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The Research on Environmental Security Level under the Current Pollution Situation

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Abstract: With the increasing application of plastic products, the plastic waste problem is becoming serious than ever. Due to the fact that plastic products do not readily break down, it is essential for us to explore a achievable environmental security level. To estimate the maximum level of single-use or disposable plastic product waste, we choose the source of the waste, the current pollution level, and the use ratio of resources as factors. Moreover, Leven berg-Marquardt (LM) method is employed to establish a nonlinear model, then depending on 5 iterations we get the fitted maximum value of 603 thousand tons. We choose China and Japan as the representatives of developed and developing countries to make the comparison. According to research, we define the environmental security level P as the per capital waste emissions, which should be below 25. Then, we choose GDP, impact on policies, substitution rate and extent of pollution as decisive factors of wastes by AHP method. After establishing the comprehensive evaluation method and BP Neural Network Algorithm, the results show the former three show greater influence on developing countries while another greater on developed countries. To set a global target, we choose four countries from different states which are typical in financial as research objectives. During research, we find that the minimum level may influence the substitution rate, environment and the production of plastic industry. By gray prediction, we get the future three-year data to establish the optimizing model. Through Particle Swarm Algorithm, we find that the optimal value is1.512679 million tons, which means the production should be reduced by 721.599 thousand tons, substitution rate will reach 86.9296% and the pollution level may reduce to 79.4013% of the current situation. We select three factors: export volume, recycling rate and plastic production per people of a country to establish an equity allocation model to address the inequality problem of distribution on plastic waste between nations and regions. From the comparison of all the factors between CHN, JPN, UK and Africa, we concluded that for the developing nations in different states, result indicated that Asian developing countries should take much responsibility than those in Africa. Otherwise, for the developed nations in different states, developed countries in Asia should be distributed more than those in Europe. In the same states, developing countries should take much responsibility. We forecast the lowest level in the next six years. The timeline reflects that the global target of 2015-2024 is steadily rising. Due to the influence of some factors, there is a certain deviation between the actual circumstance and the lowest level. We get the conclusion from above that the reverse inference may accelerate or hinder this target to achieve. We find the output of plastic industry, the substitution rate of other materials and the pollution level are affected by the lowest level, and the proportions of influence are 47.7%, 57.47% and 52.5% respectively. If the actual values of that year are larger than these proportions, it will accelerate to achieve or will hinder. While implementation of policies and natural disasters will also impact achievement, but artificial factors counts more.

Keywords: Multivariate nonlinear regression model; BP Neural Network Algorithm; Gray prediction; Waste emissions; Environmental security level

1. Introduction

With the increasing application of plastic products, the plastic waste problem is becoming serious than ever. Due to the fact that plastic products do not readily break down, are difficult to dispose of, and only about 9% of plastic are recycled4-12 million tons of plastic waste entering the oceans each year can cause predictable and invisible effect that by 2050,the oceans will be filled with more plastic than fish, which is a serious consequences in the worldwide. Through the experiment and phenomenon happened during the past few years, we can learn that, in one way, the rise of single-use and disposable plastic products results in entire industries dedicated to creating plastic waste, in the other hand, the amount of time the product is useful is significantly shorter than the time it takes to properly mitigate the plastic waste. Above all, a flexible way of slowing down the flow of plastic production and improving how we manage plastic waste is needed to better solve the current plastic waste problem we concern about.

2. Basic Assumption

To simplify the given problems and modify it more appropriate for simulating real life conditions, we make the following basic hypotheses, each of which is properly justified:

Due to the discipline of energy conservation and the fact that all the plastic wastes are discharged into marine, we assume that the number of actual consumption of plastic waste is equal to plastic waste in marine.

We assume the country we choose as the sample as an overall unit without considering the differences of regions within the country and weigh the comprehensive strength.

We assume that other influencing factors which unrelated to plastic pollution conditions with no impact on the environment.

