Evolution Characteristics and Environmental Significance of Heavy Metals in Sediments of Yanma Reservoir

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Abstract. The sediment column samples of Yanma reservoir were collected. The sedimentary age of the column sediments were confirmed based on radioisotope ^{210}Pb dating means to calculate the deposition rate and to draw out the age trend chart of the quality changes of heavy metal elements and to analyse their related factors. According to the above data this study comparatively analysed the vertical distribution characteristics of five heavy metal elements (Cr, Cu, Zn, As, Pb) and investigated the relationship between the change of heavy metal concentration and the changes of natural environment, human activities as well as explore its referential meaning, provided the basis for the ecological management of Yanma reservoir. The results showed that the main heavy metal pollutants of the Yanma reservoir were Zn and Cr, followed by Cu, Pb and As. The water environment has been polluted gradually since 1958 the Yanma reservoir established. During 1993 -1997, the metal elements were obviously enriched and the water quality of the reservoir deteriorated obviously. During 1994-2010, the water pollution of the reservoir had been weakened, and the water environment had been improved effectively.

1. Research background

Reservoir is a semi artificial ecosystem, which is the lake built by people who using natural advantages. The usual way is to build dams in the middle and upper reaches of river, it forms a reservoir when the river floods the valley. Reservoir is easy to be affected by human activities. It has the characteristics of slow water flow, weak self-purification capacity, wide source of pollutants and complex species [1]. After the completion of the reservoir, not only the dynamic characteristics and water quality of the original river water have been changed, but also the contaminants such as heavy metals entering the reservoir have been massive deposited in the reservoir area because of the slow water flow rate [2]. Sediment is an important component of reservoir ecosystem. It is the source and sink of heavy metals. It not only accumulates heavy metals in the water, but also releases heavy metals into the water when the water conditions (redox potential, temperature, pH, dissolved oxygen, etc.) change, which poisons the aquatic life and transmitting through the food chain to pose a threat to human health [3]. Heavy metals refer to metals whose specific gravity is greater than 4 g/cm^3 or 5 g/cm^3, which density is usually greater than 4.5 g/cm^3. It is a persistent toxic pollutant that can directly or indirectly cause sudden or permanent harm to human health or the stability of the ecosystem through a variety of exposure pathways, such as rocks, soil, atmosphere, sediment, etc.[4]. Sediment is not only an immediate repository of heavy metals, but also a habitat and source of nutrients for aquatic organisms, which can produce serious biological effects, among it, more than 90% of the heavy metal load is fixed by suspended particulates or sediments[5]. Heavy metals are typical, long-term and cumulative contaminants, which can not be degraded directly after entering the water, but can be enriched hundreds of thousands of times in the sediment under such factors as adsorption, complexation and precipitation[6]. Heavy metals enriched in sediments tend to be dissolved and suspended again when environmental conditions change, forming secondary pollution [7]. As a result, the sediment of heavy metals can be used as an important indicator to evaluate water environment.

Because of the favorable sedimentary environment, reservoir sediments have the characteristics of large storage information and good continuity of deposition. Therefore, it can provide long time and high resolution environmental evolution sequences [3]. By studying the sedimentary history of heavy metals in the sediments of reservoirs, we can clarify the succession process of water pollution in reservoir basin and predict its future changes in water environment in order to provide an important basis for establishing reservoir pollutant benchmark and water environment management. The mass concentration and vertical distribution of heavy metals in reservoir sediments can reflect the historical deposition process of pollutants in water environment. Therefore, this study selected the sediment of Yanma reservoir as the studying object and discussed the vertical distribution of five heavy metals (Cr, Cu, Zn, As and Pb) in sediments, explored its time evolution characteristics and pollution characteristics and made a backward deduction of historical process of heavy metal pollution in water, which is in order to provide theoretical basis for the control and management of water pollution of the Yanma reservoir. Sediment is a sensitive indicator to reflect the space and time of water and sediment pollution, it is one of the most serious environmental problems in water ecosystem [4]. Because of the difficulty of bio-degradation and amplification, the heavy metals have great ecological harm to organisms and ecosystems. Heavy metals entering the reservoir,then, which entering the sediment through physical and chemical actions can pollute the sediments and the water environment seriously. Therefore, in order to reveal the temporal evolution and concentration changes of heavy metals in Yanma reservoirs, inverse the reason of heavy metal pollution and evaluate its impact on the environment, we studied sediment samples in representative areas of reservoirs. By using the ^{210}PbCRS model dating method for the determination to determine the sedimentary age of sedimentary rock column sediments and calculate the average content of heavy metals (Cr, Cu, Zn, As, Pb). Analyzing the temporal variation characteristics of heavy metals based on ^{210}PbCRS dating so as to explore the degree of pollution and possible causes of water pollution. Meanwhile, gaining the directive significance to the environment of the Yanma reservoir so that to provide reliable basis for the management of Yanma reservoir. At the same time, by analyzing the average contents of heavy metals (Cr, Cu, Zn, As, Pb) in sediments and the sources of heavy metals in Yanma reservoir, finding out the cause of change of heavy metal concentration so as to provide basis for harnessing reservoir water pollution from the root. It is beneficial to protect the living environment of the living beings in the Yanma reservoir, protect the ecological environment around the rock horse reservoir, and help to maintain the sustainable development of natural resources.

