Analysis of flood disasters from 206 BC to 1949 in China

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Abstract

Flood disasters produces not only direct economic losses but also serious environmental problems, the government attaches great importance to flood disasters prevention from ancient times to the present. A variety of analytic methods are adopted, for example mathematical model analysis, chart analysis, qualitative and quantitative analysis. Some mathematical models are constructed by means of statistical analysis of historical data for flood disasters, such as mathematical model for flood cycle each dynasty. There are the following results. First, there are 1037 times flood disasters from 206 BC to 1936, once every 2.07 years. According to analysis of mathematical model for flood cycle each dynasty from 206 BC to 1936, the flood cycle is the declining concave curve, except for the Five Dynasties. Second, in modern history, the most number of catastrophic floods is the Yellow River reaching 8 times, the Yangtze River 5 times. Finally, water pollution caused by floods can not be ignored. In 2012 92 percent of untreated rural sewage was discharged dispersedly.The vast majority of pollution load on the ground runs into directly riverway through stormwater runoff. Water wells are easily contaminated for germs and parasite. We should pay attention to water pollution caused by floods and combine organically flood control with water environment protection.The government coordinates closely ideas, rule of law, technology and investment with rural residents for governing rural sewage to reduce the risk of water pollution caused by floods.

Keywords: flood disasters, flood cycle model, qualitative and quantitative analysis, rural sewage, water pollution

1 Introduction

The flood is one of the major natural disasters not only in China but also in the rest of the world, governments around the world are very concerned about flood control issues. The Chinese government has pay high attention to flood and drought disasters involving livelihood issues [1,2]. The number of serious flood disasters from 1950 to 2004 reached 2606 times all over the world, involving 172 countries and regions, the total affected population of 2.75 billion, the economic loss of 347.235 billion dollars [3]. According to historical records and incomplete statistics, there is about once every two years [4]. The Yangtze River is vulnerable to flood disasters, during the 20th century, there are basin-wide floods in 1998, 1954 and 1931 [5]. The impact of floods on China's national economy is much larger than the impact on the United States [6]. It is necessary to research on flood disaster, which can provide a reference for government policy makers.

Floods has also produced a series of environmental issues, for example, the destruction of the ecological environment, the destruction of arable land, the destruction of the river system, the pollution of the water environment,especially water pollution.In 2012, the discharge of rural waste water across the country was 32.2 million t every day, most of sewage is discharged directly. Rural sewage, acid rain, agricultural pollutants, and other rural pollutants will enter into natural water environment by surface runoff. Therefore, we need to focus on the impact of floods on the water environment.

There are many effects of flood hazards.Analysis of flood disasters should choose a variety of analytic methods combined with qualitative analysis and quantitative analysis, such as mathematical models, mapping analysis, spreadsheet analysis, comparative analysis.

2 The national flood disasters in ancient times

Chinese history is usually divided into ancient history, modern history and New China, ancient history means the period before 1840, modern history means the period from 1840 to 1949, New China means the period since 1949. In ancient times in China, there are many legends about disasters of flood and waterloging, due to lack of historical data records and physical proof, it is difficult to analyze the conditions of disasters of flood and waterloging in detail. Until the Qin and Han dynasties, there are more historical data, historical records are quite specific. According to the history of the Chinese famine writed by Deng Tuo [7], there are 2142 years during the period from 206 BC to 1936, the flood disasters statistics is shown in Table 1, the flood frequency is shown in Figure 1. The mathematical model of the flood cycle is constructed by means of statistical analysis of historical data for flood disasters. 1 corresponds to the Han dynasty. 2 corresponds to the Weijin dynasty. 3 corresponds to the Northern and Southern Dynasties. 4 corresponds to the Sui and Tang Dynasties. 5 corresponds to the Five Dynasties. 6 corresponds to the Song dynasty. 7 corresponds to the Yuan dynasty. 8 corresponds to the Ming dynasty. 9

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corresponds to the Qing dynasty. 10 corresponds to the Republic of China for the mathematical model of the flood cycle as follows:

$$y = 5.9307x^{-0.6763}, \quad (1)$$

where y is the flood cycle of dynasty, x is 1, 2, …, 10.

