environment pollution caused by disposable plastics and how to deal with disposable plastics. Based on multiple objective programming, we establish a maximum environmental carrying capacity model. We also analyze the amount of plastic waste reduced in China and the United States, and the impacts of these measures. Future reduction of plastic waste in developed and developing countries and the assignment of the task of disposing plastic waste are discussed in this paper. We obtain the minimum achievable level of global disposable plastic product waste.

First, we consider the maximum amount of plastic waste disposed by incineration plants and landfills as the maximum carrying capacity of the environment. Specifically, we analyze the amount of plastic waste that needs to be disposed from three aspects: the source of plastic waste, the current severity of plastic waste, and the availability of waste disposal resources. To characterize the problem under consideration, we consider the capacity of waste disposal station being greater than the output of plastic waste as the constraint and the maximum carrying capacity of the environment as the objective function. According to the collected data, we conclude that the maximum carrying capacity of the environment is 170 million tons. We also compare the maximum carrying capacity of the environment with the output of plastic waste, and predict the amount of plastic waste in the surface ocean in 2050, which shows that we must solve this problem as soon as possible.

Second, we analyze the infeasibility of plastic substitutes and turn the goal into increase revenue and reduce expenditure. We look at ways to improve our capacity to dispose plastic waste, and the extent to which landfills and incinerators affect residents. On how to reduce the amount of plastics used by residents, we study the impact of plastic waste export, policy tax, and human development index on residents. We analyze the maximum environmental carrying capacity of China and of the United States. If the level of Chinese plastic waste management reaches that of the United States, in recycling 20% of the plastics, the contribution to dealing with mismanaged plastics waste will reach 26.97%. If the United States imposes a 100% plastic tax on residents, it will only contribute 0.97% to dealing with mismanaged plastics waste, but it will reduce global plastic consumption by 5.42%.

Based on model 2, we conclude that there are 2.81 million tons of plastics waste decreased by reducing the use of plastics in developed countries. If developing countries improve the management of plastics, it will reduce 40.88 million tons of plastic waste. Plastics industry in the world will lose 24.7% capacity, and thousands of people will lose jobs. The environment will be greatly improved by 2030 with a cumulative reduction of 1,413 million tons of plastic waste.

On fair measure, the amount of waste per improper processing and human development index of linear correlation index, most countries make it satisfy the existing situation. We propose to raise the standard down by four percentage points and make it the target for each country to meet. For plastic waste that does not meet the standard, it needs to be disposed of by the country itself, and the remaining amount of plastic waste is allocated according to each country's disposal capacity and historical responsibility. The top three countries are China (19.95 percent), the United States (15.93 percent), and Germany (6.11 percent).

Finally, we write a two-page memo describing the global actual goal, and the global minimum achievable levels of single-use or disposable plastic product waste.

Keywords: Plastic waste, Environmental carrying capacity, Human development index, Multiple linear regression, increase income and reduce expenditure

Content

1. Introduction

1.1 Background

Plastics are widely used in food packaging, consumer goods, medical equipment and construction because of their good corrosion resistance, low production cost, good plasticity and insulation. Plastic production is also growing exponentially. Although plastic products bring convenience to people's life, they also have a negative impact on nature. Plastic products are not easily degraded and difficult to handle. It takes hundreds of years for plastic to rot underground According to statistics, only 9% of plastic can be recycled. Due to its non-degradability, plastic has become nature's enemy and has caused the death of many animals. About 4 to 12 million tons of plastic waste enters the ocean every year. Indigestible plastic has been found in the bodies of many dead sea animals.

If plastic waste is not controlled, in a few decades the oceans will have far more plastic than fish, occupying the oceans and causing serious harm to marine life.

To avoid this, we need to slow down plastic production and improve plastic waste management.

1.2 Restatement of the Problem

To help the International Council of Plastic Waste Management (ICM) address this escalating environmental crisis. We must develop a plan to significantly reduce, if not eliminate, the waste of disposable and disposable plastic products.

We aim to complete following tasks:

- Develop a model to estimate the maximum levels of plastic waste that can safely be mitigated without further environmental damage.
- Discuss to what extent plastic waste can be reduced to reach an environmentally safe level. This may involve considering factors impacting the levels of plastic waste to include, but not limited to, sources and uses of single-use or disposable plastics, the availability of alternatives to plastics, the impact on the lives of citizens, or policies of cities, regions, countries, and continents to decrease single-use or disposable plastic and the effectiveness of such policies. These can vary between regions, so considering regional-specific constraints may make some policies more effective than others.
- Using model and discussion, set a target for the minimal achievable level of global waste of single-use or disposable plastic products and discuss the impacts for achieving such levels. You may consider ways in which human life is altered, the environmental impacts, or the effects on the multi-trillion-dollar plastic industry.
- While this is a global problem, the causes and effects are not equally distributed across nations or regions. Discuss the equity issues that arise from the global crisis and your intended solutions, and give suggestions to ICM to address these issues.
- Write a two-page memo to the ICM describing a realistic global target minimum achievable level of global single-use or disposable plastic product waste, a timeline to reach this level, and any circumstances that may accelerate or hinder the achievement of your target and timeline.

2. Assumptions and Notations

2. 1 Assumptions

To simplify the course of modeling and draw some reasonable conclusions from our model, we make some assumptions as follows:

- Plastic waste properly managed has negligible impact on environment.
- Disposable plastics decompose very slowly. Only little plastic can be broken down. So, we do not consider the natural decomposition of plastics.
- No country has dropped out emission reduction plan halfway.
- Ignore the impact of raw material price fluctuations on the plastics industry

2. 2 Notations

Below, we summarize some notations in Table 1 that will be used in this paper.

Table1 Notations

Symbol	**Description**
$P_i(t)$	The primary plastic produced in year t
$W(t)$	The total amount of plastic produce
$Q(t)$	The total amount of plastic waste caused by poor management
$SW(t)$	The amount of secondary plastic waste
$DW(t)$	The amount of discarded plastic waste in year t
$IW(t)$	The amount of burning plastic waste in year t
HDI	human development index
β	The impact on surrounding residents
δ	Contribution to global plastic waste management
Dq	The amount of plastic waste needs to landfill
QN	The current price of plastic per unit

3. Estimation of the maximum levels of single-use plastic waste

To estimate the maximum level of single-use or disposable plastic product waste, we consider the problem from three aspects: the source of plastic waste, the severity of the current garbage problem and availability of resources to process the waste. Our goal is to figure out the maximum capacity of the environment based on the maximum amount of garbage that can be disposed of.

