IETI Transactions on Computers, 2016, Volume 2, Issue 1, 61-72.
http://www.ieti.net/tc
An International Open Access Journal

China's coal mine accident statistics analysis and one million tons mortality prediction

Qiao Tong

College of Resources and Environmental Engineering, Wuhan University of Technology, Wuhan 430070, China

168342608@qq.com

Keywords: Coal mine accident, statistical analysis, million tons mortality, grey prediction.

Abstract. In order to study the general rule of coal mine accidents in China in recent years, the data of coal mine accident in 2011-2015 is analyzed. The mathematical statistics method is used to analyze the occurrence year, type, season and area of the accident. The results of analysis shows that the coal mine accident has been reduced year by year, and the frequency of gas explosion is the highest. The frequency and the number of deaths in the second quarter of the year are the highest; Guizhou province, Hunan province, Yunnan province and Heilongjiang province are the accident prone provinces. GM (1, 1) dynamic prediction model is used to model and forecast the future million tons mortality in China. The forecast results show that the coal mine's million tons mortality rate of China showed a decreasing trend. The forecast results are scientific and reliable, and it is of great significance to the safety management of coal mine.

1 Introduction

Worldwide coal consumption is expected to grow by 25% and the vast majority of the world's energy will come from coal by 2020. Chinese increased demand for coal is the main factor driving the world coal consumption growth. China will account for two-thirds of the world's total increased by

2020 [1]. In China's energy industry, coal accounts for about 70% of China's primary energy production and consumption structure. Coal is of great strategic significance to China, bringing tremendous benefits to the country and the people. But China's coal mining deaths is four times more than the total number of the world's major coal producing countries. China has the world's worst coal mine accidents and these accidents bring great physical and psychological harm people [2]. After ten years of development, China's coal production safety has achieved long-term progress. Death rate per million tons of coal in China is 0.157 in 2015. The mortality rate fell below 0.2 for the first time, but still higher than the advanced coal-producing countries 5 times. The remainder of this paper is divided into two sections. Section II analyzes the accident types, time, region and so on through the information of serious accidents occurred in coal mines in China from 2011 to 2015. In Section III, death rate per million tons of coal in China from 2016 to 2020 is predicted by grey prediction method.

2 The basic situation and the analysis of coal mine accidents in China from 2011 to 2015

2.1 The basic situation and the overall annual trend analysis

According to State Administration of Work Safety's related statistics, there were 278 accidents in China's coal mines from 2011 to 2015[3]. These accidents caused 1772 deaths and huge economic losses. The number of coal mine accidents and deaths showed a downward trend. The number of coal mine accidents decreased from 85 in 2011 to 28 in 2015 and the deaths decreased by 280, 59.7%. So, it can be shown in Figure 1 that the overall situation of coal mine accidents in China tends to be stable in reduced state, especially in 2014, a substantial decline in the number of deaths. In recent years, the gradually improving trend of China's coal mine production safety situation is mainly due to the state of the coal mine production safety importance greatly enhance. In addition, China has also promulgated a series of coal mine production safety laws, regulations and technical specifications that playing a very key role in preventing and reducing coal mine accidents [4]. But as shown in the results of the statistics, although the number of accidents, deaths overall decline, the average accident death toll was showing increasing trend, from 5.52 people per accident in 2011 to 7.76 people per accident in 2013. The reason is that safety management is not detailed enough. While paying attention to reducing the number of accidents, property damage and casualties, we should carry out detailed safety prevention efforts to reduce the losses caused by the accident to a minimum, reducing the average accident casualties.

