Global and Regional Prediction and Evaluation Model of Plastic Pollution

Guomiao Zhang¹ *, Meiji Wang², Hui Xu³, Yunna Song³

¹School of Stomatology, Qiqihar Medical University, Qiqihar, China
²School of Public Health, Qiqihar Medical University, Qiqihar, China
³School of Basic Medicine, Qiqihar Medical University, Qiqihar, China

*Corresponding author: guomiaozhang@qmu.edu.cn

Abstract. A global and regional prediction and evaluation model of plastic pollution is proposed. We have collected the data of global plastic production and plastic related indicators of hundreds of countries in the past 100 years, and established a global disposable plastic waste accumulation prediction model based on time series model and multiple linear regression. Our model suggests that the earth's disposable plastic waste will accumulate to the maximum level in 2054, but if we do not intervene in the current development trend of plastic waste, the whole ocean will be seriously polluted in 2024. We divide 145 countries into four categories by clustering algorithm, and establish multiple linear regression models with different leading factors, so as to put forward regional countermeasures. We use factor analysis method to evaluate the plastic pollution in 136 countries, so that the countries can control the plastic pollution more pertinently.

Keywords: Plastic pollution, Time series model, multiple linear regression, cluster analysis, factor analysis.

1. Introduction

Before 1980, almost all plastics were discarded without recycling or incineration. Starting from incineration in 1980 and recycling in 1990, the garbage collection rate has increased by an average of about 0.7% per year. That is to say, only 9% of the 5.8 billion tons of original plastic waste since 1950 has been recycled, and the rest has been discarded or incinerated [1].

Considering the impact of regional differences on the amount of plastic waste, we first use k-means++ method to classify 145 countries, and then select the indicators that may be related to the amount of plastic waste from the sources, availability and impact of disposable plastic waste on citizens' lives. Finally, we do multiple linear regression between the amount of plastic waste in different countries and the relevant indicators Through the standardization coefficient to determine the correlation strength, in order to achieve the goal of more effective reduction of plastic waste to environmental safety level for different countries.

We selected 136 countries with 10 common indicators, and used factor analysis to establish a comprehensive evaluation system for each country, extracting three factors: policy improvement factor, pollution contribution factor and pollution degree factor. Through calculation and evaluation, the top five countries are United States, China, Japan, Germany, France, United Kingdom, Brazil, Italy, India, Canada. For developed countries, it is mainly to increase investment in economy, technology...
and policy to reduce pollution, while for less developed countries, it is necessary to reduce pollution from the source and jointly promote the solution of global pollution problems.

2. Prediction of Global Disposable Plastic Waste Accumulation

The disposal methods of disposable plastic waste include: discarding, burning and recycling. It takes 70-80 years for polyethylene plastics to decompose in the soil, and even 200 years for many old disposable plastic bags. We can approximately assume that the disposable plastic waste discarded within 100 years has not been decomposed. According to the research results of Hannah Ritchie and Max Roser, before 1980, people did not dispose of plastic waste other than discarding. According to the data of Geyer, R.[1], we can predict the treatment methods of plastic waste in the next 50 years.

Assuming that the discarded plastic waste will not decompose naturally in a short period of time, and only incineration, discarding and recycling are the only treatment methods. According to the global plastic production, a multiple linear regression model is established and combined with Brown Double Empirical Smothering and ARIMA (0,3,0), the maximum value of garbage accumulation in the environment can be calculated.

2.1. Trend Prediction of Disposable Plastic Waste Treatment

According to Hannah Ritchie and Max Roser's work [2], people disposed of disposable plastic waste in the form of discarding before 1980.

The decomposition time of all kinds of disposable plastics is about 100 years. We think that the plastic garbage before 1955 will be completely decomposed before 2054, while the garbage after 1955 will not be decomposed. There are:

\[ M_{d,\text{max}} = \sum_{i=1955}^{100} M_i W_i U_i \]  

(1)

\[ M_i W_i \] is the quality of plastic waste in the \( i \)th year from 1955, and \( U_i \) is the proportion of disposable plastic waste in plastic waste in the \( i \)th year from 1955.

And

\[ M_i W_i = M_i P_i N_i d_i \]  

(2)

\( N_i \) is the damage rate of plastic products in the \( i \)th year, and \( M_i P_i \) is the annual output of plastics in the \( i \)th year. We selected a series of evaluation indexes and established multiple linear regression equation to predict \( M_i P_i \). \( d_i \) is the disposal rate of plastic waste in the \( i \)th year.

2.2. Multiple Regression Prediction of Plastic Output

The output of plastic waste and plastic is related to many factors. It is better to predict or estimate the independent variable by the optimal combination of multiple independent variables than by using only one independent variable.

Through reading Geyer's works and Hannah Ritchie and Max Roser's work [2], we divide the factors that affect the level of primary plastic waste into the first stage and the second stage, where the latter can to some extent represent or belong to the former. In addition, the influencing factors of plastic output were added.

Plastics use was characterized by discretized log-normal distributions [3]. There is a linear relationship between plastic production and various factors. We selected ten factors in the second stage. Pearson correlation coefficient was used to determine more representative factors.