2. Journals reviewed

2.1. Research progress of heavy metals in sediments at home and abroad

Foreign scholars studied the pollution of heavy metals in rivers such as Amazon River, Mississippi River and the Danube at the early stage. At present, all important rivers including are basically included[8]. Foreign research content: Ahmed, El, Nemr, etc.[9] analyzed the total amounts of major heavy metals Al, Zn, Cu,, Ni, V, Pb, Cd and Hg in the surface sediments of the Red Sea coast of Egypt, and found the concentration of Al was the highest, the lowest concentration is Hg. Among them, the two heavy metals of Cd and Hg are seriously affected by human activities. Duyusen, E., Guven and Gorkem Akinci[10] studied the forms and mass concentrations of four heavy metals in Izmir, Inner, Bay sediments, which are Cr, Cu, Pb and Zn respectively. By analyzing its mass concentration to study the environmental Indication of the Heavy metal deposits, at the same time, the grain size of sediment has been studied carefully. WOITKE, etc.[11] studied the pollution status of heavy metals in suspended solids and sediments in The Danube. The heavy metal pollution in each reaches was evaluated by means of sediment enrichment coefficient method. CHARLES [12] studied the content of heavy metals in the sediments of Lahn and River rivers, calculated their concentration, and studied the spatial distribution of heavy metals and their pollution status according to the concentration of heavy metals in sediments. The total amounts of Cu, Pb, Zn, Cd and the characteristics of their forms which is changing with the seasonal in the sediments of Mapocho and River were studied by SEGURA, etc. [13], the results showed that the Pb content of the surface sediments in the river from upstream to downstream showed a gradual upward trend, Cu on the contrary appears a trend which is decreased gradually from upstream to downstream content. However, the distribution of Zn in sediments is irregular.

In the early days, domestic scholars investigated the environmental background value of Songhua River drainage system[14], at the same time the environmental background values of the lake water system in the Pearl River and the Yangtze River Basin were also studied. In recent years, a comprehensive environmental background value study has been carried out for the Yangtze River Basin and the the Yellow River River Basin[8]. At present, the studies of heavy metals in water sediments in China involve lakes, rivers, reservoirs and oceans, and the research which in the characteristics of heavy metal pollution and its environmental significance in sediments of lakes and rivers are more than those of reservoirs and oceans. However, scholars in China are gradually increasing the research on reservoirs, mainly from two aspects of time and space [15]. Scholars such As zhang fen[4] have studied 8 representative sediment sampling sites of Qingshan Reservoir in Zhejiang province, and the study emphasize on 7 kinds of heavy metal elements such as As, Cr, Cu, Ni, Mn, Pb and Zn so that analyzed its speciation and biological toxicity. By using Land accumulation index method (I_{geo}) and Hakanson potential ecological risk index method to evaluate the ecological risk of heavy metals in surface sediments of Qingshan Reservoir. Ma Yu and other scholars [16] analyzed the heavy metals in the sediments of the Pearl River Estuary, combining mathematical statistics so that to estimate the background values of five heavy metals (they are Cu, Pb, Zn, Cr and Ni respectively). Finally, by the pollution status of the Pearl River Basin is analyzed from the time scale and the historical process of heavy metal pollution is retrieved, it is found that the overall pollution level of Pearl River estuary is in a low level, heavy metal pollution areas are mainly located near the eight gates of the Pearl River, especially in the West Beach waters of the East Fourth gate. Bing Haijian and Wu Yanhong[17] scholars made a research on the middle and lower reaches of Yangtze River in different lakes area of sediment heavy metal elements, calculated concentration of metal elements and compared with the metal element background value, explores the spatial distribution of heavy metals in different lake regions. At the same time, evaluated the potential risk single elements and multiple elements of heavy metals in sediments of different lakes in the middle and lower reaches of the Yangtze River. After systematic analysis, the result shows that: Chaohu >Xijiu >Longganhu >Lake taibai. Lei , etc.[18] scholars studied 6 kinds of heavy metals in the sediments of typical reservoir areas in Danjiangkou, evaluated the pollution degree and environmental risk of heavy metals in sediments respectively. At the same time, analyzed the correlation and enrichment degree of each metal element which is based on the background value of heavy metals in the soil of Danjiangkou reservoir (yellow brown soil) and found that found that the sediment in the typical reservoir area of Danjiangkou is in high ecological risk state, and the ecological risk of Cd element is the main factor. Scholars from home and abroad have proposed more than 10 methods for the study of heavy metals in water sediment from the perspective of sedimentology. Among them, the land accumulation index method and the sediment enrichment coefficient method are the most commonly used methods for evaluating [15]. The overall analysis shows that, the study of heavy metals in sediments in China is mainly concerned with the temporal and spatial distribution characteristics of heavy metals, among them, the content of heavy metals is the most common evaluation index and there are few studies on the speciation of heavy metals. In recent years, scholars in China have made great progress in the study of heavy metals in water sediments, but there are still some shortcomings. For example, the ecological risk assessment standards of heavy metals in water sediment in China need to be improved continuously.

