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Research on the Prediction of Hazardous Chemicals Accidents Based on Improved Grey Model

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With the rapid development of China's society and economic construction, the production and use of hazardous chemicals are increasing. The possibility of hazardous chemicals accidents is increasing. Because the hazardous chemicals cause great harm and the accidents affect the normal production and life. Hazardous chemicals accidents have become the focus of attention of society and academia. The study of reducing hazardous chemicals accidents is an important research field of safety production in china. The prediction of hazardous chemicals accidents is of great significance to reduce the number of hazardous chemicals. In this paper, we propose an improved grey model for the characteristics of hazardous chemicals accidents to predict the numbers of hazardous chemicals accidents. In the experimental section, we predict the number of hazardous chemicals accidents in china. The experimental results show that the improved grey model and the better fitting result are obtained.

1. Introduction

In China, the process of industrialization continues to accelerate (Yang and Shao, 2017). At the same time, the scale and quantity of hazardous chemicals enterprises are also gradually. At present, there are about 7000000 chemicals in the world, of which more than 100 thousand chemicals have been sold in the market. Hazardous chemicals are usually explosive, toxic, and are prone to accidents in production, storage and transportation. Once a large amount of hazardous chemicals is emitted or leaked, it can cause fire, explosion, property damage and environmental pollution (Warnasooriya and Gunasekera, 2017; Benhorma et al., 2017; Gattuso et al., 2016; Cannistraro et al., 2016). At the same time, toxic gases can cause adverse effects on the human body, leading to poisoning or death, resulting in greater social and public safety incidents (Slorach, 2014; Wang et al., 2017; Birungi and Chirwa, 2017; Silva et al., 2017).

The scope of application of hazardous chemicals in China is more and more extensive. This only promotes the development of national economy, but also enriches people's production and life (Li and Hu, 2017). Hazardous chemicals accidents involve all aspects of production, storage, transportation, use and so on, and the consequences of accidents are serious (Jeremy et al., 2016). The causes of hazardous chemicals accidents are mainly including the increase of the number of chemical enterprises, the lack of supervision and the lack of safety awareness. In 2002, the State Council issued the “regulations on the safety control of hazardous chemicals”, which was revised in 2013. The regulations strengthen the safety management of hazardous chemicals, prevent and reduce hazardous chemicals accidents, protect the lives and property of the people, and protect the environment. Numbers of hazardous chemicals accidents and deaths in China are shown in figure 1.

Overseas research on risk assessment and prediction of hazardous chemicals accidents started earlier, both in theory and in methodology (Marhavilas and Koulouriotis, 2012). Some developed countries have already established a perfect safety management system for dangerous chemicals (Bonvicini et al., 2012). At the same time, according to the continuous development of the hazardous chemicals industry, the corresponding management strategies are also being adjusted (Saidi et al., 2010; Topuz et al., 2010). China is a big country in the production and use of dangerous chemicals. Although China has established a safety management

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system for dangerous chemicals, the management technology is relatively weak and there is still a big gap between developed countries and the developed countries.