Taking the top four indicators of correlation, the multiple linear regression model was established, It can be concluded that:

\[ M_i P_i = -4619137.282 x_1 + 1091862.946 x_2 + (1.74E - 06)x_3 - 0.017x_4 + 542222872.9 \]  

(3)
The R square is 0.997, and the goodness of fit of the model is good. Maximum accumulated value of disposable plastic waste in the environment \( M_{d_{\text{max}}} \) is

\[
M_{d_{\text{max}}} = \sum_{i=1}^{100} M_i N_i U_i d_i
\]  \hspace{1cm} (4)

### 2.3. Calculation of Maximum Capacity of Plastic Waste Based on GPGP

According to The Ocean Cleanup, the highest concentration of plastic waste in the Great Pacific Garbage Patch (GPGP) has an average of 100 kg of plastic waste per square kilometer. We will test the density of the area with the highest concentration ratio of GPGP as the maximum coverage rate of plastic waste on the ocean. If we take all the land as one and all the ocean as another, we can calculate the plastic waste required for all the oceans to be polluted to the same level as the GPGP. The maximum coverage rate = the maximum bearing capacity of the ocean to plastic waste / total ocean area, as shown in formula (5):

\[
W_{\text{max}} = \frac{M_{\text{omax}}}{S_o}
\]  \hspace{1cm} (5)

Relevant data show that 1.7% - 4.6% of plastic waste will enter the ocean due to poor management \([2]\). When the proportion of the flux to the sea is the smallest and the total amount of marine plastic waste reaches the maximum, the maximum bearing capacity of the earth to the plastic waste can be calculated, as shown in formula (6)

\[
M_{g_{\text{max}}} = \frac{M_{\text{omax}}}{N_{\text{min}}}
\]  \hspace{1cm} (6)

Among them,

\[
N_{\text{min}} = 1.7%
\]  \hspace{1cm} (7)

It can be concluded that,

\[
M_{g_{\text{max}}} = 2.12 \times 10^{12} k
\]  \hspace{1cm} (8)

From this, we can see that the total amount of plastic waste needed to be polluted to GPGP level is \(2.12 \times 10^{12} kg\).

### 3. Solutions to regional plastic pollution

The leading factors of plastic pollution in each country or region may be different. It is assumed that the disposable plastic waste produced by each country or region is evenly distributed in its national area. We select different indicators, and firstly classify 145 countries in the world by K-means ++ algorithm, and then build multiple linear regression models of the total amount of plastic waste generated by different countries in different categories and related indicators. Based on this, we can put forward plans to reduce the level of plastic waste for different countries.

#### 3.1. K-means ++ Algorithm

First of all, because the dimensions of the evaluation indicators are not the same, we first standardized the index data of various countries, as shown in formula (9):

\[
Z_i = \frac{x_i - \bar{x}}{\sigma_x}
\]  \hspace{1cm} (9)
$Z_i$ is the standardized value of each index, $x_i$ is the data of each index data, $\bar{x}$ is the average value of each index data, and $\sigma_x$ is the standard deviation of each index data.

### 3.2. Regional Multiple Linear Regression Model

First of all, the multiple linear regression model $Y_2$ between the total amount of plastic waste and relevant indicators in the second category of countries is shown in formula (10):

$$Y_2 = 1796900.301 - 1076701.259x_1 - 591780.952x_6$$

(10)

For the third category of countries, the multiple linear regression model $Y_3$ between the total amount of plastic waste and relevant indicators is shown in formula (11):

$$Y_3 = -2532620.941 + 6010715.462x_1 - 35857.858x_2 + 11612606.540x_7 + 89.495x_8 + 71.971x_5 - 551283.592x_6$$

(11)

Similarly, for the fourth category of countries, the multiple linear regression model $Y_4$ between the total amount of plastic waste and relevant indicators is shown in formula (12)

$$Y_4 = 702412.039 + 1052819.331x_1 - 3757.225x_2 + 654141.037x_3 - 3.611x_4 - 395.983x_5 - 4836.554x_6$$

(12)

The amount of data for China is too small to support the establishment of multiple linear regression model. Therefore, through descriptive statistics of 145 countries including China, combined with China's large population base, vast territory, high degree of aging, and the two child policy and garbage classification policy launched in recent years, we conduct a comprehensive analysis. For China, we can achieve the goal of reducing plastic waste level to environmental safety level by vigorously developing the economy of backward areas, continuing to implement the two child policy, and implementing waste classification measures nationwide.

### 4. Conclusion

The plastic crisis has regional characteristics. In the first category of countries represented by China, the amount of plastic waste is mainly affected by the rapid economic development, large population base, high population density, rapid population growth rate, vast territory, and difficulty in evenly distributing resources; in the second category countries or regions represented by Singapore, the plastic waste volume is mainly affected by the two factors of per capita plastic waste production and population growth rate; In the third category of countries, represented by Australia, Canada and the United States, the amount of plastic waste is mainly affected by the global share of poorly managed plastic waste, per capita GDP, and population growth rate; in the fourth category of countries, represented by Algeria, India and Nigeria, the amount of plastic waste is mainly affected by the total amount of undermanaged plastic waste, and global management is not. The total amount of plastic waste, population density and other factors.

There is a big difference in the scores of plastic pollution among different countries. United States, China, Japan, Germany, France and other countries contribute a lot to the plastic waste, so we should take relatively strict measures to control the pollution. In the actual distribution of state responsibility, joint efforts are still needed.

### Acknowledgments

This study was supported by the award of Innovation and Entrepreneurship for Undergraduate Students of Heilongjiang Province, China (No. 201911230017).
References

[1] Geyer R, Jambeck J R, Law K L. Production, use, and fate of all plastics ever made[J]. ence Advances, 2017, 3(7):e1700782.

[2] Hannah Ritchie and Max Roser (2020) - "Plastic Pollution". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/plastic-pollution' [Online Resource]

[3] Jambeck, Jenna R., Geyer, Roland, Wilcox, Chris, et al. Plastic waste inputs from land into the ocean[J]. Science, 2015, 347(20.13 TN.6223):768-771.