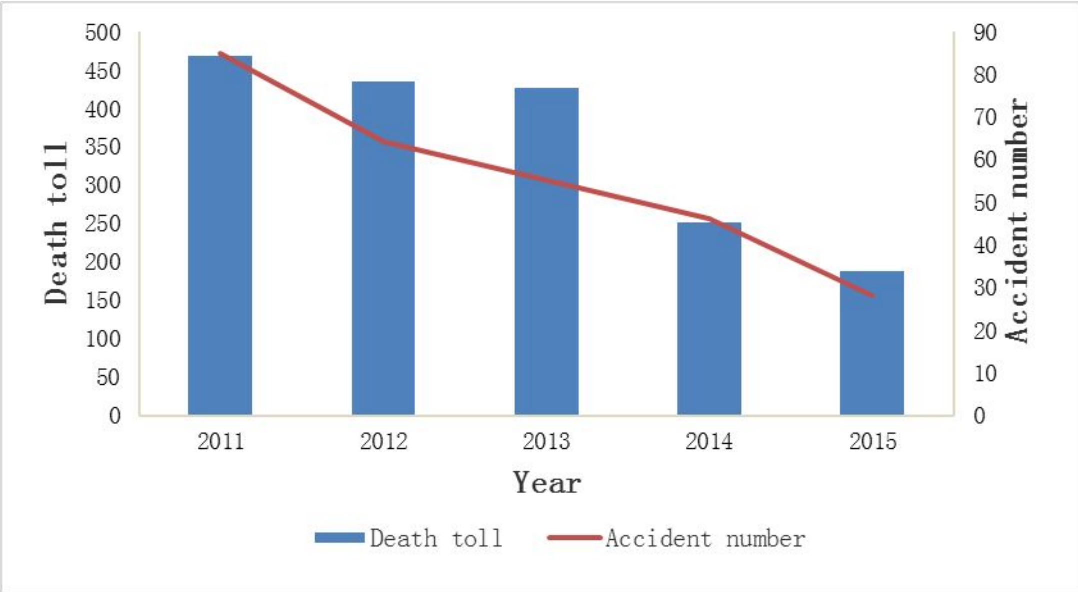

Fig. 1 Annual accident statistics

2.2 Types of the accidents

The types of accidents are counted according to the characteristics of China's coal production and related statistics from State Administration of Work Safety. From 2011 to 2015, coal mine accidents in China are mainly gas explosion, coal and gas outburst accidents, water inrush accident, accident of the roof, roof fall accident, poisoning accident, transportation accident and other accidents (including collapse accident, car accident, rockburst accident, falling accident). The specific data was shown in Figure 2 and Figure 3. The main types of coal mine are gas explosion accident, coal and gas outburst accident and water inrush accident. The average number of deaths of gas explosion accident which causing the greatest harm degree is the highest, reaching 10.7 people per accident.

2.3 Time of the accidents

The number of extraordinarily serious coal mine accidents and the death toll of accidents of every quarter from 2011 to 2015 are shown in Figure 4. The first quarter has the least number of coal mine accidents in four quarters. The reason of it is that the spring festival in the first quarter and most of the coal mines during the Spring Festival is in a semi-shutdown state.