We assume that four factors: the source of the waste, pollution level and the use ratio of resources to process the waste and financial costs satisfy the rule of Multivariate nonlinear regression model.

3. Notations of Parameters

Table 1. List of notations and parameters

Symbols	Definition
S_i	The population of an area in the year
X_i	The waste emissions in the i^{th} year
w	Inertia factor
c_1	Learning factor 1
c_2	Learning factor 2
$rand_1$	Random number 1
$rand_2$	Random number 2
k_e	Composition score coefficient of national export
k_r	Composition score coefficient of recycling rate
k_c	Composition score coefficient of pollution production per people

4. Application of Our Models

4.1. Model one-Multivariate nonlinear regression model

4.1.1. Primary indicator system

We use Leven berg-Marquardt (LM) method to establish the regression model. First, we select five main factors, which is the source of the waste, pollution level and the use ratio of resources to process the waste, financial costs and population, as parameters influencing the levels of single-use or disposable plastic product waste country could hold.

Source of the waste

Source of the waste here refers to the consumption of single-use or disposable plastic product waste, which can be distributed to five ways: Catering industry, Medical Services, Agriculture, Packaging industry, Personal necessities.

4.1.2. Model establishment

While data processing, due to the conservation of energy, we can concluded that actual consumption of plastic waste is equal to plastic waste which finally discharge to marine. In that way, we get the data of whole actual consumption of plastic waste in three spatial dimensions of sea surface, beach and sea just means that we get the total plastic waste consumption number, which we can see as followed:

Table 2. The annual wastes charged to sea surface,beach and sea from 2008 to 2014

Year	Wastes on sea surface (t)	Wastes on the beach (t)	Wastes in the sea (t)
2008	1200	8000	400
2009	3700	12000	200
2010	1662	30000	759
2011	3697	62686	2543
2012	5482	72581	1837
2013	2819	70252	575

2014	2206	50142	720

And the tendency of other four sectors' data from 2008 to 2014:

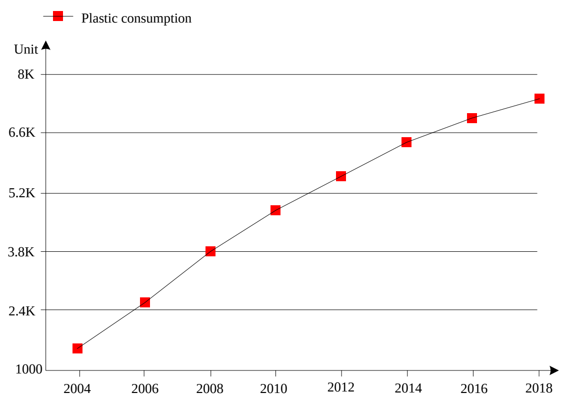

Figure 1. Factor 1: plastic consumption

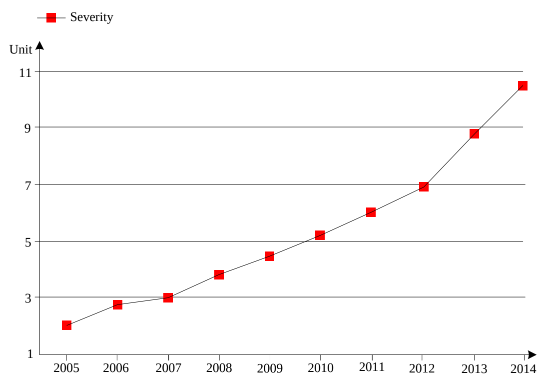

Figure 2. Factor 2: severity of waste problem

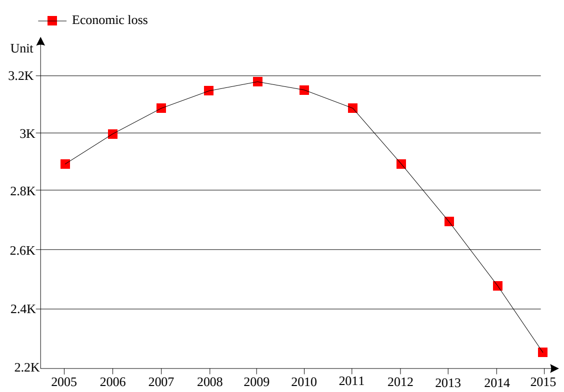

Figure 3. Factor 3: economic loss

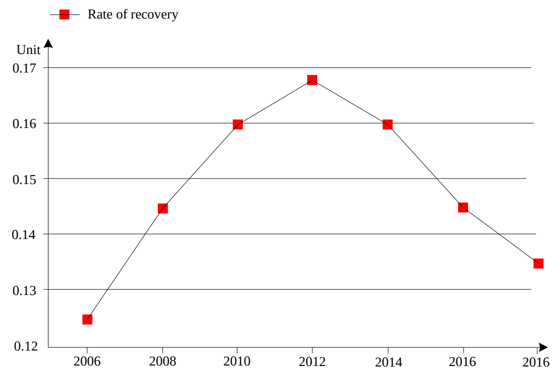

Figure 4. Factor 4: use ratio

It can be concluded from the figure above that:

With the time passing by, the number of plastic wastes which are difficult to degrade after landfill is growing faster year by year, which means the current pollution problem is becoming serious.

The growth rate per year of plastic wastes is slowing down while the total number of plastic wastes per year is still growing.

Financial costs first was growing, then it reached peak value in 2009,after that it was reducing use ratio's tendency just like the financial costs but it reached peak value in 2012.

Then, the multi attribute decision of different dimensions of plastic waste consumption to change into a single dimension is made under time series, and we also need to preprocess the data of five factors by normalizing them to better fit the Leven berg-Marquardt method which has fast convergence speed, good convergence stability. By using this method, we establish a nonlinear recurrence model. From the data available, we know the growing of population is sure and consistent so we remove it from model to simply the calculation process. In order to get a larger volume sample. We set $Z(k) \in R_n$, $Z = x_1, x_2, x_3, x_4, x_5$ to express weight vector after the k^{th} time iterations, so we can get the weight vector $Z = (k+1)$ by the rule:

$$Z(k+1) = Z(K) + \Delta Z \tag{1}$$

Error indicators function:

$$E(Z) = \frac{1}{2}\sum_{I=1}^{N} e_i^2(Z) \tag{2}$$

We get the formula of the Leven berg-Marquardt method:

$$\Delta Z = -[J^T(x_1,x_2,x_3,x_4,x_5)J(x_1,x_2,x_3,x_4,x_5) + \mu I]^{-1} J^T(x_1,x_2,x_3,x_4,x_5)e(x_1,x_2,x_3,x_4,x_5) \tag{3}$$

Then we choose the amount of plastic waste a nation can hold to be the target function and the least square method was used to get the parameter of curve under all five factors concerned.

We compared fitting data produced from computational model with which from the linear model, and to do the fitting optimization test for the both to select minimum one with the sum of the squares of the distance between the estimated value and the actual measured value. We set R^2 as the determination coefficient which is the square of the correlation coefficient.

$$R^2 = \frac{\sum_{i=1}^{i=n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\left[\sum_{i=1}^{i=n}(X_i - \overline{X})^2 \sum_{i=1}^{i=n}(Y_i - \overline{Y})^2\right]}} \quad (4)$$

By comparing R^2 produced by both two models, we find that R^2 value of the linear model is higher0.972 which close to 1, so we choose the linear model to be the best iterative relationship model.

$$Y = 1.137 - 0.824x_1 - 2.391x_2 + 0.904x_3 - 2.30x_4 + 1.836x_5 \quad (5)$$

To use it in the iterative forms:

$$Z(k+1) = Z(K)[J^T(Z)J(Z) + \mu I]^{-1} J^T(Z)Y(Z) \quad (6)$$

4.1.3 Results

After five times operation, the iteration was over and we get that 603 thousand tons is the maximum levels of single-use or disposable plastic product waste.