The flood cycle is the declining concave curve from 206 BC to 1936 in China, except for 5 representing for the Five Dynasties.

TABLE 1 The flood disasters statistics from 206 BC to 1936

Dynasty	Number of flood disasters
The Han dynasty	76
The Weijin dynasty	56
The Northern and Southern Dynasties	77
The Sui and Tang Dynasties	120
The Five Dynasties	11
The Song dynasty	193
The Yuan dynasty	92

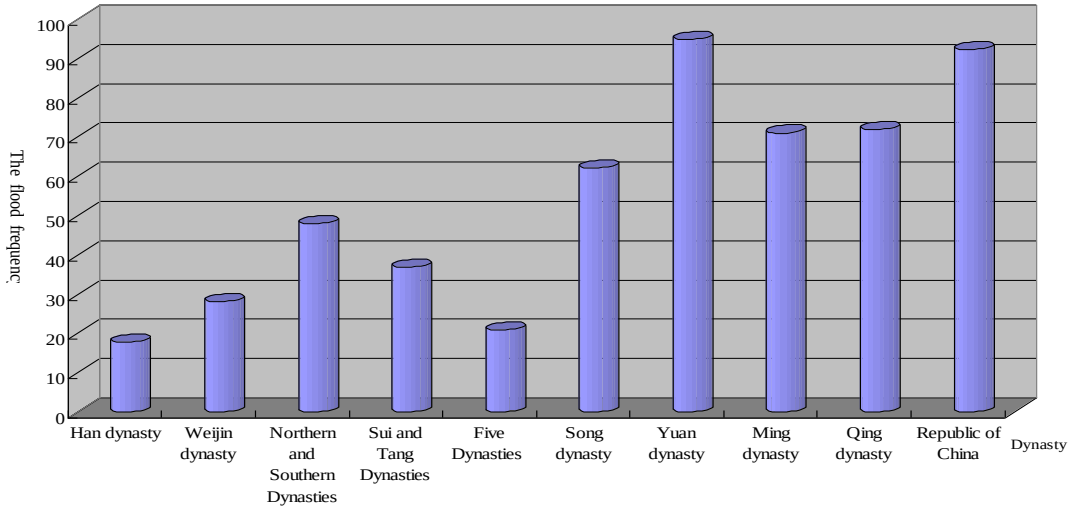

FIGURE 1 The flood frequency (%) of flood disasters from 206 BC to 1936

Table 1 shows that there are 1037 times of flood disasters from 206 BC to 1936 in China.At the same time, changing characteristics of flood frequency is depicted by graphing method. Figure 1 shows that the trends in flood frequency is divided into two phases in ancient times in China. The first stage from the Han dynasty to the Five Dynasties, flood frequency is relatively lower. The second stage from the Song Dynasty to the Qing Dynasty, flood frequency is relatively higher. There are 1165 years from the Han dynasty to the Five Dynasties,and 340 times of flood disasters, the flood frequency of 29.2 percent on average; 951 years from the Song Dynasty to the Qing Dynasty, times years of flood disasters,the average flood frequency 70.8 percent. However, the average flood frequency in Yuan Dynasty reached 94.8 percent, which is the highest flood frequency in the ancient Chinese dynasties, and is the dynasty of the most frequent occurrence of floods. Meanwhile, the flood frequency reached 92.3 percent from 1911 to 1936 in Republic of China. The average flood frequency from the Song Dynasty to the Qing Dynasty is 2.4 times from the Han dynasty to the Five Dynasties. Therefore, whether it is the first stage or second stage, basically first increase and then decrease, but generally speaking, the flood frequency is the rising trend from the Han dynasty to the Qing Dynasty. In ancient flood statistics, due to various conditions limits,it is difficult for precise statistics,but there is a very obvious trend that the flood frequency is higher and higher.