3. 1 The source of plastic waste

3. 1. 1 The usage of plastics

Plastics are widely used in food packaging, consumer goods, medical equipment and construction because of their good corrosion resistance, low production cost, good plasticity and insulation. As report goes, global primary plastics production by industrial use (millions of tons) is mainly used for packaging. The main polymer components in the package are LDPE, HDPE, PP, PET. The use of plastics and the polymers used in packaging are as follows:

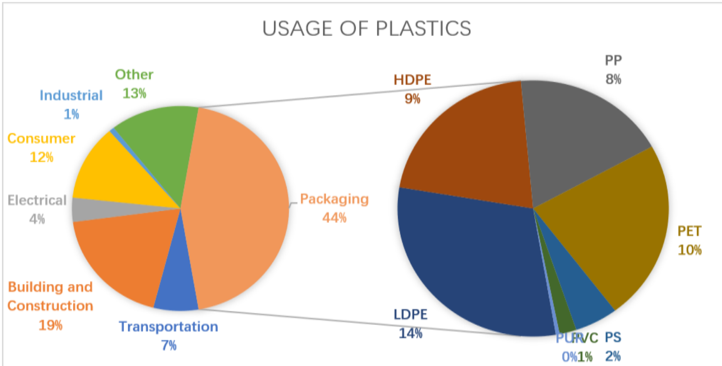

Figure 1 The use of plastics and the polymers in packaging

3. 1. 2 Production of plastic waste

According to relevant statistics, about 270 million tons of primary plastic and 275 million tons of plastic waste produced every year in the global word. Coastal plastic waste has 99.5 million tons per year. Among coastal plastic waste, 31.9 million tons of plastic waste is caused by poor management, and 8 million tons of plastic waste ends up in the ocean every year. And there is 10,000 to 100,000 tons of plastic waste in the surface water. Therefore, we need to take measures to deal with plastic waste.

At present, there are only three ways to deal with plastic waste, one is recycling, the second is incineration, and the last is discarding.

3. 2 The extent of the current waste problem

3. 2. 1 Existing problems

There is much plastic waste caused by poor environment every year. We've made statistics of the top five countries that produce the most mismanaged plastics waste.[1]

Table 1 plastic waste caused by management in five countries

Rank	Country	Coastal pop [millions]	Percent of mismanaged waste	Mismanaged plastic waste [MMT/year]	Per of total mismanaged plastic waste	Plastic marine debris [MMT/year]
1	China	262.9	76	8.82	27.7	1.32-3.53
2	Indonesia	187.2	83	3.22	10.1	0.48-1.29
3	philippines	83.4	83	1.88	5.9	0.28-0.75
4	Vietnam	55.9	88	1.83	5.8	0.28-0.73
5	Sri Lanka	14.6	84	1.59	5	0.24-0.64

3. 2. 2 **Plastic waste needs to be disposed of**

Current volume of plastic waste, include the amount of disposable plastic waste produced at present and the amount of plastic previously produced that has passed its lifetime. If the primary plastic produced in year t is $P_i(t)$, α_i percent of it is applied to production and living. So, the total amount of plastic produced at this stage [2][3]:

$$W(t)=\sum_{i=1}^{7}P_i(t)\cdot\alpha_i \tag{1}$$

There is a lot of plastic waste into the environment because of poor management. Mismanaged plastic waste accounts θ_1 for the plastic. Mismanaged plastic waste:

$$Q(t)=W(t)\cdot\theta_1 \tag{2}$$

The lifetime of plastics is characterized by a discrete log-normal distribution [2]. Probability distribution function of the useful life of plastic products $LCD(x)$:

$$LCD(x)=\frac{1}{x\sigma\sqrt{2\pi}}e^{-\frac{(lnx-\mu)^2}{2\sigma^2}} \tag{3}$$

So, the total amount of primary plastics without lifetime in year t:

$$W_1(t)=\sum_{i=1}^{7}\sum_{j=1}^{65}P_i(t-j)\cdot LCD(j)\cdot\alpha_i \tag{4}$$

The lifetime of plastics for different industrial uses as follows：

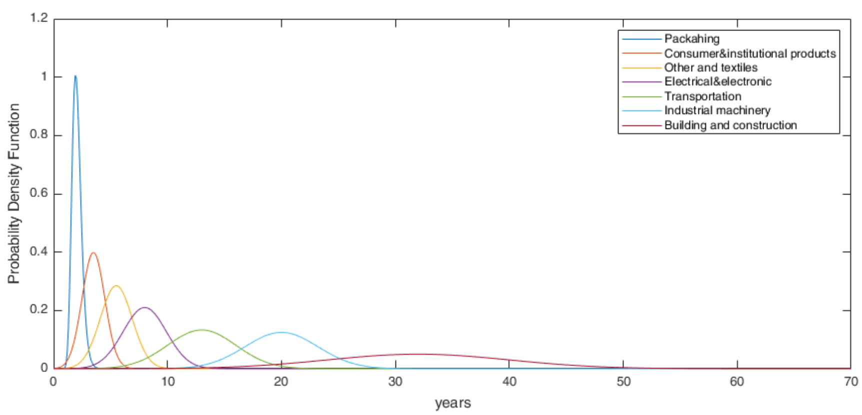

Figure 2 The lifetime of plastics for different industrial uses

We count plastic recycled before year k as the amount of secondary plastic waste produced in year t. And there is $RR(t-k)$ rate of plastic can be recycled every year.

The secondary plastic waste in year t has:

$$SW(t)=[W_1(t-k)+SW(t-k)]RR(t-k) \tag{5}$$

Discarded plastic waste in year t has:

$$DW(t)=[W_1(t)+SW(t)]DR(t) \tag{6}$$

For discarded plastic waste, there is

$$Dq=DW(t)\cdot(1-\theta_1) \tag{7}$$

plastic waste need landfill. Burning Plastic waste in year t is:

$$IW(t)=[W_1(t)+SW(t)]IR(t) \tag{8}$$

3.3 The availability of resources to process the waste

Here, the resources we are considering to process the waste are landfills and incinerators

1. The quantity and scale of landfill is proportional to the capacity of processing plastic waste. We set the number of landfills as M,the size of a landfill as F_i. So, the total processing capacity of the landfill is:

$$SD = \sum_{i}^{M} F_i \tag{9}$$

2. We set the number of incinerators as N,the size of a incinerators as I_i. So the total processing capacity of the incinerators is：

$$SF = \sum_{i}^{N} I_i \tag{10}$$

3.4 Nonlinear optimization model

We think that the amount of plastic that humans can handle without further polluting the environment is the amount of plastic that landfills and incinerators can handle. Therefore, our objective function is to find the maximum amount of garbage that can be handled by the garbage disposal station:

$$\max Z = SF + SD \tag{11}$$

To avoid polluting the environment, landfills should be able to handle more waste than needs to be buried:

$$SD \geq Dq(t) \tag{12}$$

Incineration plants should be able to handle more waste than needs to be incinerated:

$$SF \geq IW(t) \tag{13}$$

To sum up, we develop an objective planning model:

$$\max Z = SF + SD$$

$$s.t \begin{cases} SD \geq Dq(t) \\ SF \geq IW(t) \\ SD = \sum_{i}^{M} F_i \\ Dq = DW(t) \cdot (1 - \theta_1) \\ SF = \sum_{i}^{N} I_i \\ IW(t) = [W(t) + SW(t)]IR(t) \\ DW(t) = [W(t) + SW(t)]DR(t) \\ W(t) = \sum_{j=1}^{65} P(t-j) \cdot LCD(j) \\ LCD(t) = \frac{1}{t\sigma\sqrt{2\pi}} e^{-\frac{(lnt-\mu)^2}{2\sigma^2}} \\ t \geq 0 \end{cases} \tag{14}$$

3. 5 Results analysis

Based on the model, we calculated the maximum environmental capacity (the maximum amount of garbage that can be disposed of). And compare it with the global production of plastics. The difference value between them is the amount of undisposed plastic waste.