4.2. Model two-comprehensive evaluation model

4.2.1. Environmental security level

We assumed that if taking sources and uses of single-use or disposable plastics, substitution rate of plastics, the impact on the lives of citizens, or policies among cities, regions, countries, and continents to decrease single-use or disposable plastic and the effectiveness of regional-specific policies into consideration, environmental security level may be related to waste emissions, API and WPI.

Quantify the impact on policies, a non-quantitative factor, as a measure of how much of plastic waste is reduced annually after policies being issued. In 2007, China introduced restrictions on plastic uses and then, in 2008, imposed a ban on the production and sale of ultra-thin plastic bags nationwide and a system of paid plastic bags, which reduced plastic waste by about 4 to 6 % a year. While Japan introduced edible cutlery and trays in 2011 to reduce the use of plastic waste, but initially only sold about 3,000 pieces a year because of the narrow range of sales, finally has shown the effectiveness during following few years by the use of plastic having been reducing the proportion of about 0.0002%-0.001%since 2015.When it comes to 2020, Japan implements a plastic ban.

The possibility of substitution is reflected in the rate of using degradable products under having the same effects as plastic and the use of cloth and fabric instead of plastic. Therefore, according to the analytic hierarchy process (AHP), it is divided into target layer, factor layer and index layer, based on which we establish a primary model.

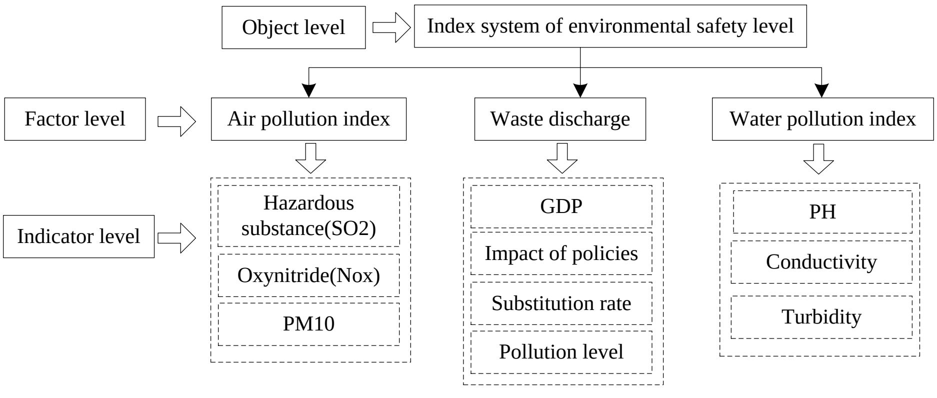

Figure 5. The analytic hierarchy process (AHP)

Since the latter two factors are not within the scope of the study, these two factors are not taken into account, which means environmental security level is decided by waste emissions.

Establishing a comprehensive evaluation model F:

$$F = X_i \quad (7)$$

X_i is influenced by the city's GDP per citizen, policy, substitution rate, pollution level, so we conduct qualitative analysis through the neural network.

4.2.2. BP neural network algorithm and training

a. BP neural network algorithm

The following is a two-layer BP neural network in which the hidden layer and the output layer are the node layers involved in the computation and weights adjustment.