3 The flood disasters in ancient times in the yellow river valley

The Yellow River valley is the China's political, economic and cultural center in ancient times, in the Spring and Autumn and Warring States Period, there are historical records of flooding of the Yellow River. According to the records statistics of history books and local chronicles [7], the flood disasters statistics in the Yellow River valley is shown in Figure 2 in ancient times. Here, the flood disasters indicates the scope of flood disasters including most parts of middle reaches or the middle and lower reaches of the Yellow River,the flood situation is very serious disaster.

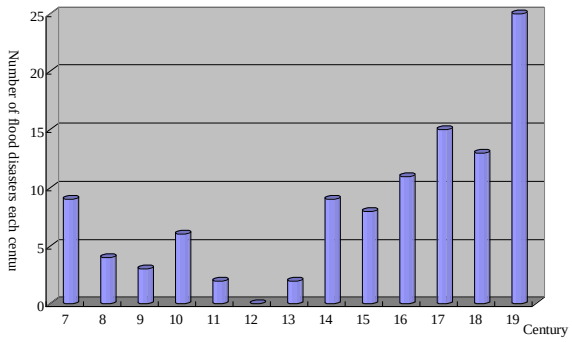

FIGURE 2 The flood disasters situation in the Yellow River valley from the 7th century to 19th century

The mathematical model of flood disasters is constructed in the Yellow River valley from the 12th century to 19th century. If 1 means the 13th century, 2 means the 15th century, 3 means the 17th century, 4 means the 19th century,as follows for the mathematical model of flood disasters:

$$y = 7.6x - 6.5, \quad (2)$$

where y is the number of flood disasters each century, x is 1,2,3,4.

1 corresponds to the 12th century, 2 corresponds to the 14th century, 3 corresponds to the 16th century, 4 corresponds to the 18th century for the mathematical model of flood disasters as follows:

$$y = -1.75x^2 + 12.85x - 10.75, \quad (3)$$

where y is the number of flood disasters each century, x is 1,2,3,4.

At the same time, changing characteristics of flood disasters is depicted by graphing method. Figure 2 shows that on the whole number of flood disasters first decrease and then increase in the Yellow River valley from the 7th century to 19th century. Number of flood disasters reached 26 from the 7th century to 13th century, average 3.7 times per century, in other words, floods occur once every 27 years. At the same time, the flood did not happen in the 12th century. Number of flood disasters reached 81 from the 14th century to 19th century, average 13.5 times per century, once every 7.4 years. On the whole, number of flood disasters reached 107 from the 7th century to 19th century, average 8.2 times per century, once every 12.2 years, but once every 4 years in the 19th century. It can be seen that the flood disasters is relatively severe from the 16th century to 19th century, particularly in the 19th century.

4 The flood disasters in ancient times in other river basins and region

In other river basins in China, floods also often occur, and caused huge losses of people's lives and property. According to the historical data of the main river and region in china, through further statistical analysis, flood disasters statistics of the main river and part of region in china is shown in Table 2 in ancient times [7-19], the flood cycle is shown in Figure 3.

TABLE 2 The flood disasters statistics of the main river and part of region

River and region	Time	The flood frequency (%)
The Yellow River	From 602 BC to 1938	62.60
The Huaihe River	From 1279 to 1840	12.46
The Haihe River	From 1368 to 1840	65.54
The Yangtze River	From 618 to 1911	17.23
The Yellow Sea coast	From 798 to 1949	125.00
The Southeast coast	From 66 to 1911	91.39
The Jiangsu and Zhejiang coast	From 1368 to 1911	3.13
Hunan province	From 221 BC to 1644	3.16
The Jianghan Plain	From 1276 to 1911	55.56
The Guanzhong Reach of Weihe River	From 1600 to 1859	41.15
Kaifeng Area	From 1644 to 1911	29.10
The middle reaches of river Fenhe	From 1644 to 1911	38.81
The Sushui River	From 1368 to 1911	16.18
Jinan city	From 1644 to 1911	41.04
Wuzhong region of Ningxia	From 1644 to 1911	34.33
Yulin Area	From 1369 to 1644	42.75
Jinghe River valley	From 618 to 907	28.28
Luohe River Basin	From 1368 to 1644	20.22
Liaoning Province	From 1791 to 1911	64.46