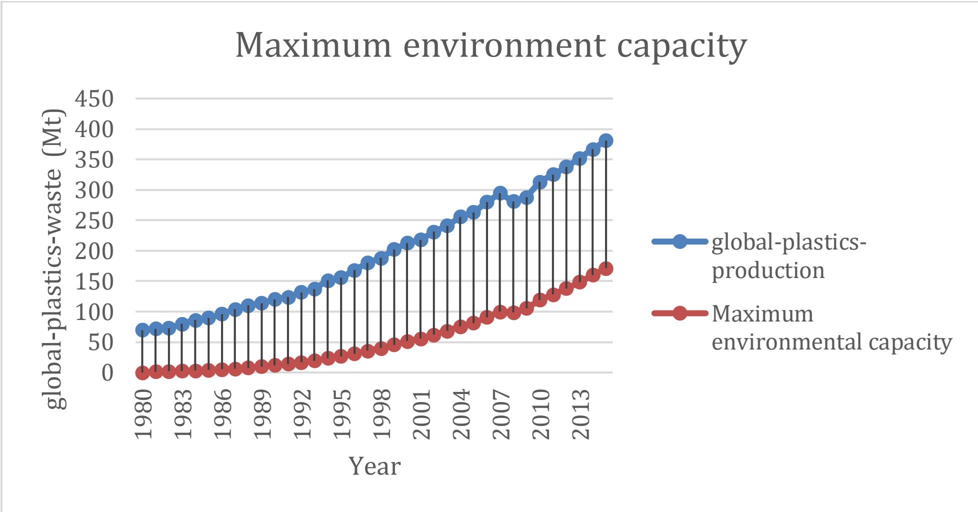

Figure 3 The maximum environment capacity

The amount of global plastics production is far more than the maximum environmental capacity. And the difference value between them is increasing by time. By 2014, global plastic production had reached nearly 400 million tons. The maximum environmental capacity is170 million tons. There are still about 230 million tons of plastic that can't be disposed efficiently.

Undisposed garbage will flow into nature. The amount of plastic garbage entering nature is:

$$O(t) = Q(t) + DW \cdot \theta_1 \tag{15}$$

In addition, according to the current situation of plastic waste disposal and the amount of garbage in the ocean [1], we predict the plastic waste in the surface ocean. We consider three situations: emissions stop in 2020, keep steady emissions growth to 2020, keep increasing emissions growth to 2050.

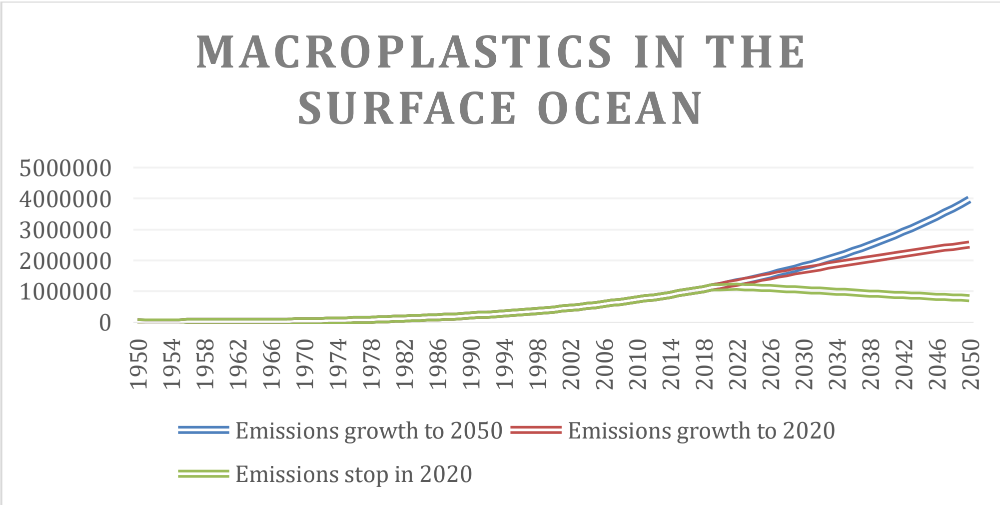

Figure 4 Plastics waste in the surface in three situations

If, by 2020, no more garbage goes into the ocean, plastic will remain in the ocean for decades because of previous accumulation, and it will take a long time make plastic disappear. If plastic emissions into the ocean remain stable, the plastic waste on the surface ocean will continue to increase. If emissions keep rising, there will be four million tons of plastic waste on the ocean surface by 2050. At that time, the plastics will occupy the ocean and threaten the balance of nature. If the plastic waste system is not completely reformed now, there will be more garbage in the ocean than fish [4]. We can see the importance of proper and effective disposal of plastic waste.

4. Environmental safety level model

4.1 Looking for alternatives [5]

When we look for alternatives to plastic, we have to consider, is it better to use alternatives? As to which alternative is better, we should consider many factors. Compared with paper, glass and other materials, plastic's energy consumption and greenhouse gas emissions are significantly lower. The only disadvantages are non-degradability and Marine pollution. In order for Organic cotton to reach the level of plastic emissions, it needs to be used repeatedly 149 times, which is obviously difficult. When ecosystems, eutrophication and water impacts are included, it takes 20,000.

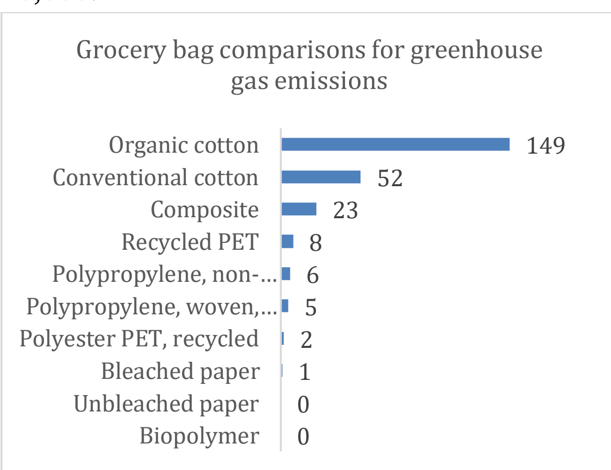

Figure 5 gas emissions of different material

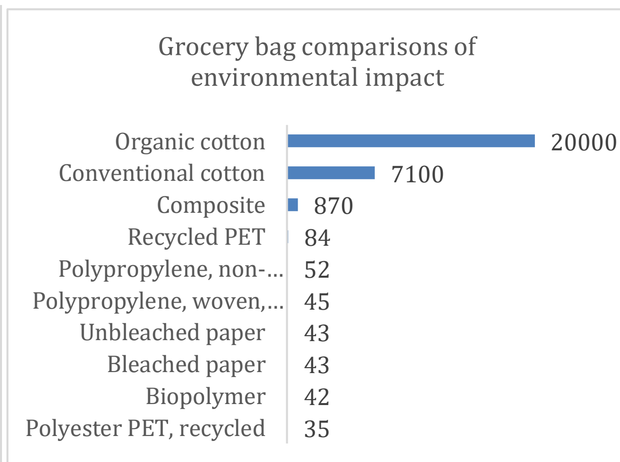

Figure 6 the environmental impact of different material

So far, it is inappropriate to look for alternatives. But the amount of biodegradable plastic is low, about four million tons a year (just accounts for one percent of global plastic production). It does not meet the demand for plastic disposal.[6][7] So we should consider how to reduce the amount of plastic used by residents, and increase the capacity to deal with plastic waste, etc.