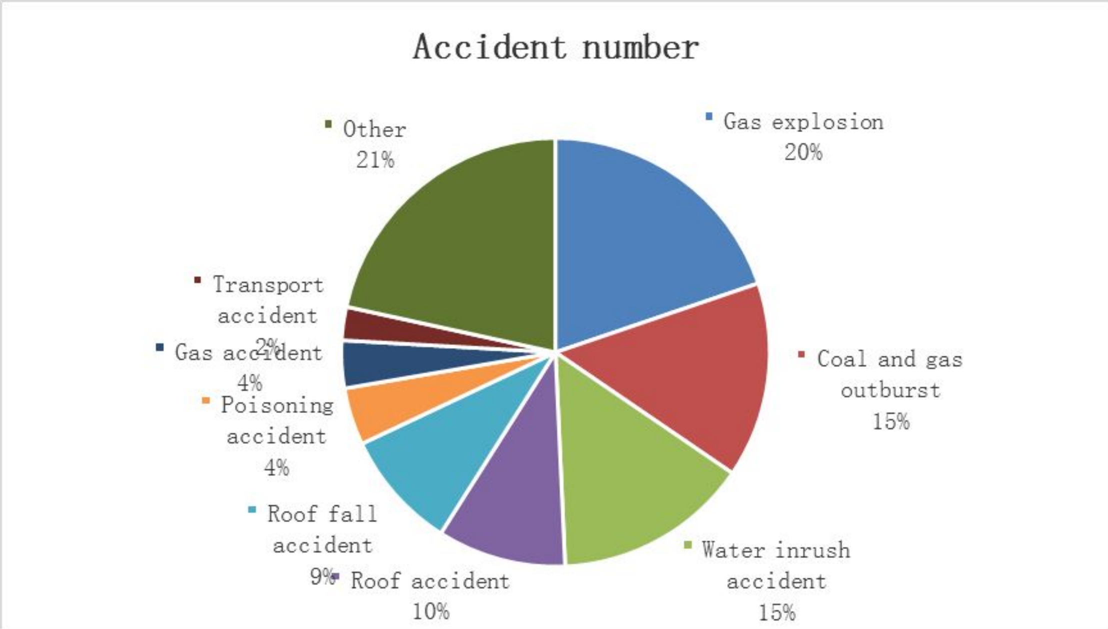

Fig. 2 Number of accidents of various types

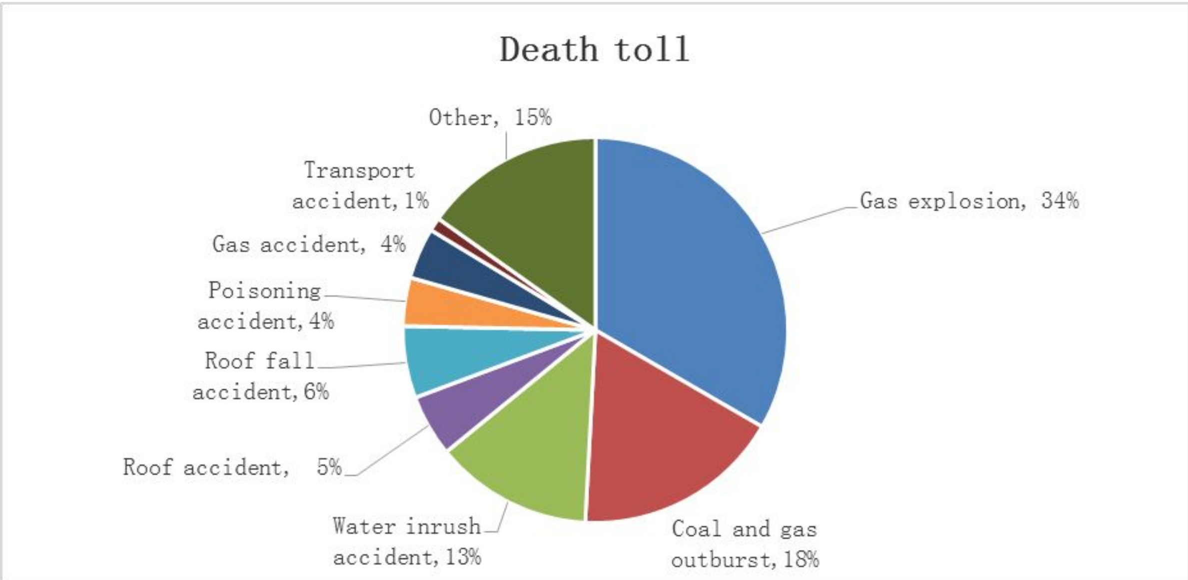

Fig. 3 Death toll of accidents of various types

Accidents occurred more in the second and third quarter, especially the second quarter. The number of accidents and deaths have shown a peak in the second quarter. This is because when the weather is turning into a hot, human inertia is relatively large that the workers has "provincial energy psychology 'and managers management loopholes more in this period from a physiological point of view. [5] Safety management and accident prevention should be strengthened in the fourth quarter due to cold weather, the North increased demand for coal, also at the peak of coal production.