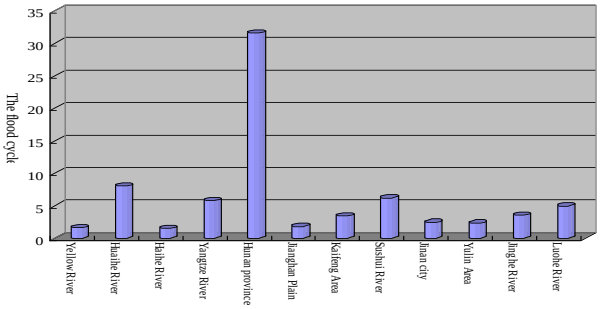

FIGURE 3 The flood cycle in the main river and part of region

According to records of governance and development of the Yellow River, the Yellow River flooding reached 1590 from 602 BC to 1938, there are a total of 543 years of flooding, the larger watershed change course 26 times. On the basis of the rough estimate based on historical data, the Yangtze river basin flooding reached 223 from 618 to 1911, once every 5.8 years on average. Among them, 16 times in Tang dynasty, once every 18 years; 79 times in Song and Yuan dynasty, once every 5.2 years;128 times in Ming and Qing dynasty, once every 4.2 years. Figure 3 shows that Hunan's flood cycle is longest, once every 31.6 years; The shortest cycle in Haihe River, once every 1.5 years, which shows a very high flood frequency of Haihe River; The remaining flood cycle, once every 3.8 years, in addition to Hunan Province.

Because historical records of floods is relatively simple in ancient times in China, it is difficult for accurate statistics of flood conditions. But some historical documents record the floods situation of part of the river and the areas, it can be used as one of research information. Currently, there are some other scholars researching on flooding of part of the rivers and regions, some research results are as follows. The floods disasters in the Tang Dynasty in Jinghe River valley can be divided into three periods, the medium-term flood-prone period, early and late period of less frequent floods [18]. Annual total flood duration day's and annual average flood duration days increase in the period from 1736 to 1948 in china [19]. The dominant periods are different in different times, which are the centennial scale oscillation during from 1644 to 1833 [20].130 flood disasters occurred in the Guanzhong region of the Weihe River Basin in the Qing Dynasty, once every 2.06 years on average, the occurring frequency of flood disasters increased obvio-

usly in the middle and late stages of the Qing Dynasty [21].

The major kinds of floods were mountain torrents and river torrents in Ancient Hunan, which brokes out more and more frequently from distribution of time [8].The earliest record of flood disasters in Liaoning Province is the first year of Ming King Emperor in 237. According to the historical records of Wei Kingdom Survey in History of the Three kingdoms, in the fall of the July, there were ten days of continuous rainfall, the water level of the Liaohe River rised. According to the statistical analysis of recorded data, there were a total of 78 floods during the period from 1791 to 1911,of which: catastrophic floods 4 times, serious floods 24 times, common floods 50 times; consecutive 3-year floods 3 times, consecutive 4-year floods once, consecutive 5-year floods 5 times, consecutive 6-year floods 2 times, consecutive 7-year floods once, consecutive 9-year floods once; in flood years, the interval of 1 year 11 times, the interval of 2 year 4 times, the interval of 3 year 4 times, the interval of 5 year once. Flood period in Liaoning Province is 1.6 years on average once, the average flood frequency is 64.5 percent.