4.2 How to improve the ability to deal with garbage

4.2.1 Expanding landfills

It cost QD to maintain landfills and increase the burden rate of residents:

$$dL1 = QD/GDP \tag{16}$$

But considering that landfills will permanently occupy the land, the impact on surrounding residents is

$$\beta_1 = pGDPe^{ATY} \tag{17}$$

We set $pGDP$ as per capital GDP, ATY as education level per capita.

4.2.2 Expanding incineration station

It cost QF to maintain incineration station and increase the burden rate of residents:

$$dL2 = QF/GDP \tag{18}$$

But considering that Burning garbage waste will cause air pollution, the impact on surrounding residents is:

$$\beta_2 = pGDP \cdot ATY \tag{19}$$

4.2.3 Export plastic waste

Exporting recyclable plastic waste can get benefits. However, since China completely banned non-industrial plastic waste in 2017, this is a past thing for high-income countries, so we will not consider it.

4. 3 Reduce expenditure- how to eliminate unnecessary plastic use

4. 3. 1 Impact of the human development index [12]

According to research, the higher the human development index, the higher the environmental requirements. Human development index (HDI) includes: life expectancy index (HDI), education index (EI), income index (II)

$$HDI = \sqrt[3]{LEI \cdot EI \cdot II} \tag{20}$$

- life expectancy index

$$LEI = \frac{LE - 20}{85 - 20} \tag{21}$$

- education index

$$EI = \frac{MYSI + EYSI}{2} \tag{22}$$

In the formula, average years of education index $MYSI$ and expected years of education index $EYSI$:

$$MYSI = \frac{MYS}{15} \quad EYSI = \frac{EYS}{18} \tag{23}$$

MYS are average years of education[3]. EYS is expected years of education.

- income index

$$II = \frac{\ln(pGDP) - \ln 100}{\ln 75000 - \ln 100} \tag{24}$$

We fit plastic waste per capita per capita with human development index, get a linear function:

$$IM = -1.9572 \cdot HDI + 1.7638 \tag{25}$$

1 http://hdr.undp.org/en/content/human-development-report-2010

2 https://www.indiastudychannel.com/resources/141517-New-method-of-calculation-of-Human-Development-Index-HDI.aspx

3 https://www.nber.org/papers/w15902

The variance $R^2 = 0.037$ and most of the points are around this datum line, indicating that the fitting effect is good. We found that the higher the human development index, the less waste caused by poor management.

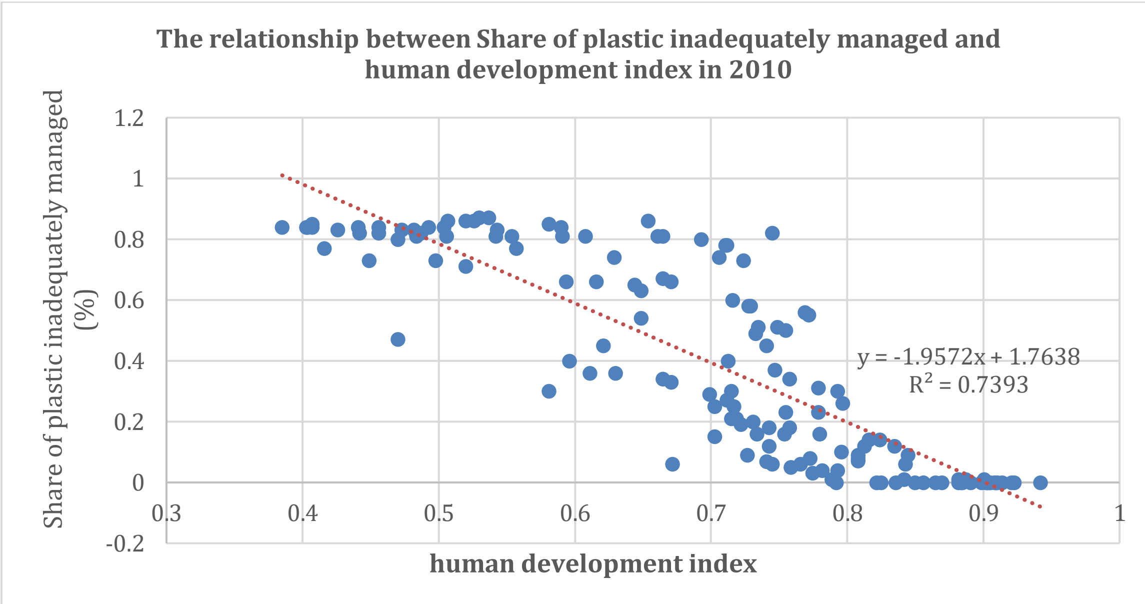

Figure 7 The relationship between plastic waste and human development

4. 3. 2 Policy influence

Government measures to charge disposable plastic bags.[3] If the unit price of plastic is QD, and the punitive tax rate imposed by the government is α, then the current price of plastic per unit is:

$$QN = QD(1 + \alpha) \tag{26}$$

We refer to Ireland's tax on plastic bags in 2007, from 15-euro points to 22-euro points, increasing 46.7 percent. The number of using plastic bags decreased by 46.9 percent. We can get reduced number of plastic bags:

$$dN = (1 - \frac{21.2\%}{46.7\%}\alpha) \cdot N \tag{27}$$

Burden rate for residents:

$$dL3 = \frac{(1 + \alpha)(N - dN) - N}{pGDP} \tag{28}$$

4. 4 Nonlinear optimization model

We transform the extent plastic waste can be reduced to reach an environmentally safe level into the minimum impact on surrounding residents. Our objective function is:

$$\min \delta = dL1 + dL2 + dL3 + \frac{\beta_1}{SD} + \frac{\beta_2}{SF} \tag{29}$$

To sum up, our environmental safety level model:

$$\min \delta = dL1 + dL2 + dL3 + \frac{\beta_1}{SD} + \frac{\beta_2}{SF}$$

$$s.t.\begin{cases} dL1 = QD/GDP \\ dL2 = \dfrac{QF}{GDP} \\ dL3 = \dfrac{(1+\alpha)(N-dN)-N}{pGDP} \\ \beta_1 = pGDPe^{ATY} \\ \beta_2 = pGDP \cdot ATY \\ HDI = \sqrt[3]{LEI \cdot EI \cdot II} \\ LEI = \dfrac{LE-20}{85-20} \\ EI = \dfrac{MYSI+EYSI}{2} \\ MYSI = \dfrac{MYS}{15} \\ EYSI = \dfrac{EYS}{18} \\ II = \dfrac{\ln(pGDP) - \ln 100}{\ln 75000 - \ln 100} \\ IM = -1.9572 \cdot HDI + 1.7638 \\ QN = QD(1+\alpha) \\ dN = \left(1 - \dfrac{21.2\%}{46.7\%}\alpha\right) \cdot N \\ dL3 = \dfrac{(1+\alpha)(N-dN)-N}{pGDP} \end{cases} \tag{30}$$

5. The global impact of plastic waste

China is the biggest producer of plastic waste, while the United States has the most plastic waste per capita. Countries have different policies. So, we study two representative countries. We compare two countries from four aspects： plastic waste per person, per capital GDP, the amount of mismanaged plastic waste.