3. research area and research method

3.1. Overview of Yanma reservoir

The Yanma reservoir located in upstream from the central city Fengmao town in Zaozhuang Shanting District of Shandong Province, was founded in 1958, is the biggest reservoir of zaozhuang, shandong province one of the top ten reservoir, water quality protection target III for water quality. The reservoir is surrounded by hills and the water area of 16.7 km^2, the total capacity of 2.03×10^8 m^3, Hennessy capacity of 1.04×10^8 m^3, which has two dams , one is the main dam, the other is the auxiliary dam. The climate of zaozhuang is a temperate monsoon climate, and the average annual precipitation in the reservoir area of the Yanma reservoir is 765.8 mm, and the rainfall of June and September accounts for more than 75% of the rainfall in the whole year. In May 2011 Yanma reservoir was designated as the two water function area, which has the flood control, irrigation, power generation, industrial water supply, aquaculture, tourism and other six major functions, many fruit trees around, forming aunique geographical features of “ Mountain water town, Linhai orchard”. Water storage is An Ling River andjiuqu River and the reservoir area shows U type. The reservoir is located Fengmao town which has about 2.91×10^6 hm^2 of arable land, 1.997×10^6 hm^2 of woodland, 35 administrative villages. Because the villages and towns, villages and industrial districts are concentrated around the reservoir area, the environmental pollution is serious and has an impact on the water quality of the reservoir.

Figure 1. Sampling sites in Yanma Reservoir

3.2. Sample collection and pretreatment

In June 2010, in the Yanma reservoir position (35°11′51″N，117°21′46″E), the water level is 125 m, and the water depth is 15 m(see figure 1.), 1 sediment column samples (column length 60 cm) were collected from a polypropylene cylinder sampler made in Austria (8.7 cm in diameter). The sedimentary rock column has clear water at the interface and the suspended layer is undisturbed. Firtly,sealed back into the laboratory and placed in a cryogenic refrigerator, frozen at -50 °C for 48 h, and then using self-made cutting machine, according to 0.5 to 1 cm intervals for sampling, serial number, called wet quality. Secondly, using a freeze dryer to dry the sample and Call for dry quality (take the size of soybean sediment particles, other numbers stored for particle size test). Thirdly, after grinding 60 mesh sieves, take about 10 g in a plastic container of the same size as the standard source. Shake and seal. Place 21d for radioisotope (^{137}Cs, ^{241}Am, ^{210}Pb and ^{226}Ra) tests. Finally, the remaining samples are packed into the self sealing bag and sealed in numbers which are used for testing and analyzing the physical and chemical indexes of nutrients, heavy metals and so on. The samples were dried at low temperature and dried to remove impurities and milled over 200 mesh sieves for heavy metal determination.