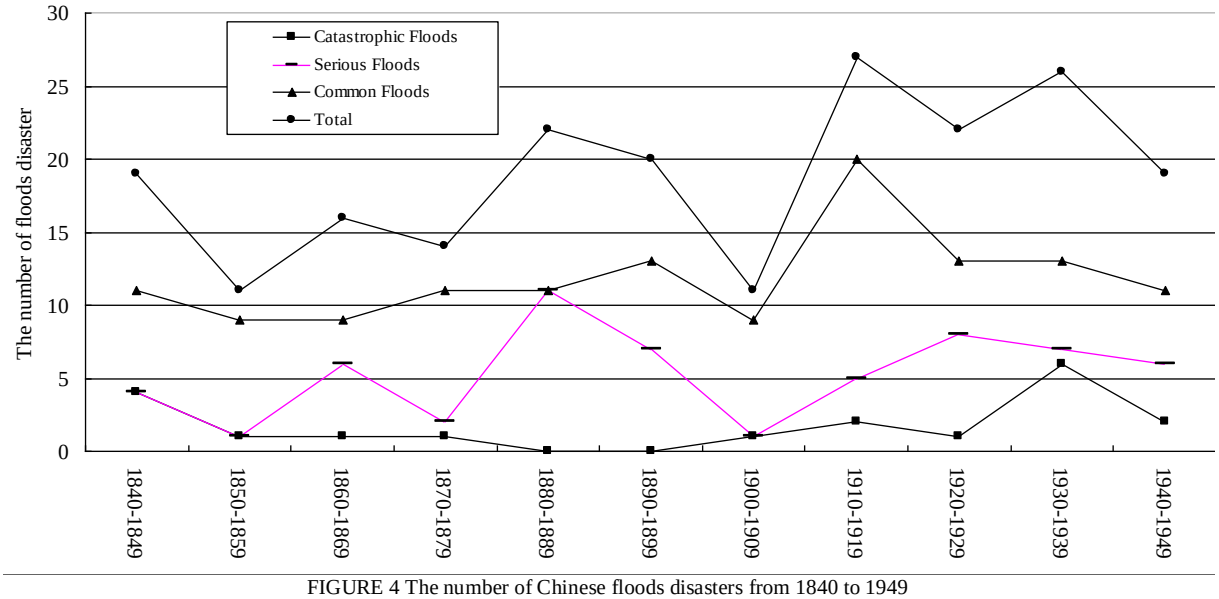

FIGURE 4 The number of Chinese floods disasters from 1840 to 1949

5 The national flood disasters in modern times

Although there was still in semifeudal and semicolonial society, the historical records of flood disasters in modern history is relatively better than in ancient times in China.The national and local flood situations were recorded in accordance with flood time, flood danger and the different basins. In order to better record the actual situation of the flood, the flood is divided into catastrophic floods, serious floods and common floods. Catastrophic floods means flood frequency below 5 percent, serious floods from 5 percent to 10 percent, common floods from 10 percent to 20 percent. Meanwhile, according to the distribution of China's major rivers, the flood situation was recorded in different rivers. According to the Chinese flood disasters chronology from 1840 to 1949 [4,7], 10 years as a unit of measurement, the number of Chinese floods disasters is shown in Figure 4 from 1840 to 1949, the number of affected counties is shown in Figure 5 every 10 years.

1 corresponds to the period from 1840 to 1849, 2 corresponds to the period from 1850 to 1859, 3 corresponds to the period from 1860 to 1869, 4 corresponds to the period from 1870 to 1879, 5 corresponds to the period from 1880 to 1889, 6 corresponds to the period from 1890 to 1899, 7 corresponds to the period from 1900 to 1909, 8 corresponds to the period from 1910 to 1919, 9 corresponds to the period from 1920 to 1929, 10 corresponds to the period from 1930 to 1939, 11 corresponds to the period from 1940 to 1949 for the mathematical model of the flood cycle as follows:

$$y = 0.12x^2 - 1.3224x + 4.1394, \quad (4)$$

where y is the number of catastrophic floods, x is 1, 2,…, 11.