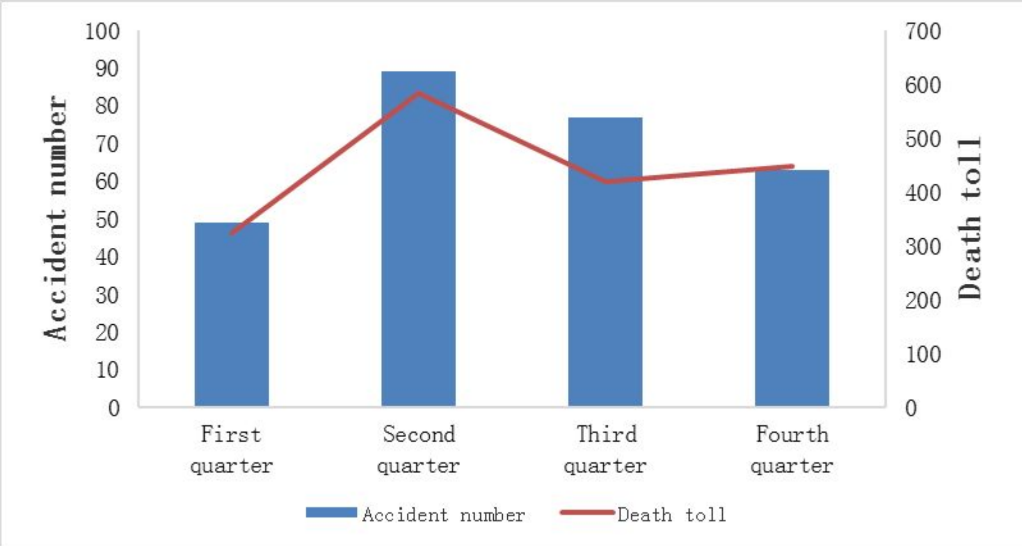

Fig. 4 Accident statistics for each quarter

2.4 Area of the accidents

According to the geographical situation of the accident analysis, Guizhou, Heilongjiang and Jilin provinces are the accident-prone provinces. From 2011 to 2015, nine provinces including Beijing, Tianjin and Shanghai did not occur coal mine accidents. The number of accidents of the first cluster which including eight provinces accounts for 63.7% of the total number of accidents and the deaths accounts for 72.9% of the total number of deaths (in figure 5).