3.3. Experimental and data processing

Take deposits of about 5g air dried sample, grinding, 200 mesh sieve, stamping mechanism of boric acid soil cake, application of Panalytical Axios X fluorescent element content of Cr, Cu, Zn measurement analyzer, As, Pb and other elements, the measurement error is less than 10%.All of the above tests were completed at the Key Laboratory of environmental change and ecological construction, Nanjing Normal University, Jiangsu.

Methods: the analysis of gamma ray analysis method using gamma rays, using the EG & G ORTEC production of high purity germanium detector P, DSPEC-jr2.0 and 16 K digital spectrum analysis system for determination of radionuclides ^{137}Cs, ^{241}Am, ^{226}Ra and ^{210}Pb. the main performance index of the gamma spectrometer for:The Co 1.33 Mev energy resolution is 2.25 Mev, the peak of more than 60 studies: 1, relative efficiency is 62%, the low base size lead chamber is diameter 28 cm×40 cm high, whose main body from the outside to the inside by 9.5 mm low carbon steel lined, with101 mm old lead, 0.5 mm tin and 1.6 mm soft copper lining system, the bottom is less than 2 CPS (40 Kev-2 Mev), has a good stability. Real time measurement of 40000 s samples, including the activity of ^{137}Cs by gamma ray at 661.6 Kev of peak area; the activity of ^{210}Pb by 46.5 Kev gamma ray spectrum peak area calculation;According to the specific activity of ^{226}Ra, ^{214}Pb (351.9 Kev) gamma ray spectrum peak area calculation; short half-life of ^{214}Pb is the decay product of ^{226}Ra, the specific activity of difference samples of $^{210}Pbex$ and ^{226}Ra for the specific activity of ^{210}Pb. The test and analysis of the sample were completed at the gamma spectrometer Laboratory of the school of Geographical Sciences, Nanjing Normal University.

^{210}PbCRS model dating method: the sediment of rock horse reservoir is continuous and stable in chronological order, and the sediment particles are relatively small. The ^{210}PbCRS dating method is based on the decay characteristics of the radioactive lead isotope ^{210}Pb, the intermediate product of the radioactive isotope 238U decay process. The sediments measured by ^{210}Pb are aged about 100 years.
Human activity coefficient method (*AF*): calculated according to (3-1)

$$AF = EI_S/EI_B \qquad \text{formula (3-1)}$$

Style: EI_S is the content of the target element; EI_B is the background value of the target element (see table 1.). When the *AF* value is about 1, the target elements in the sediments of the reservoir are mainly from the natural source, and >1.0 shows pollution.According to (3-1), the sedimentary rock column of Yanma reservoir is analyzed in this paper.

Table 1. Background value of the heavy metal elements（$mg \cdot kg^{-1}$）

Heavy metal elements	Cr	Cu	Zn	As	Pb
background value	60	13	40	7.5	15

The geological accumulation index method (I_{geo}), proposed by German scholar Muller, is also the most commonly used method to evaluate the heavy metal pollution in water sediment [20~22]. The formula for this method is:

$$I_{geo} = \log_2^{\left(C_n/1.5B_n\right)} \qquad \text{formula (3-2)}$$

Formula: C_n is the target element content, and B_n is the background value of the target element. The higher the I_{geo}, the greater the disturbance.
Data processing using Excel2010, using SPSS13.0 for data correlation analysis, using Grapher8.0 to draw data maps.

4. Data processing, analysis and evaluation of heavy metals in sediments of rock horse reservoir

4.1. Evolution characteristics of heavy metals in sediments of Yanma reservoir

According to ^{210}PbCRS dating results, this study was main analyzing the concentrations of heavy metals in sediments from 0 to 12 g/cm^2 (Since 1871 AD) sediment cores(see Figure 2.). The contents of two heavy metals in sediments are Zn, Cr, among it, the average content of Zn element is 152.08 mg/kg, the average content of Cr element is 121.68 mg/kg. This shows that the main heavy metal pollutants in rock horse reservoir are Zn and Cr, followed by Cu, Pb and As. In a sediment column, the two elements of Zn and Cr exhibit similar three stages change patterns. In the range of 9 ~ 12 g/cm^2 the change is weak, the element content with in 7 ~ 7.4 g/cm^2 and 7.4 ~ 9 g/cm^2 presents a surge sharply trend, and has a maximum value at 7.4 g/cm^2 and 8.4 g/cm^2, in the range of 0 ~ 7.4 g/cm^2, two kinds of metal elements were in trend weakened, especially the Cr remained stable state. The overall variation of As elements fluctuates greatly, but its content is the least. Pb elements are enriched at 7 ~ 9 g/cm^2, and have gradually slowed down in recent years. The content of Cu elements showed two peaks at 6.8 g/cm^2 and 9.6 g/cm^2, and there were two troughs at 1.9 g/cm^2 and 7.3 g/cm^2.