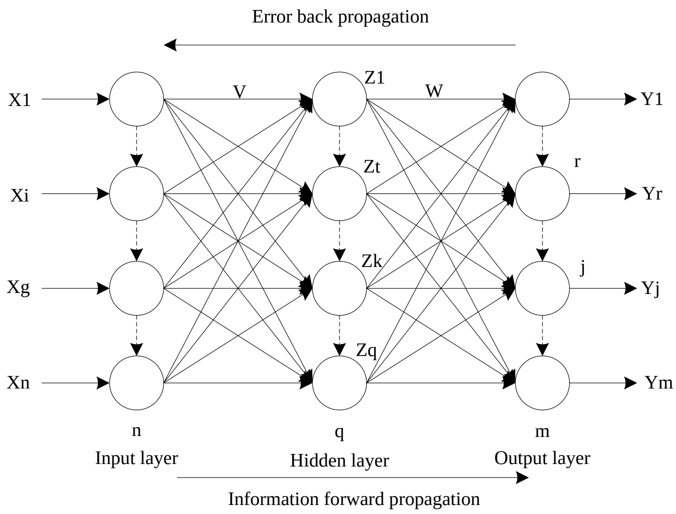

Figure 6. Error back propagation

Our neural network has two layers (see above), the input of each node in the first layer is the same as $x_1, x_2, ..., x_n$, and the hyper plane of each node can be used $g(v) = wv + b$ to represent. However, all nodes have only two states of the last output function: 0 or 1, so the activation function is a *Logistic* function:

$$f(v) = \frac{1}{1+e^{-(w^T v+b)}} \quad (8)$$

The activation function is introduce by these two combined variables.

$$f(t) = \frac{1}{1+e^{-t}} \quad (9)$$

$$t = w^T v + b \quad (10)$$

b. Training process

Error Calculation: By using the least squares method, we find a way to make the weights we set match the classification of as many training samples as possible, and we defined the error as a function of the independent variable. Then calculating the coefficients under the minimum error by finding the peak.

According to the input and output points of the hidden layer and the output layer respectively,

We get the error function of whole network,

$$E = \frac{1}{2}\sum_{i=1}^{n} E_i = \frac{1}{2}\sum_{i=1}^{n}(d_{oi} - y_{oi})^2 \quad (11)$$

Back Propagation and Weights Update: First of all, we get the partial differential through the error function, and error partial differential of the output layer,

$$\frac{\partial E}{\partial w_{ho}} = \frac{\partial E}{y_i}\frac{\partial w}{\partial w_{ho}} \quad (12)$$

$$\frac{\partial E}{\partial y_i} = \frac{\partial \frac{1}{2}\sum_{i=1}^{n}(d_{oi} - y_{oi})^2}{\frac{1}{2}\sum_{i=1}^{n}(d_{oi} - y_{oi})^2 yi} = -(d_{oi} - y_{oi}) f'(y_i) = -\delta_o \quad (13)$$

Then,

$$\frac{\partial E}{\partial w_{ho}} = \frac{\partial\left(w_{ho}h_o + b_o\right)}{\partial w_{ho}} = h_o \quad (14)$$

$$\frac{\partial E}{\partial w_{ho}} = \frac{\partial E}{y_i}\frac{\partial y_i}{\partial w_{ho}} = -\delta_o h_o \quad (15)$$

The gradient of error,

$$\delta_o = -(d_{oi} - y_{oi}) f'(y_i) \quad (16)$$

We can get the gradient of the error of the hidden layer in the same way,

$$\delta_h = (\delta_o - w_{ho}) f'(h_i) \quad (17)$$

In that way, implicit layer is updating:

$$w_{ho}^{N+1} = w_{ho}^{N} + \eta\delta_h x_i \quad (18)$$

Output Layer is updating:

$$w_{ho}^{N+1} = w_{ho}^{N} + \eta\delta_o h_o \quad (19)$$

Defining the scope: based on the weights of the factors of China and Japan (table 3),

Table 3. Comparison of four factors' weights between China and Japan

Japan		China	
Factors	Weights	Factors	Weights
GDP	-0.783	GDP	3.068
Level of pollution	1.218	Level of pollution	1.932
Substitution rate	-0.863	Substitution rate	-0.033
Policy implications	-0.919	Policy implications	-0.608

We distributed environmental security level in comprehensive evaluation model F to four standards: Excellent

(15≥P >0), Good (25≥P >15), Normal (35≥P >25), Bad (P>35).