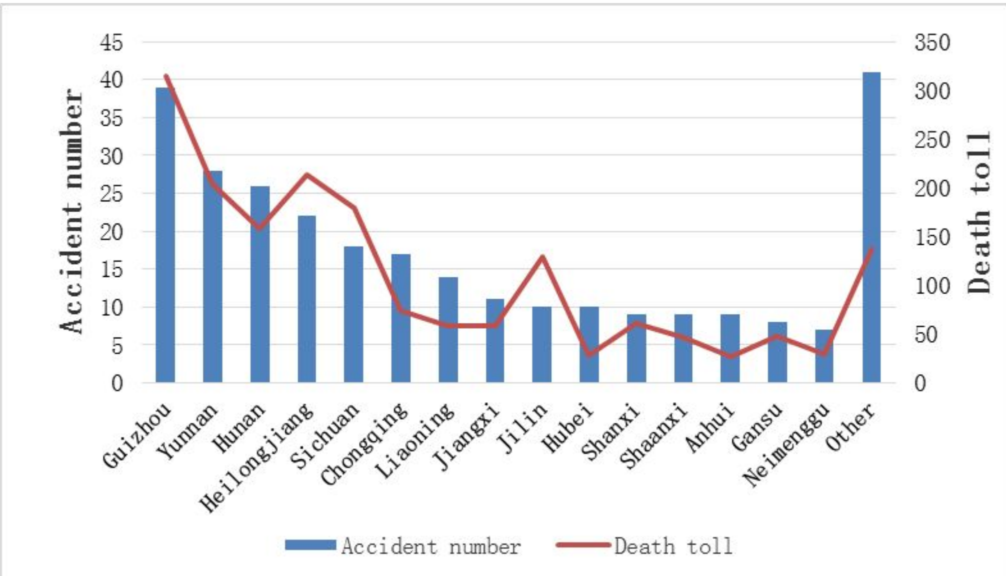

Fig. 5 Accident statistics of provinces

Geographical features of coal mine accidents is very obvious. The natural conditions in the area and the objective reason have a great relationship with the occurrence of the accident. All the accident-prone provinces of the first groups are major coal producing provinces which facing many problems such as the presence of small-scale mines, more complex conditions, the development of a long time, difficult to supervise and manage. Because Guizhou province has many high-gas coal mines and coal and gas outburst mines, the probability of occurrence of large gas disaster is big. With the increase of mining depth, coal seam gas content, the amount of gas emission, outburst hazard, Gas disaster accidents are more likely to occur [6].Higher average number of deaths of coal mine accident in Heilongjiang and Jilin province, which is due to the large probability of heavy and serious accidents in Heilongjiang Province and Jilin Province whose high gas coal mines accounts for about 10% of the total number of mine [7].

Accident-prone provinces in China are major coal-producing province. The problems such as more resource exhausted mine, dispersive production layout, complex system, more mining sites, longer mining line and more underground workers, etc , become more and more. It is very easy to have the situation of super-layer and cross-border mining, private indiscriminate digging, disorderly production which increasing the difficulty of mine safety production management.

3 The forecast of death rate per million tons of coal in China

After ten years of development, China's coal production safety have made long-term progress. As shown in Figure 6, death rate per million tons of coal in China significantly reduced year by year. China's coal million tons mortality rate of 2015 is 0.157, for the first time down to 0.2, but still five times higher than the advanced coal-producing countries. GM (1, 1) dynamic prediction model that from grey forecasting method is used to model and forecast the future million tons mortality in China. It has important directive function to the coal mine industry related laws and regulations and safety management.

3.1 Grey forecasting method

Grey System [8] is a systems theory proposed by Professor Deng Julong. The main advantage of using grey system theory to predict is that it makes a set of original data sequence which is out of order having obvious regularity through a series of data generation method (direct cumulative, moving average method, the weighted cumulative, genetic factor accumulation, etc.). It solves the calculus