As a developing country, China produces a large amount of plastic waste every year because of poor management. It results in a huge waste of resources. In 2010, The mismanaged plastic waste in China accounts for 27.7 percent of the world's total mismanaged plastic waste.[1] 120 million tons of plastic waste has polluted the environment because of poor management. Therefore, the Chinese government should strengthen the classification management measures for plastic waste.

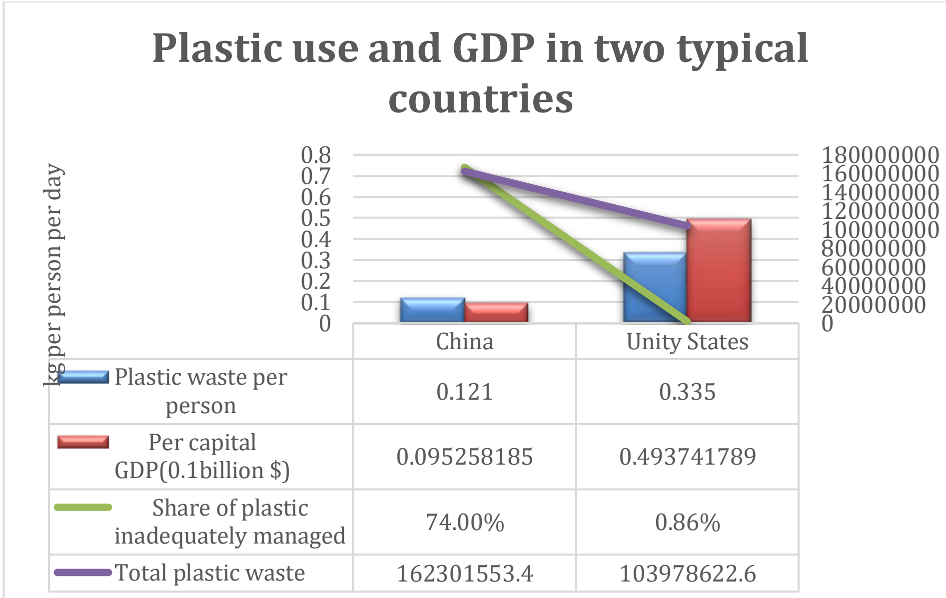

Figure 8 The difference between china and America in four aspects

If Chinese government takes measures to make ρ_1 of plastic waste be recycled, there will be $W_{China}(t) \cdot \rho_1\ Mt$ plastic waste reduced. The amount of mismanaged plastic waste will be decreased to:

$$dW_{China} = W_{China}(t) \cdot 74\% - W_{China}(t) \cdot (1 - \rho_1) \cdot \sigma_1 \tag{31}$$

Contribution to global plastic waste management:

$$\delta_{China} = \frac{dW_{China}}{W_{gobal}(t)} \tag{32}$$

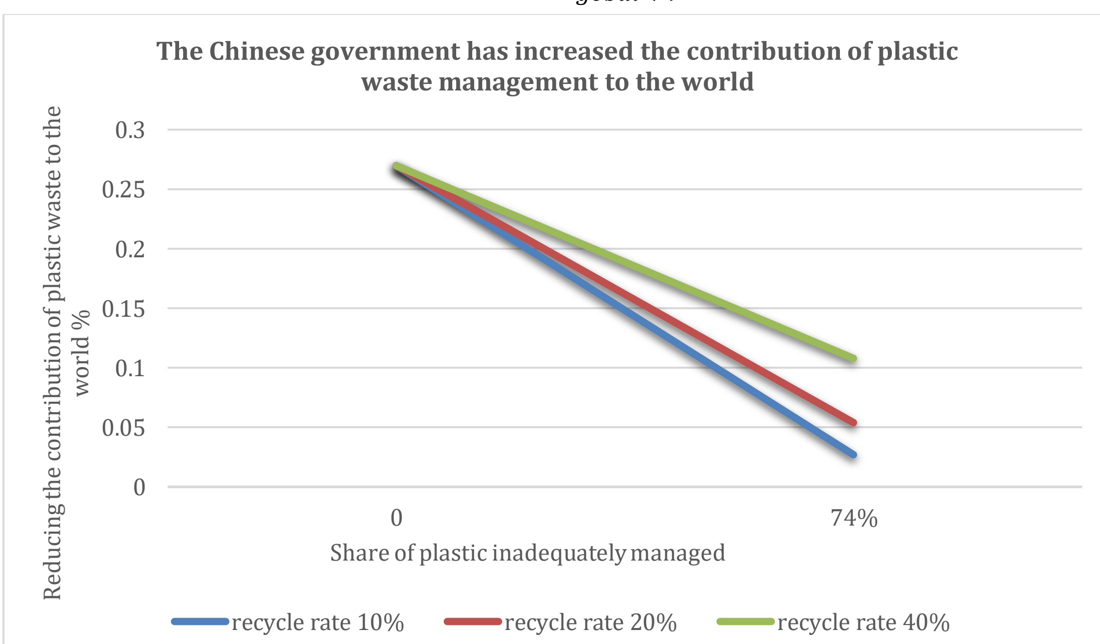

Figure 9 Contribution of plastic waste management to the world (China)

With the reduction in the level of improper management, the Chinese government has made a significant contribution to the world by reducing the amount of plastic waste by more than 25%, and by increasing the recycling rate of plastic waste, the amount of plastic waste caused by improper management can be alleviated.

To meet the goal, the government needs to build additional dW_{China}-scale plastic landfills or incinerators to meet demand. The impact on residents in China is:

$$\delta = \frac{dW_{China}}{pGDP} + \beta_1 + \beta_2 \tag{33}$$

There is higher per capita plastic use in the U.S. To significantly reduce total usage.