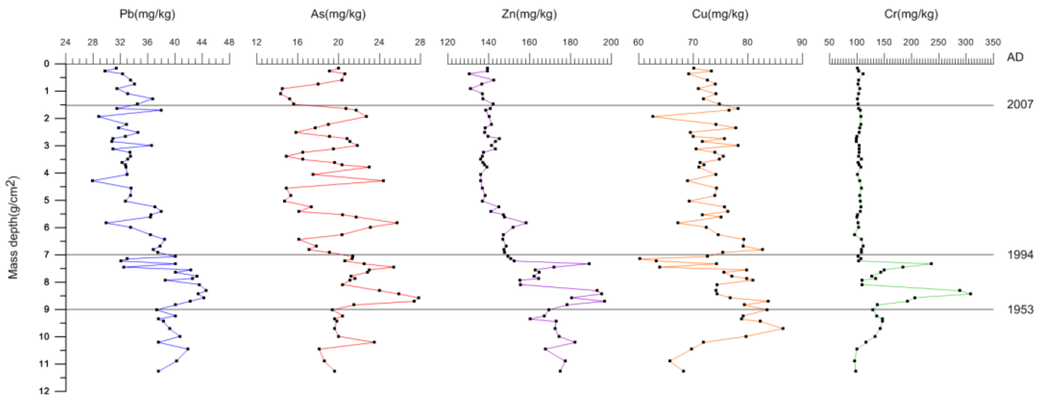

Figure 2. Concentrations of the heavy metals in Yanma Reservoir sediments

4.2. Sources of heavy metals in sediments

The sources of heavy metals in water sediments can be generally divided into natural sources and anthropogenic sources. Natural sources mainly come from natural physical and chemical processes of rocks and minerals and the anthropogenic sources are heavy metals that are emitted directly or indirectly by human activities, such as factory production, mining, metal smelting, fossil fuels, chemical fertilizers and pesticide use, etc. These all cause heavy metals to accumulate in water sediment[23]. The change of metal elements is not only affected by climate and hydrological factors, but also influenced by physical and chemical properties of sediments, man-made pollution and industrial development. Human activity coefficient method, when the *AF* value is about 1, the target elements in the sediments of the reservoir are mainly from the natural source, >1.0 indicates contamination. According to profiles of five(Cr, Cu, Zn, As and Pb), the *AF* of heavy metals (see Fig.3) , the sources of heavy metals in Yanma reservoir are anthropogenic sources. The data show that the order of heavy metal content in Yanma reservoir is determined by human activities: Cu >Zn >As > Pb>Cr. In this study, the average *AF* of Cu is 5.71, the average *AF* of Zn is 3.80 and the two elements, Cu and Zn, are relatively seriously affected by human activities. In the following, with a history of Shanting, the sources of heavy metals in Yanma reservoir are analyzed mainly from four aspects of agriculture, industry, transportation and human daily life.

Yanma reservoir is located Fengmao town, which agricultural land in 1983 was 1700 hm^2, reaching 1865 hm^2 by 2000. In 1983, 13,382 tons of chemical fertilizer was supplied in Shanting district. With the price of fertilizers rising in 1984-1994, the amount of cultivated land chemical fertilizer decreased, in 1995, there was a gap in fertilizer supply. In 1996, agriculture fertilizer turned into the high-efficiency fertilizers, such as urea, diammonium, and ammonium bicarbonate phosphate is unsalable. In 1999, the state abolished the mandatory plan and fertilizer was provided adequately. Fertilizer sales reached 35,062 tons in 2002. In 2002-2007, the government advocated standardized agricultural production and farmers' fertilization idea was changed. After 2007, farmers began to use formula fertilizer.

In the use of pesticides, there are more than 40 varieties of pesticides in Shanting District, such as "1605" dichlorvos, Long acting phosphorus, bactericide and methamidophos. In 1983, 252 tons of pesticides were sold. In February 1987, with the serious shortage, the sale of pesticides was 118 tons. In 1998, as the Shanting District established 30 "crops hospital", and a substantial increase the sales of pesticides increase substantially. By the end of 2002, a total of 1,574 tons of pesticides were sold in 20 years. But since 2000, the government has promoted green production and banned the use of highly toxic and highly pesticide residues.