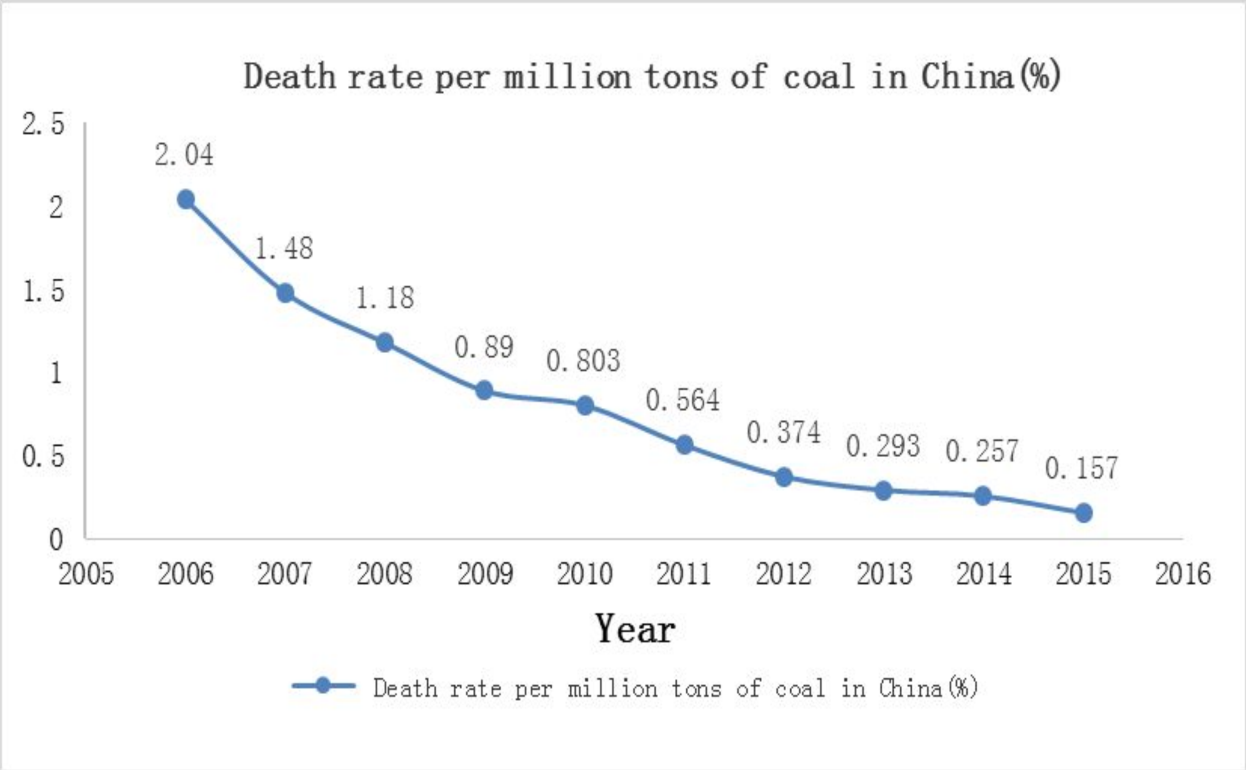

Fig. 6 Death rate per million tons of coal in China from 2006 to 2015

equation modeling problem that mathematical community can not solve.

Grey Forecast is a new concept, viewpoint and method of prediction obtained from the idea of modeling, correlation degree and residual identification of grey system. GM (1,1) model is currently the most widely used Gray Forecast Model. Symbol GM (1,1) is the meaning: G (grey), M (model) , (1,1), respectively, the first-order equation, a variable.

3.2 Examples forecast

Selecting death rate per million tons of coal in China from 2006 to 2015 to make GM (1,1) grey prediction. Thus we have:

$$x^{(0)} = [0.803 \quad 0.564 \quad 0.374 \quad 0.293 \quad 0.257 \quad 0.157] \tag{1}$$

$$x^{(0)} = [0.803 \quad 1.367 \quad 1.741 \quad 2.034 \quad 2.291 \quad 2.448] \tag{2}$$

It can establish the data matrix： B, y_N:

$$\mathrm{B} = \begin{bmatrix} -1.085 & 1 \\ -1.554 & 1 \\ -1.8875 & 1 \\ -2.1625 & 1 \\ -2.3695 & 1 \end{bmatrix}, \tag{3}$$

$$y_N = [0.564 \quad 0.374 \quad 0.293 \quad 0.257 \quad 0.157]^T \tag{4}$$

Through the formula

$$\hat{a} = (B^T B)^{-1} B^T y_N \tag{5}$$

we can get： $\hat{a} = \begin{bmatrix} a \\ u \end{bmatrix} = \begin{bmatrix} 0.2961 \\ 0.8654 \end{bmatrix}$

The numerical value of $\hat{a}$ is substituted into the formula

$$\hat{x}_{k+1}^{(1)} = \left(x_1^{(1)} - u/a\right) e^{-ak} + u/a. \tag{6}$$

And the forecasting models was established:

$$\hat{x}_{k+1}^{(1)} = 2.9228 - 2.1198 * e^{-0.2961k} \tag{7}$$

Through the formula

$$\hat{x}_{k+1}^{(0)} = \hat{x}_{k+1}^{(1)} - \hat{x}_k^{(1)}, \tag{8}$$

the calculation results from 2010 to 2015 are shown in table 1:

Table 1 Calculation results from 2010 to 2015

Number	Year	Actual values $x^{(0)}(k)$	Simulation values $\hat{x}^{(0)}(k)$	Residue values $\varepsilon^{(0)}(k)$
1	2010	0.803	0.803	0
2	2011	0.564	0.543	0.021

3	2012	0.374	0.404	-0.03
4	2013	0.293	0.301	-0.008
5	2014	0.257	0.224	0.033
6	2015	0.157	0.166	-0.009

4 Conclusions

4.1 Test precision

The average value of the original sequence: $\bar{x} = \frac{1}{n}\sum_{k=1}^{n} x^{(0)}(k) = 0.408$,

The average value of the residue values: $\bar{\varepsilon} = \frac{1}{n}\sum_{k=1}^{n} \varepsilon^{(0)}(k) = 0.00117$,