In order to adopt uniform standards to evaluate environmental security on different continents, countries and regions around the world, according to the global database, it is stipulated that P less than 25 means that the place achieves environmental security.

$$P = \frac{F}{S_i} \qquad (20)$$

S_i is the population of an area in the i^{th} year; X_i is the wastes emission in the i^{th} year.

We compared the data of China and Japan to do the research on the influence of different factors on environmental carrying capacity. According to national database data, each country's annual population and P value can be calculated at a safe level of plastic production, compared with actual production.

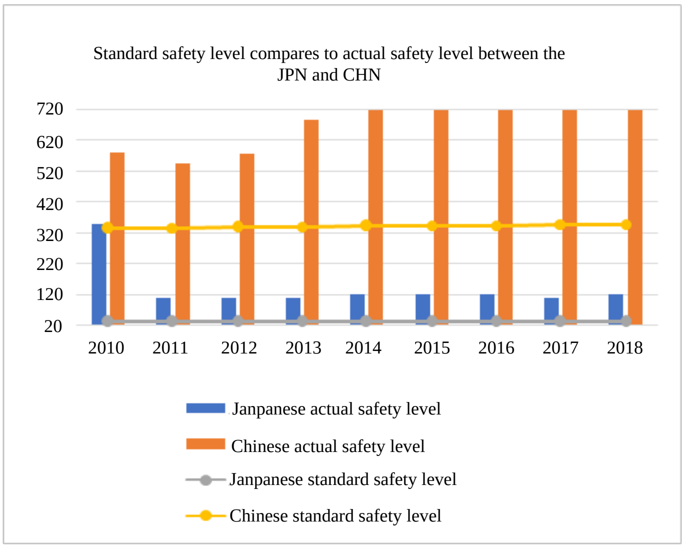

Figure 7. Standard environmental security level compares to actual on between JPN and CHN

Comparison of actual and standard security level between China and Japan from 2010 to 2018. As shown above, there is a difference between the actual and standard levels in the both two country. Depending on the weights of different factors, the extent to which each factor should be reduced to the carrying capacity of the environment, in order to make sure which should be within the level of environmental security.

Table 4. The value of GDP, level of pollution, substitution rate and policy implications JPN and CHN need to achieve to be under the level of environmental security

	Japan	China
GDP (10,000)	(61.27,69.10)	(646.1,1265.29)
Level of pollution	(95.00,107.49)	(406.87,796.79)
Substitution rate(%)	(67.317,76.16)	(6.95,13.61)
Policy implications	(71.68,81.10)	(128.04,250.75)

Conclusions after comparison: By comparing the developing countries with the developed countries and overall strength of two countries, we assumed that:

At the economic level, Japan should raise at least 612.7 thousand GDP a year, while China should increase at least 6.461million GDP. For developing countries with large population, economic strength is becoming an important factor for these countries to solve the problem of environmental carrying capacity.

At the social level, greater recycling of plastics reduces current pollution levels, with Japan reducing at least 95t of current waste production and China at least 406.87t, which is acted as a factor that has a significant impact on developing countries.

In terms of policy, under the situation that China and Japan are at the closest extent of policy improvement. China has introduced a ban on plastic products 10 years earlier than Japan with more scathing action, while Japan has introduced less effective policy by using edible tableware in recent years, which suggested that national policies are more effective in developing countries than in developed countries.

In technology aspects, looking for more substitution that can replace the plastic uses is necessarily needed. Japan has increased its substitution rate by at least 67.31% and China by at least 6.95%.China, as a big exporter in manufacturing area, is specialized in industry and manufacturing industry, so it has more kind and number of domestic alternative materials than the developed countries, which is an important decisive factor to solve the environmental carrying capacity of developed countries.

Combined with all the views above, we can easily concluded that GDP, increased recovery and reduced severity, as well as national policies, should be more pronounced for developing countries, and the production of plastic substitutes should be more pronounced for developed countries.