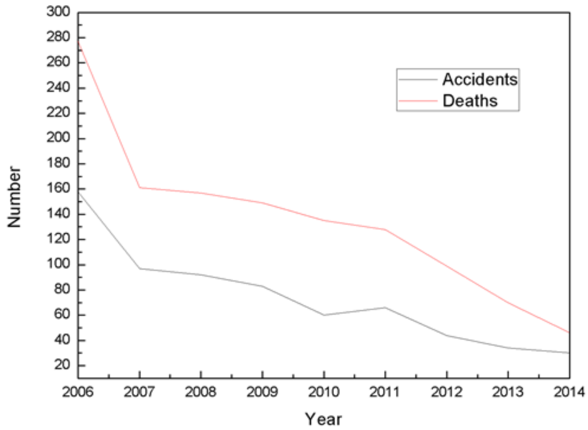

Figure 1: Numbers of hazardous chemicals accidents and deaths in China

The grey model was put forward by Professor Deng Julong, a Chinese scholar in 1982 (Wang et al., 2017). The naming of grey systems is defined by color. The clarity of information represented by "grey" is between "known" and "unknown" (Yu et al., 2017). The modeling of grey system is to use historical data to produce new data sequence. Then, the differential equations are established. After accumulating the historical data, the grey system turns it into an ascending sequence of exponential growth (Ma et al., 2017). When this new theory was born, it has received extensive attention in academic and practical. Many practical workers and young and middle-aged scholars have joined the ranks of grey system theory research and exploration, and have written a lot of scientific and technological applied papers in this field. The grey system theory in different fields of success has been widely recognized by academic circles (Ene et al., 2017).
In this paper, we study the prediction of hazardous chemicals accidents. In order to better achieve the goal of research, we propose an improved grey model. The first part of this article is the introduction. The first part introduces the research background. The second part analyzes the dangerous chemicals accident. The third part introduces the grey model. In the fourth part, we propose an improved grey model for prediction of hazardous chemicals accidents. The fifth part is the experiment and the last part is the conclusion.

2. Hazardous chemicals accident analysis

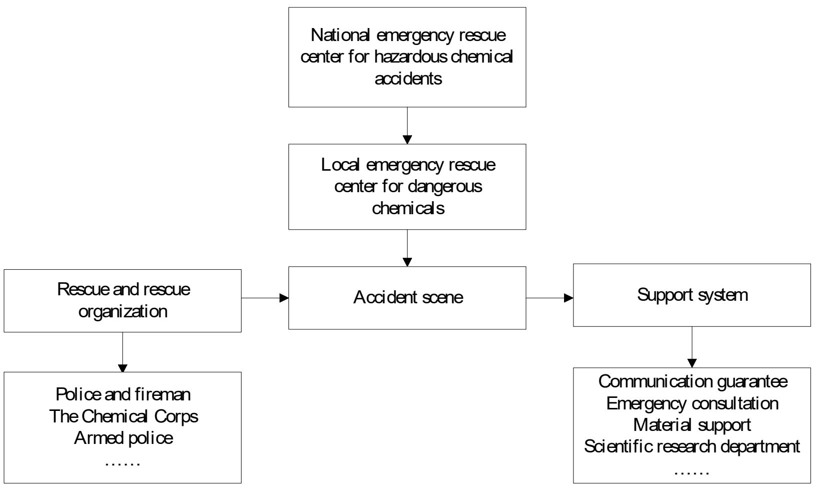

Figure 2: The emergency organizational relationships about chemical accidents

Hazardous chemicals accident refers to an accident caused by dangerous chemicals, which endangers human life and health, property safety and environmental protection. Hazardous chemicals accident has the following characteristics:

Abrupt: When many hazardous chemicals accidents happen, there is no warning before. So it is not easy to detect

Multiple: Hazardous chemicals appear in people's life. From the production, storage, transportation, civil, or to all aspects of fireworks, it is at any time.

Susceptibility: Because of the characteristics of hazardous chemicals, it is easily affected by the external environment, contact with water, or by the impact, extrusion and so on. These all may lead to accidents.

Diffusion: When a dangerous chemical accident occurs, it involves a wide range. As the gas continues to diffuse, people and surroundings are easily affected.

The rescue is difficult: Because of the danger of hazardous chemicals accidents, it is necessary to have special rescue team and some professionals at the same time

Social image and economic losses are greater: The occurrence of hazardous chemicals accidents brings a series of negative social impacts, and the economy will suffer great losses.