The variance of original sequence: $s_1^2 = \frac{1}{n-1}\sum_{k=1}^{n}\left[x^{(0)}(k) - \bar{x}\right]^2$=0.0561088,

The variance of residue values: $s_2^2 = \frac{1}{n-1}\sum_{k=1}^{n}\left[\varepsilon^{(0)}(k) - \bar{\varepsilon}\right]^2$=0.000513367,

According to the above results, we can find:

$$c = \frac{s_2}{s_1} = 0.0091 < 0.35,\ \ p = p\left\{\left|\varepsilon_1^{(0)}(i) - \bar{\varepsilon}_1^{(0)}(i)\right| < 066745 s_1\right\} = 1 > 0.95$$

Table 2 shows the accuracy of prediction results is good, reasonable and reliable.

Table 2 Precision inspection level

Prediction precision grade	P	c
Excellent	>0.95	<0.35
Good	>0.80	<0.5
Fair	>0.70	<0.45
Good	≤0.70	≥0.65

4.2 Forecast

Accuracy of the model meets the requirements, so the numerical value of next time serial number can be predicted. Through the time response function of mortality million tons of coal GM (1, 1), we can predict the fatality rate per million tons of China's coal mine in the next five years by assigning 7,8,9,10,11 to k. The prediction results are listed in Table 3.

4.3 Prediction result analysis

These prediction results led to the conclusion that the million tons mortality in China's coal mine decreased and the security situation of coal mine continues to improve. This prediction results is carried out under the premise of the model is accuracy and reliable. At the same time, the grey prediction with a rigorous and complete theoretical system and scientific analysis of the calculation method, and the relative error of prediction was lower than 10%. Thus, the prediction of the results are scientific and reliable which has great guiding significance of the coal mine safety management [9]. The million tons mortality in China's coal mine can not unlimitedly decrease to zero because of the

Table 3 Prediction results of the million tons mortality in China's coal mine

Number	Year	Actual values $x^{(0)}(k)$	Simulation values $\hat{x}^{(0)}(k)$
6	2015	0.157	0.1662
7	2016		0.1236
8	2017		0.0919
9	2018		00.684
10	2019		0.0508
11	2020		0.0379

science and technology development level, management level, coal mine mining factor and so on. Death rate per million tons of coal may change slow or stagnant or rebound when it reaches a certain value. Therefore, we must constantly updated data, establish the new model, use the new method to predict to ensure the reliability of scientific prediction.

5 Acknowledgment

Thanks a lot for Dr. Xiao-Guang Yue and Shun-Li Zhao. They give me lots useful suggestion for this project research.

References

[1] Zheng Ninglai. Coal will become the world's major energy in 2020. Petroleum Refinery Engineering, 2014, 44 (3):17.

[2] An Mingyan, Du Zesheng, Zhang Lianjun. Coal mine gas accident statistics analysis in China from 2007 to 2010 . Coal mine safety, 2011, 42 (5):177-179.

[3] Information on http://www.chinasafety.gov.cn/newpage/

[4] Chen Juan, Zhao Yaojiang. Statistical analysis of coal mine accidents in China in recent ten years and its inspiration . Coal Engineering, 2012, 44 (03):137 -139.

[5] Deng Qi, Liu Mingju, Zhao Fajun. China's coal mine accident statistical analysis in 2008 and countermeasures . Coal Technology, 2010, 29 (6): 14 - 16.

[6] Wang Zhongkui. Analysis of coal mine accident cause in Guizhou. Journal of Guizhou Polytechnic University (Natural Science Edition), 2008, 37 (02):15-18.

[7] Yu Bin. Discussion on the law of coal mine accident in Heilongjiang Province. Coal Technology, 2014, 33 (04):37-39.

[8] Deng Julong. Grey forecast and decision. Wuhan: Huazhong University of science and Technology Press, 1987

[9] Zhao Hongmei, Chen Kaiyan, Wang Chao. Grey prediction of the mortality of million tons of coal mine in China . Mining Safety and Environmental Protection, 2006, 8 (4).