Research on Plastic Waste Pollution Based on Coupling Model

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Abstract. In order to discuss to what extent plastic waste can be reduced to reach an environmentally safe level, we establish the coupling model of safety level and reduction degree, to study the relationship between the reduction degree of plastic waste and the environment safety level. In this model, we have introduced the Public Environmental Awareness Index, the disposable plastic waste recovery rate, and the effectiveness of policies to limit the use of disposable plastic, which constitute the Plastic Waste Reduction Index (DRL). Based on this, six indicators closely related to plastic waste were determined from three aspects, which are included in the environmental safety level index (ESL) by entropy method. Then, the grading evaluation table of environmental safety level was established based on the references. And through Pearson correlation analysis, we found that the level of environmental safety and disposable plastic waste reduction has a high correlation. Then we choose the European Union as the research object, and study the changes of ESL and DRL in the past ten years. Finally, we test the model by Correlation Coefficient analysis, the results show that our model is reasonable. Then through the calculation of the critical point, in order to make the environment reach the safe level, the degree that the disposable plastic waste should be reduced is obtained.

Keywords: disposable plastic waste, environmentally safe level, reduction, coupling model.

1. Introduction
Since the 1950s, the manufacturing of plastics has grown exponentially [1]. Due to its light weight, low cost, strong plasticity and durability, it has been widely used in many fields such as aerospace, military, agriculture, industry and daily life [2] [3]. While there are significant benefits, the environmental problems associated with increased production of plastics are concerning. The large number of plastic waste which is difficult to dispose of has caused serious damage to the environment, effects can be seen by the approximately 4-12 million tons of plastic waste that enter the oceans each year [4]. And the problem caused by plastic waste even triggered a global environmental crisis. In this case, it is urgent to solve the plastic waste problem.

The current recycling rate of plastic products is relatively low; it is reported that only about 9% of plastics are recycled [5], and plastic products are not easy to degrade. According to the survey, by 2015, approximately 63×108t of plastic waste was generated globally, of which only 9% was recycled, 12% was incinerated, and 79% was discarded [6] [7]. These discarded plastics would then enter in the
environment. These hard-to-decompose plastic garbage thrown away by us will remain in our environment for a long time, there may be other organisms into the food chain, endangering human health, and the storage of plastic waste also caused a large amount of waste of resources. Take China as an example, according to statistics, in 2012 the national city of urban garbage removal volume reached 171 million tons, including plastic products consuming 11.4 million tons of oil, equivalent to more than two annual crude oil production of about 4.5 million tons of North China oil field.

However, even if the large-scale production and application of plastics brings serious environmental and safety problems, our daily life still cannot leave disposable plastic products. Plastic products have many advantages that cannot be ignored. For example, in medical services, disposable products is much safer than products used multiple times and it can effectively reduce the spread of infectious diseases. Many medical supplies must use disposable plastic products to ensure hygiene. In short, disposable plastic is a double-edged sword. We need to minimize the use of disposable plastics and minimize the consumption of disposable plastics if they cannot be completely abandoned.

2. Coupling Model of Safety Level and Degree of Reduction

2.1. Plastic Waste Reduction Index DRL

We established a safety level-reduction coupling model based on environmental safety level and plastic waste reduction level, and calculated the correlation coefficient between RDL and ESL to determine the impact of changes in plastic waste reduction level on environmental safety level.

Based on our understanding of the problem and review of relevant literature, we define the main factors influencing the degree of reduction of disposable plastic waste: public awareness of environmental protection, the extent of recycling of disposable plastic waste, and the effectiveness of policies to limit the use of disposable plastic.

Since there are many factors influencing the reduction degree of disposable plastic waste, the international research on this aspect seems to be still limited. Therefore, after reviewing relevant literature and taking a comprehensive consideration, we chose the three factors that are believed to have the highest correlation with the reduction degree of disposable plastic waste, and obtained: Public environmental awareness index \( d_1 \), an indicator within the range of (0,1), reflects the public’s environmental awareness in a certain region; Disposable plastic waste recovery \( d_2 \), recycling is an important way to reduce the generation of disposable plastic waste, the value can be obtained by referring to relevant reports; The effectiveness index of the policy of limiting the use of disposable plastics is \( d_3 \). And the computational formula:

\[
DRL = \frac{1}{3} \times (d_1 + d_2 + d_3) \times 100
\]

2.2. Environmental Safety Level Index Based on Changes in Plastic Waste Reductions

The model defines six indicators related to the volume of disposable plastic waste and incorporates them into the environmental safety level index based on changes in the degree of plastic waste reduction. These six indicators are shown in Table 1.