Figure 4 shows the number of floods disasters in different time periods, 10-year as a time period, including the number of catastrophic floods, serious floods, common floods and total floods. The most number of catastrophic floods is the period from 1930 to 1939 reaching 6 times, secondly from 1940 to 1949 4 times, then from 1910 to 1919 and from 1940 to 1949 2 times, but from 1880 to 1889 and from 1890 to 1899 zero time. The most number of serious floods is the period from 1880 to 1889 reaching 11 times, secondly from 1920 to 1929 8 times, then from 1890 to 1899 and from 1930 to 1939 7 times. The number of catastrophic floods and serious floods is the most period from 1930 to 1939 totaling 13 times, meanwhile,the affected counties most totaling 2339.

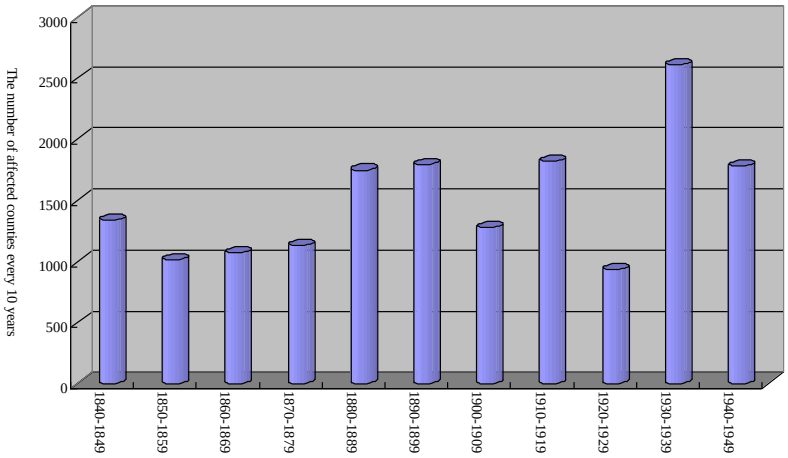

FIGURE 5 The number of the covered counties every 10 years from 1840 to 1949

Figure 5 shows that the number from 1840 to 1949 is the most affected counties in 1931 reaching 592, secondly in 1935 368. The catastrophic floods frequency or serious floods frequency is 130 percent during the period from 1930 to 1939; from 1880 to 1889 110 percent, but no catastrophic floods; from 1920 to 1929 90 percent; from 1840 to 1849 and from 1940 to 1949 80 percent; only the lowest frequency in the period from 1850 to 1859 and from 1900 to 1909 20 percent. It can clearly be seen that there is a increasing trend in floods disasters in the late modern history, especially during the period from 1930 to 1939.

6 The flood disasters of the major rivers in modern history

There are seven major rivers in China, including the Yangtze River, the Yellow River, the Pearl River, the Huaihe River, the Hailuanhe River, the Liaohe River, the Songhua River. In modern history, the major rivers in china occurred the serious floods, according to the Chinese flood disasters chronology from 1840 to 1949[4], by further analysing, the number of floods disasters of the major rivers is shown in Figure 6, the flood cycle is shown in Figure 7, the size distribution of flood is shown in Figure 8.

Figure 6 shows the number of floods disasters in different river. Figure 8 shows the size distribution of flood in modern history. China's seven major river floods is mainly the common floods, secondly the serious floods, and then the catastrophic floods. The most number of catastrophic floods is the Yellow River reaching 8 times, secondly the Yangtze River 5 times, then the Pearl River 3times, the Huaihe River 2 times, the Hailuanhe River and the Songhua River once, but the Liaohe River no catastrophic floods. The most number of serious floods is the Yangtze River reaching 21 times, secondly the Yellow River 11 times, and then the Liaohe River 7 times, the least the Songhua River only 2 times. Basically, the trend of the common floods and the total number of floods is same as the serious floods, the most number the Yangtze River, secondly the Yellow River, and then the Liaohe River, the least the Songhua River. This shows that china's seven major river floods are basically the same trends with the exception of catastrophic floods, but catastrophic floods mainly focusing on the Yellow River, the Yangtze River and the Pearl River, especially the Yellow River and the Yangtze River.