The government should raise taxes on plastic bags to reduce the use of plastic. If the U.S. government imposes a tax rate on plastic bags, reduction of plastic bags up to:

$$dW_{USA} = \left(1 - e^{\frac{21.2\%}{46.7\%}\rho_2}\right) \cdot W_{USA}(t) \tag{34}$$

Contribution to global plastic waste management:

$$\delta_{USA} = \frac{0.864\% \cdot W_{gobal}(t) - dW_{USA}\sigma_2}{W_{gobal}(t)} \tag{35}$$

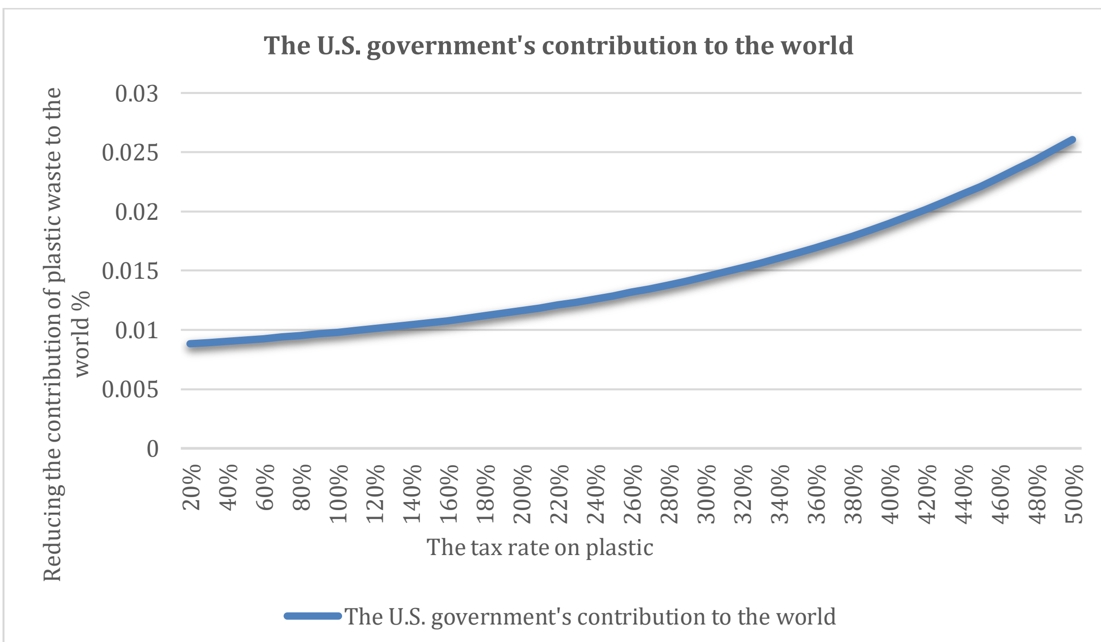

Figure 10 Contribution of plastic waste management to the world (America)

As can be seen from the figure above, due to the proper management of the government, even if the tax is raised to curb residents' consumption of plastic, the direct pollution to the environment is still small, but the reduction of the total plastic consumption is significant. The impact on residents in America is:

$$\delta = \frac{(1+\rho_2)\big(W_{USA}(t) - dW_{USA}(t)\big) - W_{USA}}{pGDP} \tag{36}$$

We can see that increasing taxes will curb consumption in plastics, directly reduce environmental pollution and significantly decrease plastic waste.

6. Global plastic waste distribution

We can use China to represent the vast majority of developing countries, and the United States to represent the vast majority of developing countries. Assuming that the management of plastic waste in developing countries is increased to 30% and the plastic recovery rate to 20%, the total amount of plastic that can be reduced is 22.89 million tons and the amount of plastic that causes environmental pollution is reduced by 40.88 million tons. We assume that the developed countries increase the plastic tax rate by 100% and manage the plastic waste by 5%, then the total plastic use can be reduced by 54.42 million tons and the amount of plastic polluting the environment reduced by 2.81 million tons.

6. 1 Impact on the world plastics industry

The number of people working in the plastics industry in the world in 2010 was 847,200. Due to the total capacity reduction of 77.31 million tons, 24.7% reduction of output plastic of will cause hundreds of thousands of people lose jobs in the plastics industry.

6. 2 Impact on the environment

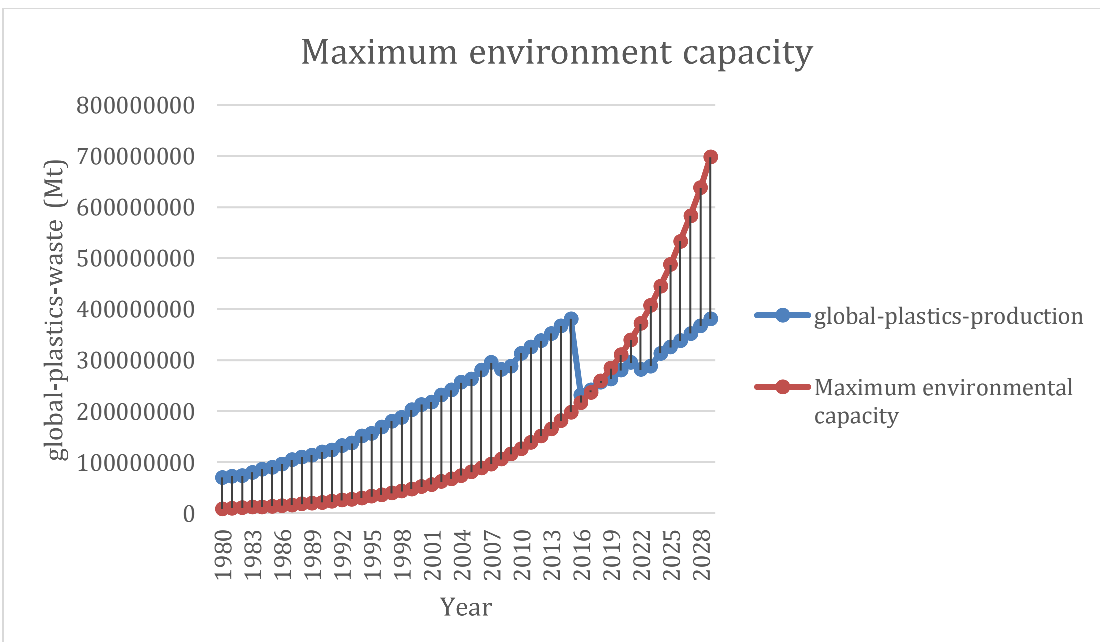

Figure 11 The maximum environment capacity

If by 2015 every country can make concessions, up to the minimum level and maintain the current development in waste disposal capacity, the global plastic waste problem will be greatly improved by 2030, adding up to a reduction in plastic waste.

6. 3 Global plastic disposal distribution

Plastic waste pollution is a global problem. Strengthening plastic waste management is not just for developed countries. Even if developed countries stopped using plastic bags, the rate of poorly managed plastic in global world would decline by less than 5 percent. The main problem in developing countries is poor management of plastic waste.

The current goal is to eliminate the amount of mismanage plastic waste without further damage environment. Eliminating plastics that have not been properly processed starts from two aspects: first, reducing the amount of plastics that are not properly processed, and second, letting developed countries help with the processing.

6. 3. 1 **Reduce the amount of mismanaged plastic waste**

From the perspective of fairness, the per capita plastic use U should tend to be equal, but for developed countries, this will obviously seriously inhibit their economic development, so we use the human development index to measure the amount of plastic that a country restricts according to "fair" standards.