4.3. Model three-comprehensive evaluation model optimization

4.3.1. Data forecasting-GM (1, 1)

Due to different geographic position, different nations have different economic levels and polluted level. And, the nations worldwide can be classified as developing country and developed country, due to the larger number of developing countries, population and areas, their economic strength are closer to the average standard. So, we think that choosing the countries from different areas is more typical and finally chose China and Africa.

In order to reach a minimum level of global wastes, human lifestyles, the environment and the plastics industry will inevitably be affected. And we should consider these three aspects, then choosing substitution, pollution levels and the production of the plastics industry as factors of it. To explore the effect of achieving the target from now to the future, we use gray prediction to estimate the situation of a period of time in the future depend on the data from 2012 to 2017 collected. First, we use the summation to get the discrete series then establishing its differential equation and changing it to the discrete forms, and then transfer it to matrix expressions. Finally, we can get the predictor formula.

$$\hat{x}^{(1)}(k+1) = [x^{(1)}(1) - \frac{\hat{u}}{\hat{a}}]e^{-\hat{a}k} + \frac{\hat{u}}{\hat{a}} \qquad (21)$$

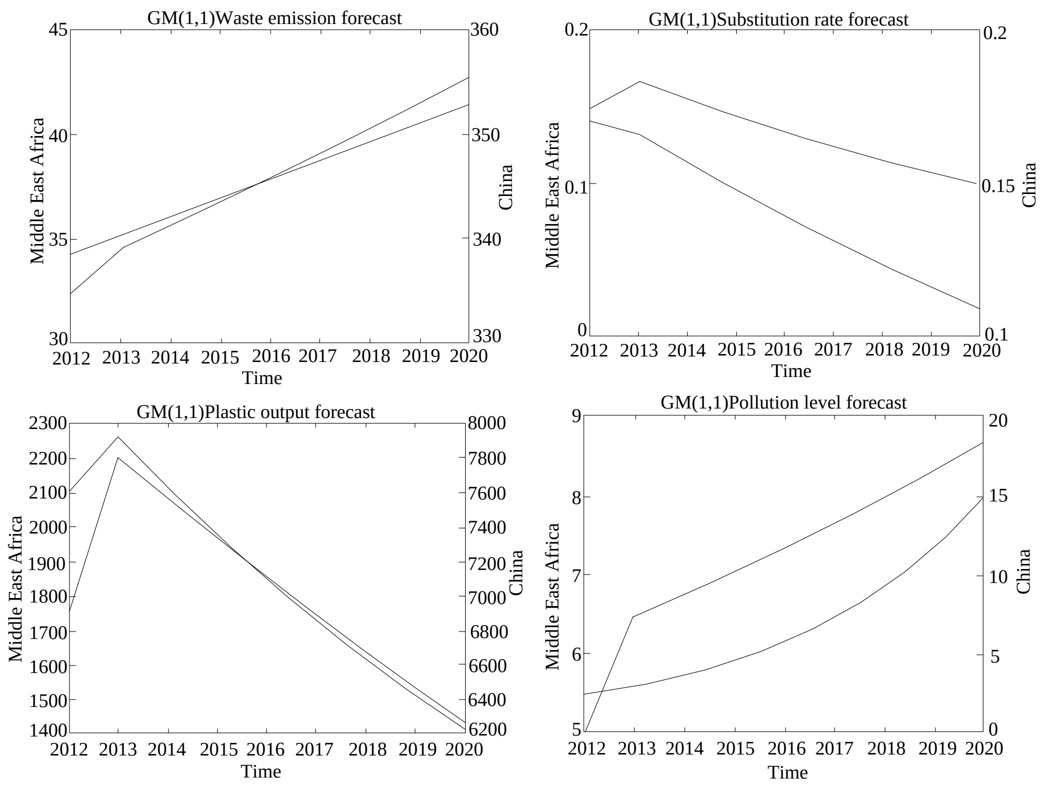

Figure 8. The changing tendency of wastes, recycling rate, plastic output and pollution level