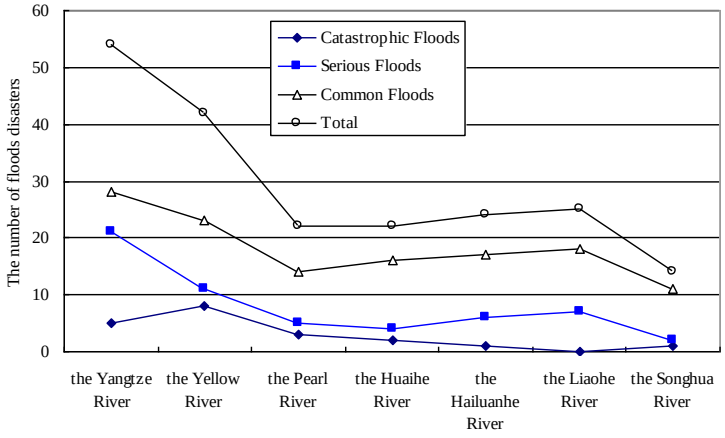

FIGURE 6 The number of floods disasters of the major rivers from 1840 to 1949

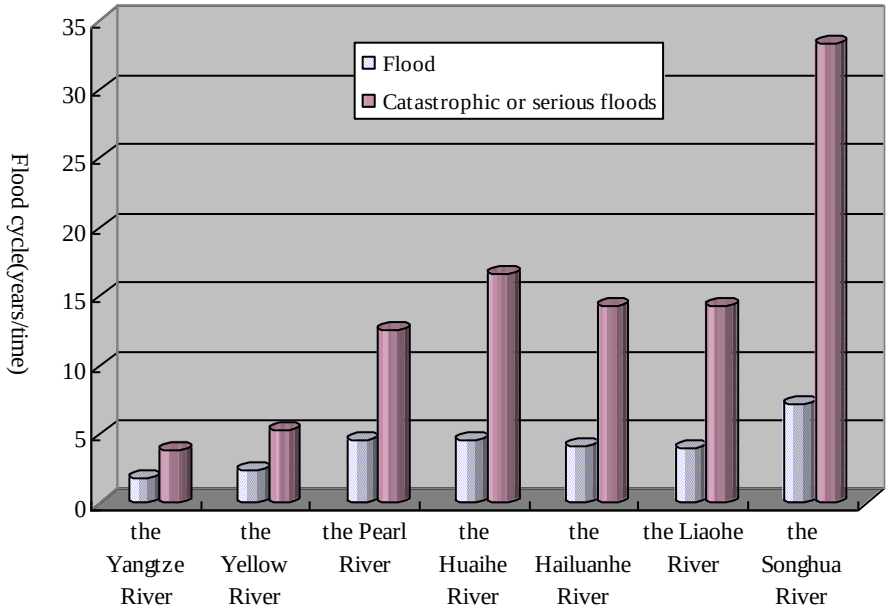

FIGURE 7 The flood cycle of the major rivers from 1840 to 1949

Figure 7 shows the flood cycle of the major rivers. The shortest cycle of the major rivers in China is the Yangtze River, the flood cycle once every 1.85 years, the catastrophic floods or serious floods once every 3.85 years; Secondly, the flood cycle of the Yellow River once every 2.4 years, the catastrophic floods or serious floods once every 5.3 years; This shows the flood happened in very high frequency in the Yangtze River and the Yellow River, on the whole the flood frequency of the Yangtze River higher than the Yellow River, But the number of catastrophic floods in the Yellow River is more than 60 percent of the Yangtze River. However, the longest cycle is the Songhua River, the flood cycle once every 7.1 years, the catastrophic floods or serious floods once every 33.3 years. Generally speaking, the variation trend of flood cycle is same as the catastrophic or serious floods with high similarity.