We compare global per capita waste data with the human development index fit. Among them, we regard plastic waste as waste caused by poor management.

$$U = -0.1321 \cdot HDI + 0.14 \tag{37}$$

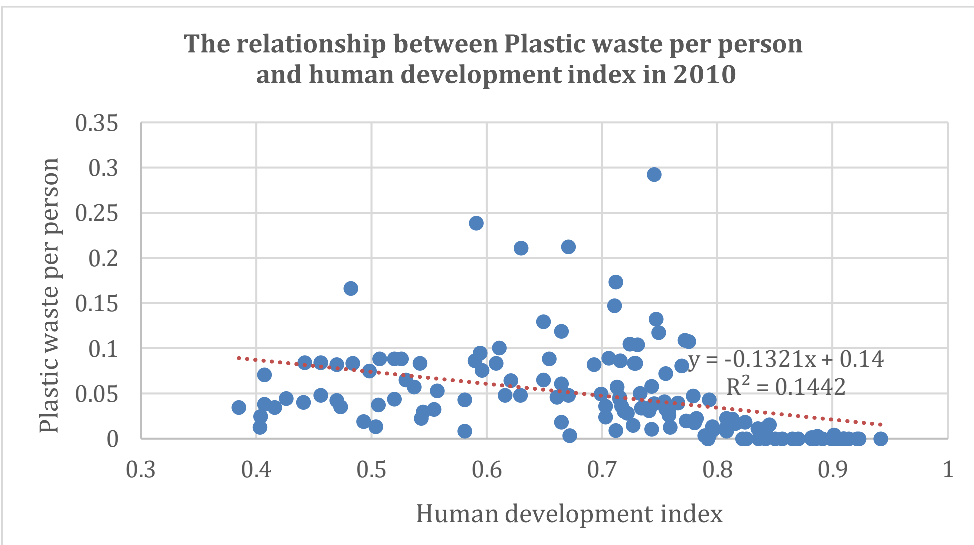

Figure 12 The relationship between Plastic waste per person and human development index

We can see that the higher the human development index, the lower the pollution. In order to reduce environmental pollution as soon as possible, we need to lower the benchmark of U to:

$$U = -0.1321 \cdot HDI + 0.1 \tag{38}$$

Based on U, up to 5%.

For plastic waste that is not processed normally, we require that the country must dispose of it by itself, and it is not included in the joint commitment. Therefore, the waste that needs to be treated separately by a country is:

$$dU = \max(\sigma - U, 0) \cdot R_i(t) \tag{39}$$

Where σ is the per capita number of plastic waste pollution caused by improper management in a country at this stage, and $R_i(t)$ is the population of the country.

6. 3. 2 **Increase a percentage of plastic production**

- Historical responsibility

The developed countries have sacrificed the global environment in the past development process, and now they should shoulder the historical responsibility. We consider that countries with a per capita GDP of less than 20,000 US dollars do not need to increase the amount of plastic wastes:

$$\alpha = \begin{cases} \dfrac{\text{pGDP} - 20000}{\text{pGDP}}, pGDP > 20000 \\ 0, pGDP < 20000 \end{cases} \tag{40}$$

- Processing capacity

In the face of fairness, we also need to consider the disposal capacity of plastic waste in a country.

In terms of processing plastic waste, we believe that the greater the plastic output of a country, the smaller the amount of incorrectly processed plastic waste, and the stronger the processing capacity of this country:

$$C_i = \frac{P_i(t) - Q_i(t)}{P_i(t)} \tag{41}$$

- Cumulative total untreated plastic waste in history

$$H = \sum_{i=1980}^{T} O_i \tag{42}$$

T is the current year. A country should increase its share of plastic wastes disposal:

$$A2_i = 1 - (1 - \alpha) \cdot (1 - C_i) \tag{43}$$

In addition to the quantity that should be met in a country, the quantity of plastic wastes to be processed should be increased:

$$W = \frac{A2_i \cdot P_i(t)}{\sum_{i=0}^{k} A2_i \cdot P_i(t)} \cdot H + dU \tag{44}$$

Then the amount of reduction and increase should be equal to the plastic output Q minus the environmental carrying capacity:

$$Q - Z = \mu R + (1 - \mu) W \tag{45}$$

We allocate global plastic waste disposal share:

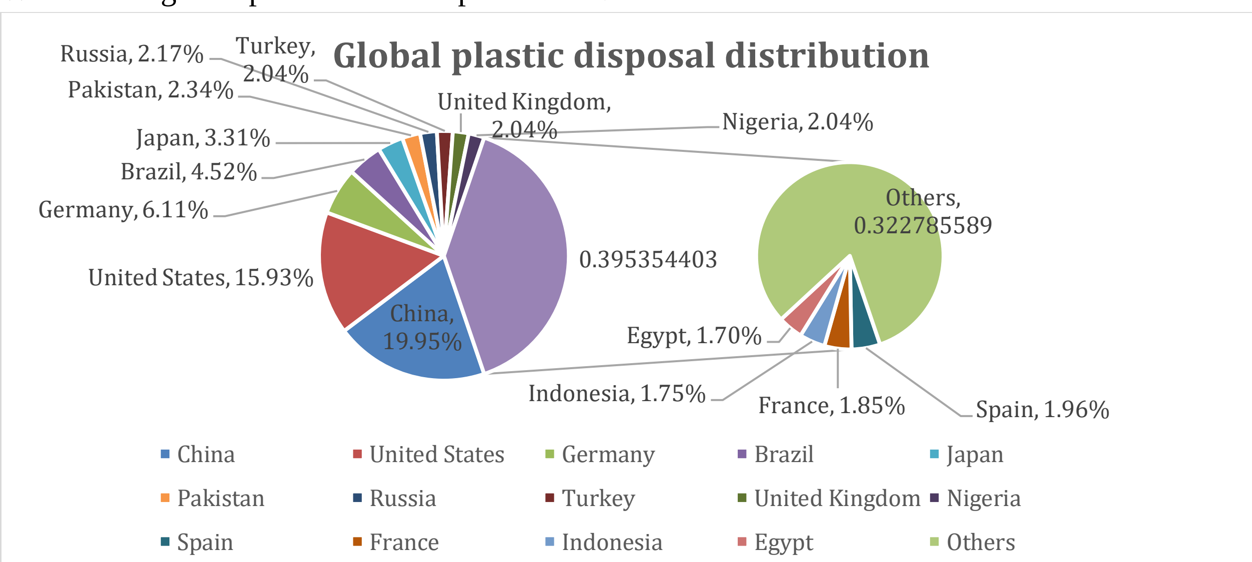

Figure 13 Global plastic disposal distribution

According to the chart, China needs to handle 19.95% of the world 's plastic waste, and the United States needs to handle 15.93% of the world 's plastic waste.

7. Strengths and Weaknesses

7.1 Strengths

- Use Human development index to comprehensive consider several factors that it simplifies the model.
- In the question four, we find that mismanaged plastic waste plays an important role in damaging the environment. Therefore, we only distribute mismanaged plastic waste to simplify the model. From the perspective of reducing the amount of mismanaged plastic waste and increasing the amount of plastic waste that can be disposed of, it is subdivided into four elements: human development index, historical responsibility, per capita equity and handling capacity, these balance equity and development.

7.2 Weaknesses

- Increasing the ratio of incineration to landfill will increase economic pressure, but we ignore the increase in economic pressure will reduce the rate of increase in incineration and landfill
- The effect of geography on distributive equity is not taken into account
- The impact of import and export trade of plastic wastes on the quantity of mismanaged plastics waste is not considered.