3. Grey prediction GM(1,1)

In order to use historical data to predict the future, we call the non negative random sequence $X^{(0)}=\{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\}$ that reflects historical data as parameter sequence. *n* is called the parameter data length. Make an accumulation.

$$x^{(1)}(k)=\sum_{i=1}^{k} x^{(0)}(i) \tag{1}$$

The resulting sequence is

$$X^{(1)}=\{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\} \tag{2}$$

It is assumed that the accumulated sequence $X^{(0)}=\{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\}$ is satisfied with the parameter sequence $X^{(0)}=\{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\}$

$$x^{(0)}(k)+a x^{(1)}(k)=b \tag{3}$$

The equation is called the original form of the model GM(1,1). Generating the sequence $X^{(0)}=\{x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)\}$ for immediate generation

$$z^{(1)}(k)=\frac{1}{2}[x^{(1)}(k)+x^{(1)}(k-1)] \qquad k=1,2,\cdots,n-1. \tag{4}$$

The lower model is called the basic form of the model GM(1,1), which is called the grey differential equation

$$x^{(0)}(k)+a z^{(1)}(k)=b \tag{5}$$

The least squares method is used to estimate the parameters of the upper model

$$A=\begin{bmatrix} a \\ b \end{bmatrix}=(B^T B)^{-1} B^T Y \tag{6}$$

Where

$$B=\begin{bmatrix} -\frac{1}{2}(x^{(1)}(1)+x^{(1)}(2)) & 1 \\ -\frac{1}{2}(x^{(1)}(2)+x^{(1)}(3)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(x^{(1)}(n-1)+x^{(1)}(n)) & 1 \end{bmatrix} \tag{7}$$

$$Y_n=[x^{(0)}(2), x^{(0)}(3), \cdots, x^{(0)}(n)]^T$$

In order to predict the accumulated generating sequence, the set of cumulative generating sequences satisfies the differential form (usually called the whitening equation)

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=b \tag{8}$$

Initial condition

$$x^{(1)}(1)=x^{(0)}(1) \tag{9}$$

The solution may be expressed as

$$\hat{x}^{(1)}(k+1)=(x^{(0)}(1)-\frac{b}{a})\cdot e^{-a(k-1)}+\frac{b}{a} \tag{10}$$

We know

$$\hat{x}^{(1)}(k)=\sum_{i=1}^{k}\hat{x}^{(0)}(i)=\sum_{i=1}^{k-1}\hat{x}^{(0)}(i)+\hat{x}^{(0)}(k)=\hat{x}^{(1)}(k-1)+\hat{x}^{(0)}(k) \tag{11}$$

A regressive fitting sequence obtained reduction. Fitting sequence of $X^{(0)}$ is $\hat{X}^{o}$

$$\hat{x}^{(0)}(k)=\hat{x}^{(1)}(k)-\hat{x}^{(1)}(k-1) \tag{12}$$

4. Improved grey model

The cumulative formula of $GM(1,1)$ model is rewritten as

$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i)=\sum_{i=1}^{k-1}x^{(0)}(i)+x^{(0)}(k)=x^{(1)}(k-1)+x^{(0)}(k) \tag{13}$$

We know

$$x^{(0)}(k)+\frac{a}{2}(x^{(1)}(k)+x^{(1)}(k-1))=b \tag{14}$$

The parameters a and b are still given.
Grey prediction iterative equation

$$x^{(0)}(n)=\frac{(m-a)^{n-2}}{m^{n-1}}(-ax^{(0)}(1)+b) \tag{16}$$

Bring a, b and m into the upper model

$$x^{(0)}(n)=\frac{2(2-a)^{n-2}}{(a+2)^{n-1}}(b-ax^{(0)}(1)) \tag{17}$$

Since the genetic algorithm has good search performance, it can automatically accumulate and acquire the knowledge about the search space. The search process of the adaptive control algorithm is used to obtain the optimal solution. Therefore, the genetic algorithm is used to optimize the parameters. Firstly, the genetic algorithm encodes the solution of the problem with the proper coding method. Then the algorithm measures the fitness values of the current group. A series of genetic manipulations such as selection, crossover and mutation is applied to the present group. New population is generated. The specific steps are as follows.
The steps of the improved grey model are as follows:
(1) Initial population generation. A series of grey model parameters are generated randomly. The binary encoding scheme is adopted to encode each grey model parameter. The initial population of the genetic algorithm is formed.
(2) Calculate the fitness. Calculate the prediction error of each individual in the colony and then determine the fitness of the individual.
(3) Select individuals. The genetic algorithm uses the selection operator to select the fittest of the population, and chooses the fitness of each individual according to the size of each individual. The basic genetic algorithm employs proportional selection operators.