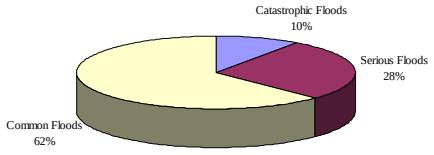

FIGURE 8 The size distribution of flood from 1840 to 1949

7 The water pollution caused by floods

Water pollution caused by floods can not be ignored. Rural sewage, garbage, dead animals, agricultural pollutants, toxic substance diffuse with the flow during the flood. Rivers, ponds and wells are easily contaminated for germs and parasite, which results in a variety of disease outbreaks and endanger seriously people's health. For example, in 1991, in the hardest-hit areas caused by floods in Anhui, the total number of bacteria was 10 times higher than standards for drinking water quality, escherichia coli was 700 times higher than standards for drinking water quality. In 2012, the discharge of rural waste water across the country was 11.7 billion t. Because operation and management for rural sewage treatment is relatively backward, sewage treatment rate is very low [22]. 92% of rural sewage untreated was discharged dispersedly on the ground. Agricultural pollution has become the dominant source of water pollution in China. In 2009, the total COD discharge of agricultural pollution was 12.8 million t, the total TN discharge was 3.46 million t, the total TP discharge was 460 thousand t [23]. Excessive amounts of pesticides and chemical fertilizer is on the ground. The vast majority of pollution load on the ground for rural sewage and agricultural pollutants runs into directly riverway through stormwater runoff. According to Report on the State of the Environment in China 2013, in 2013, among the 473 cities (counties) under monitoring, 210 cities (counties) had acid rain, accountting for 44.4%; 130 cities had acid rain frequency over 25%, taking up 27.5%; 43 had acid rain frequency over 75%, taking up 9.1%. In 2013, 29.6% of the cities (counties) had the annual average of precipitation pH value less than 5.6 (acid rain), 15.4% of the cities (counties) had the annual average of precipitation pH value less than 5.0 (relatively heavy acid rain) and 2.5% of the cities (counties) had the annual average of precipitation pH value less than 4.5 (heavy acid rain). For example, pH value for some reservoir in Zhejiang is low, which meet quality standards of water sources. In short, we should pay attention to the impact of flood on water environment.

8 Conclusion and suggestion

There are the characteristics of flood disasters in china including a wide range of floods, the frequent occurrence, the strong sudden and the large losses. In this paper, the flood disasters are analysed in ancient history, modern history and the impact of flood on water environment, conclusion and suggestion are the following:

First, before 206 BC, the relative lack of historical records of floods, until the Qin and Han dynasties, there are more specific historical records of flood. Therefore, the floods from 206 BC to 1840 are mainly analysed. There are 1037 times of flood disasters from 206 BC to 1936 in China. The flood cycle is the declining concave curve from 206 BC to 1936, except for the Five Dynasties. The trends in flood frequency is divided into two phases in ancient times in China, the first stage from the Han dynasty to the Five Dynasties, flood frequency is relatively lower; The second stage from the Song Dynasty to the Qing Dynasty, flood frequency is relatively higher. The flood disasters is relatively severe from the 16th century to 19th century in the Yellow River valley, particularly in the 19th century.

Second, in order to better record the actual situation of the flood, the flood is divided into catastrophic floods, serious floods and common floods. The most number of catastrophic floods is the period from 1930 to 1939 reaching 6 times, secondly from 1940 to 1949 4 times, then from 1910 to 1919 and from 1940 to 1949 2times,but from 1880 to 1889 and from 1890 to 1899 zero time. China's seven major river floods is mainly the common floods, secondly the serious floods, and then the catastrophic floods. The variation trend of flood cycle is same as the catastrophic or serious floods with high similarity.

Finally, we should pay attention to Water pollution caused by floods and combine organically flood control with water environment protection. By the rule of law and the media, the government strengthens publicity to raise public awareness of disaster prevention and water environmental protection, and organizes regularly the exercises of water pollution and flood disaster prevention. The government coordinates closely ideas, rule of law, technology and investment with rural residents for rural sewage governance. At present, there are no laws and regulations for rural sewage treatment in China. It is very important for urban and rural residents to change ideas of rural sewage treatment. It is good for rural sewage treatment, which can reduce the impact of floods on water pollution, especially the spread of germs and disease. Therefore, the government and residents should attach great importance to not only the direct loss of flooding but also the impact of the floods on water pollution.

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