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MEMORANDUM

To: International Council of Plastic Waste Management
From: Team #2020183
Subject: Global plastic waste problem
Date: Monday, February 17,2020

Minimum level of global environmental security:

By 2030, the minimum safe level of disposable plastic product waste in the world is 0.69 billion tons. In terms of reducing the problem of poorly managed plastic waste, compared with 2010, East Asia and the Pacific need to reduce by 40%, South Asia by 30%, Sub-Saharan Africa by 20%, and the Middle East and North Africa by 30% A 30% reduction in Latin America, a 40% reduction in Europe and Central Asia, and a 40% reduction in North America. In terms of increasing the treatment of plastic wastes, East Asia and the Pacific should deal with 201.2Mt, South Asia should deal with 28.22Mt, Sub-Saharan Africa should deal with 9.453Mt, Middle East and North Africa should deal with 39.95Mt, and Latin America should deal with it.65.74Mt, Europe and Central Asia should process 121.92Mt, North America should process 109.91Mt.

By 2050, the minimum safe level of disposable plastic product waste worldwide is 2.13 billion tons. In terms of reducing the problem of poorly managed plastic wastes, compared with 2010, East Asia and the Pacific need to reduce by 70%, South Asia by 50%, Sub-Saharan Africa by 40%, and the Middle East and North Africa by 50%. A 50% reduction is needed in Latin America, a 60% reduction in Europe and Central Asia, and a 70% reduction in North America. In terms of increasing the treatment of plastic wastes outside the country's environment, East Asia and the Pacific should accumulate 621.11Mt, South Asia should accumulate 87.11Mt, Sub-Saharan Africa should accumulate 29.18Mt, Middle East and North Africa accumulate 123.34Mt, Latin The Americas should accumulate 202.95Mt, Europe and Central Asia should accumulate 376.37Mt, and North America should accumulate 339.31Mt.

Potential influencing factors:

1. According to relevant data from Our World in data website, the per capita mismanaged plastic waste generation rate and per capita GDP have an inverse U-shaped curve, that is, the per capita plastic mismanagement rate in middle-income countries is often the highest.
2. According to a study by Geyer R et al. [1], the recovery and incineration rates of plastics are getting higher and higher, and it is predicted that [7] the incineration rate will increase to 50% by 2050; the recovery rate will reach 44%; discarded waste will decrease to 6%. This will accelerate to the level.
3. Since the 1980s and 1990s, China has imported about 76% of plastic waste . At the end of 2017, China completely banned the import of non-industrial plastic waste products[4]. With the projected BAU Chinese import data, an estimated cumulative 111 million MT of plastic waste will be displaced by 2030. After China completely banned the import of non-industrial plastic waste products, the import volume of plastic wastes in many countries in Southeast Asia surged, but domestic opposition was also getting louder[5]. Whether other Southeast Asian countries will replace China or follow China 's similar ban on the import of plastic wastes is still an uncertain factor, but

4 https://www.nber.org/papers/w15902

5 https://www.globenewswire.com/news-release/2019/07/25/1887795/0/en/Global-Biodegradable-Plastic-Packaging-Market-Growth-Trends-and-Forecasts-2019-2024.html

in general it has accelerated China ’s own compliance rate and slowed down the rest of the world ’s compliance rate.

4. Recyclable and degradable plastics may replace disposable plastic tapes in the future and speed up compliance 1 2.

5. According to the findings of Japanese researchers, a bacterium named Ideonella sakaiensis 201-f6 can be used to decompose disposable plastics (PET) [8], which has achieved good results in a small scale. In the future, more bacteria that can decompose plastics may be found, which will greatly improve the processing capacity of plastics and speed up the reaching of standards.

6. At present, most plastics are obtained from petroleum products after processing. According to relevant data, oil is only enough for mankind to continue to drill for 50 years [9]. The rise of oil price will lead to the rise of the price of plastics made from petroleum processing and the decline of plastic production, accelerating the speed of reaching the target level

Sincerely,
Team #2020183

Appendix

```
close all
a=[0.121,9525.818483;0.01,4404.697005;0.171,35749.75668;0.335,49374.17889];
a(:,2)=a(:,2)/100000;
bar(a)
hold on
b=[162301553.4;12246143.27;21637642.32;103978622.6]/500000000;
plot(b)
xlabel('country')
ylabel('kg per person per day & 0.1 billion dollor')
set(gca,'xticklabel',{'China','India','Japan','Unity States'});
text(0.9,162301553.4/500000000+0.05,'162Mt')
text(1.9,12246143.27/500000000+0.05,'12Mt')
text(2.9,21637642.32/500000000+0.05,'21Mt')
text(3.9,103978622.6/500000000+0.05,'103Mt')
legend('Plastic waste per person','per capital GDP','Total plastic waste')
title('Plastic use and GDP in four typical countries')
figure
m =
[0;400;600;1000;1300;1800;2400;3000;3800;4600;5600;6700;8100;9600;11500;13500
;16000;18800;22000;25900;30200;34900;40300;46500;53100;59200;66200;73600;8160
0;90400;99300;108400;117800;127800;138500;149600;161300;174000;187300;201200;
215900;231000;247000;263600;281600;300200;320200;341500;363900;387800;413100;
439200;466800;495500;525900;557100;590200;625000;658800;693400;730100;768000;
807200;847900;890200;934100;979500;1026500;1075200;1125400;1177400;1231200;12
86800;1344400;1403900;1465500;1529300;1595300;1663700;1734500;1807700;1883600
;1962200;2043500;2127800;2215100;2305500;2399100;2496100;2596600;2700600;2808
400;2920100;3035800;3155700;3279900;3408600;3542000;3680200;3823500;3971900];
plot(1:71,m(1:71),'b')
hold on
plot(71:101,m(71:101),'b--')
xlabel('years')
ylabel('Macroplastics (>0.5cm) (tonnes)')
set(gca,'xticklabel',1950:20:2070);
title('Microplastics in the ocean')


x=0:0.1:70;
a=0.2;
b=0.7;
y1=1./(a*sqrt(2*pi)*x).*exp(-(log(x)-b).^2/(2*a*a));
plot(x,y1)
hold on
x=0:0.1:70;
a=1;
b=3.5;
y2=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y2)
hold on
x=0:0.1:70;
a=1.4;
b=5.5;
y3=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y3)
hold on
```

```
x=0:0.1:70;
a=1.9;
b=8;
y4=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y4)
hold on
x=0:0.1:70;
a=3;
b=13;
y5=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y5)
hold on
x=0:0.1:70;
a=3.2;
b=20;
y6=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y6)
hold on
x=0:0.1:70;
a=8;
b=32;
y7=1/(a*sqrt(2*pi))*exp(-(x-b).^2/(2*a*a));
plot(x,y7)
xlabel('years')
ylabel('pdf')
legend('Packahing','Consumer&institutional products','Other and
textiles','Electrical&electronic','Transportation','Industrial
machinery','Building and construction')
y=[y1;y2;y3;y4;y5;y6;y7]';

a=162301553.4;
g=445358566;
p=0.40;
si=0:0.001:0.74;
dw=a*0.74-a*(1-p)*si;
s=dw/g;
plot(si,s)
ro=0.2:0.1:5;
g1=313000000;
dw1=(1-exp(-0.212/0.467*ro))*103978622;
ss=dw1/g1;
si1=(0.00864*g-dw1*0.0086)/g;


plot(t)
hold on
y=7.752e+06*exp(0.09*x);
plot(y)
y=7.93e+07*exp(0.0459*x);
```