4.3.2. Model optimization

Based on the conclusion of task2, we have obtained the ruled waste emissions within the level of environmental security level, and we have established the inequality model of ternary quadratic.

$$Y \geq 38.441x_1 - 0.605x_2 - 2.656x_3 + 0.001x_1x_3 \\ -0.063x_2x_3 - 38.444x_1^2 - 0.524x_2^2 - 2.369x_3^2 + 365.262 \qquad (22)$$

x_1 represents the production of the plastic industry, x_2 represents the substitution rate, x_3 represents the of pollution.

Through Particle Swarm Optimization, starting from the random solution, we know the degree of effects on all the factors under the optimal solution by iteration, which refers the lowest level. Particles update their speed and position by the formula,

For speed,

$$v_{i+1} = w * v_i + c_1 * rand_1 * (pbest_i - x_i) + c_2 * rand_2 * (gbest_i - x_i) \quad (23)$$

For location,

$$x_i = x_i + v_{i+1} \quad (24)$$

Here v_i, x_i denotes the velocity and position of the i dimension particle, $pbest_i$, $gbest_i$ respectively represent the value of the i dimension at the best position of a particle, and the value of the i dimension at the best position of the whole population.

Through the Mat lab running, we find that the fitness of the function does not change after the 100th iteration, which indicated that local optimization appears at this time. (Fig.9) We get the best value which is equal to 151.2679.

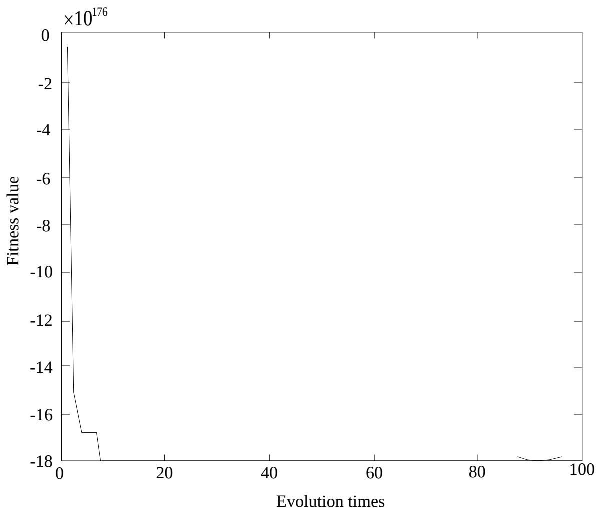

Figure 9. The changing tendency of fitness value during 100 times evolution

Combined with the data available and the future estimation, we can conclude that the production of the plastics industry will reduced by 721.599 million tons, a substitution rate of 86.9296% and the improvement in pollution levels can be 79.4013% of the current situation once we setting the minimum level of global waste at 1.512679 million tons.

As we all know that the production of plastic will inevitably bring a great burden to the environment. There is no doubt that too much production of plastic will lead to the increase in the amount of plastic waste and increase landfill work, difficulties of degrade garbage, which will inevitably increase the pollution level. We are sure that there is a certain correlation between these factors.

5. Conclusion

A regression model is established to research the relationship between waste sources, the severity of waste problems, resource use ratio, economic losses, population and the reduction of plastic waste. On this basis, define an environmental security level, gradually optimize to determine the reduction degree of relevant factors, and set the minimum level of waste to research the impact of this level on human life, environment and plastic industry. Different countries have different economic strength and relevant policies, different regions determine different environmental conditions. For a global problem such as the reduction of plastic waste, it is particularly important to solve the problem by fair distribution. Under the influence of many factors, if there is a factor that does not reach the security level, it will cause the realization of this global target to be advanced or delayed, so we choose countries with different economic strength and regions as representatives to extend the conclusions to the world.

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