| Symbol | Definition                                      |
|--------|------------------------------------------------|
| X1     | Water available per person                     |
| X2     | Offshore pollutant concentration               |
| X3     | air pollution Greenhouse gas emissions per capita |
| X4     | Annual air pollution days                      |
| X5     | soil pollution Cultivated area per capita      |
| X6     | biodiversity Endangered species ratio          |
What’s more, we use the Entropy method to determine the index weight, since some of the six indicators are cost indicators and some are benefit indicators, standardization is carried out first, so that the optimal value and the worst value of each variable after alternations are 1 and 0 respectively. The evaluation indicators are X1, X2, ..., Xi = {xi1, xi2, ...}. The level of environmental safety is proportional to the value of the indicators. The formula is as follows:

\[
y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}
\]

\[
p_{ij} = \frac{\max(x_{ij}) - x}{\max(x_j) - \min(x_j)}
\]

As shown in the figure 1, the environmental security level of the EU countries has remained in a good state in the past 10 years, and the value of DRL is also rising, which is consistent with the actual situation of the EU actively responding to plastic pollution in recent years, and it can be seen that the rise of DRL has a certain improvement effect on ESL.

![Comparison of EU’s ESL and DRL](image)

Fig. 1 Comparison of EU’s ESL and DRL

3. Correlation between environmental safety level and reduction of plastic waste

3.1. Correlation coefficient analysis method
Analyze RDL and ESL according to the corresponding tables and corresponding line charts of DRL and ESL to reflect the correlation between the level of environmental safety and the reduction of plastic waste. The advantage of the correlation coefficient is that the relationship between variables can be measured by numbers, and it has directionality. 1 indicates positive correlation and -1 indicates negative correlation.

Calculate covariance

\[
cov(X, Y) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{n-1}
\]

The covariance value of two sets of data can be obtained directly through the COVAR () function in Excel.

3.2. Correlation Coefficient
Covariance measures the correlation between variables by numbers. Positive values indicate positive correlations and negative values indicate negative correlations. However, it is not possible to measure the degree of relevance. So next we calculate the correlation coefficient:

\[
r_{xy} = \frac{s_{xy}}{s_x s_y}
\]

Where \( r_{xy} \) represents the sample correlation coefficient, \( S_{xy} \) represents sample covariance, \( S_x \) represents the sample standard deviation of X, \( S_y \) represents the sample standard deviation of Y. The
following are the formulas for calculating the covariance of \( S_{xy} \) and the standard deviation of \( S_y \). Because it is sample covariance and sample standard deviation, the denominator uses \( n-1 \).

\[
S_{xy} = \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})
\]  

Sample standard deviation calculation formula:

\[
S_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]

\[
S_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (y_i - \bar{y})^2}
\]

After calculation, we get the value of the correlation coefficient \( r \) of 0.5872. The result is not very good, but because the level of environmental safety is affected by many aspects, we only consider the main aspects, and the situation of the world’s environmental safety level is more complicated than that of a certain area. So it is reasonable to assume that our model is still valid. From this we can draw the conclusion that as the reduction of plastic waste increases, the level of environmental safety increases.

Finally, through the calculation of the critical point, we have concluded that when the value of DRL is lower than 27.58, the risk of the world environment falling into "unsafe" levels is very high, that is, to alleviate the current crisis caused by waste plastics, we should work hard to increase the value of DRL above 27.58.

4. Conclusions

After we establish a coupling model of safety level and reduction degree, and introduced the Public Environmental Awareness Index, a complete set of judgment indicators has been established by consulting a large number of documents. We tested our model with the relevant data of the European Union in the past ten years as an example, and proved that our model is effective for the problem solved through Correlation Coefficient analysis.

1) Because our generalization of the sources of disposable plastic waste is not comprehensive and some factors are ignored, the final results are likely to have some errors.

2) The correlation between the environmental safety level and the degree of reduction of plastic waste are reasonable and have certain reference significance. But in actual applications, it may be necessary to further refine the model to obtain More accurate conclusions.

In conclusion, the effectiveness of our model has been confirmed by us. However, the treatment of plastic waste pollution is a very complex and comprehensive problem. Our model contains most of the most important factors related to this problem, but it is not very important. All aspects are well considered, and in the process of model establishment, we have idealized some factors. Therefore, the error of the model is inevitable. Next, we can further optimize on the basis of the model. Get more accurate prediction results about the problem.

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