(4) Individual crossover. Randomly select two individuals from a group as cross objects to exchange one or more bits of two individuals and form two individual individuals. Crossover operations produce offspring, which inherit the basic features of the parent.
(5) Variation. The genetic algorithm uses a small probability to change the individual gene code in the population and creates a variant of the offspring, which makes the genetic algorithm have a broader search space.
(6) Repeat step 2-5 and keep the grey model parameters evolving until the training target meets the termination condition. Finally, the optimal solution of the parameters is substituted into the grey model and a grey prediction model based on genetic algorithm optimization is obtained.

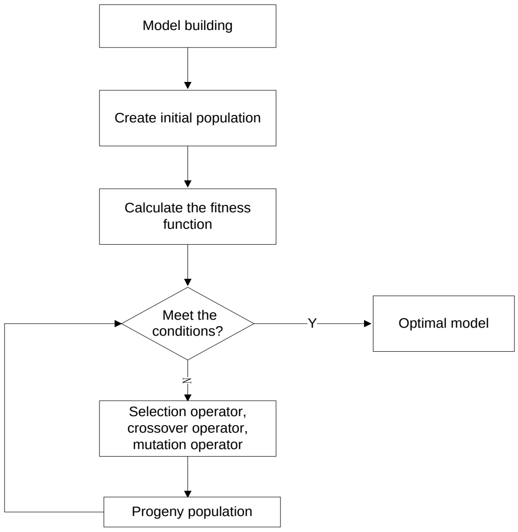

Figure 3: The specific steps of improved grey model

5. Experiment

In order to illustrate the superiority of the improved grey model in the prediction of hazardous chemicals accidents, we use the model to predict the numbers of hazardous chemicals and the numbers of fatalities. We use 2006-2010 of the data as a training set and 2011-2014 years of data as the prediction set.
From Figure 4, we can see that the improved grey model curve is more similar to the actual value, which shows that the improved grey model has a good effect on the prediction of the number of hazardous chemicals accidents.
From Figure 5, we can get the result of the improved grey model. The fitting result is basically consistent with the actual value. It shows that the improved grey model obtains the good result in the prediction of the death toll of hazardous chemicals.

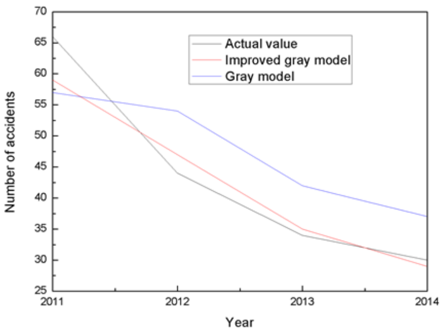

Figure 4: Number of accidents

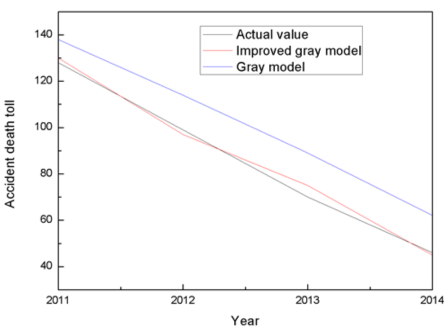

Figure 5: Accident death toll

6. Conclusion

The use of chemicals has brought a great convenience to people's life and improved the quality of life. The increase of kinds and quantities of chemicals increases the probability of chemical accidents. Hazardous chemicals are prone to accidents and such accidents can not only cause direct bodily harm, but also pose a great threat to the environment. In order to reduce the occurrence of hazardous chemicals accidents and control the accidents of hazardous chemicals, we predict the number of hazardous chemicals accidents. In this paper, we propose an improved grey model and use the model to predict hazardous chemicals accidents. The main work of this paper includes: (1) Introducing the research background; (2) Analyzing the characteristics and causes of hazardous chemicals accidents; (3) Introduction of grey model; (4) Putting forward an improved grey model and the model being used to predict hazardous chemicals accidents.

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