In industrial field, in 1983, Fengmao town only a pingmou farm tool factory. In 1984, with the rapid rise of some enterprises, 14 factories were constructed, such as Lime factory, Quartz factory, Sacks factory and Cement plant. Since 1998, with the industrial restructuring of the town, revitalize the existing assets and the development of private enterprises, private enterprises reached more than 140 and became the first town of Lunan carton processing in 2010. The industrial districts in Fengmao town North shop Town were also expanding. While expanding industrial production, production technology has also been constantly updated, after 1995, the government advocated energy-saving emission reduction policy, the factory production process is more standardized.

In traffic, from 1983 to 2010, Shanting District was continuing to modify highway, the number of farm machines, buses and private cars were increasing. As a result, automobile exhaust emissions were increasing.

The population of Fengmao town was 50,780 in 2002, which increased to 52,602 in 2010. Residential housing was continuing to increase. In 2010 the implementation of "Dragon Garden" of the western town and the construction plans of" new rural Greenville community" of Nan Zhao Zhuang was to build a centralized city community. The increase of population leads to the increase of consumption of coal and other resources. In recent years, along with the Yanma reservoir tourism development, population flow Fengmao town also increased, human activities gradually strengthened.

Synthetic analysis, the use of pesticides and fertilizers in agricultural production is the major source of heavy metals of Zn, As, Cu and Cr in sediments of Yanma reservoirs and sewage and solid waste from people's lives are also one of the sources of heavy metals in sediments. Heavy metals As and Cu in sediments of Yanma reservoir may be introduced by waste water and fertilizer from factories surrounding Yanma reservoir and the human disturbance factors of Pb mainly come from the large amount of sewage and industrial waste water from the residents around the reservoir. In addition, the combustion of coal has also become an important source of Pb in the reservoir sediments and Pb elements in automobile exhaust gases enter the water through wet and dry deposition of the atmosphere. It is difficult to determine the specific sources of heavy metals only on the basis of data analysis, which needs to be supported by other indicators.

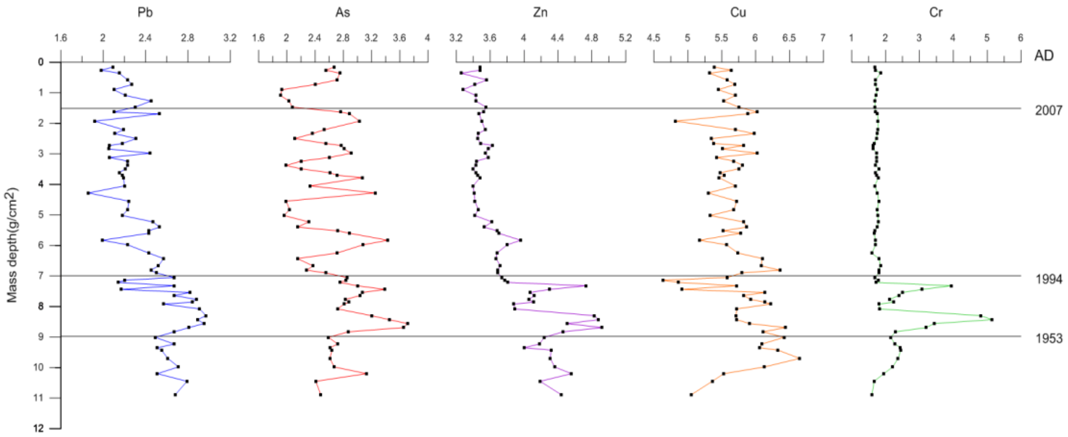

Figure 3. changes of heavy metals *AF* values in sediments of Yanma reservoir

4.3. Pollution characteristics and prediction evaluation of heavy metals in sediments of Yanma reservoir

In the geological accumulation method, The higher the I_{geo}, the greater the interference with human activity. Based on the analysis of I_{geo} data of heavy metals(see table 3.) and I_{geo} change profiles of heavy metals(see Figure 4.), it is shown that the order of interference of heavy metals by human activities is: Cu >Zn >As > Pb>Cr. The I_{geo} average of the Cu element is 1.92, and the average I_{geo} of the Zn element is 1.33 are in a period of less than I_{geo}<2. Therefore, the pollution degree of Cu and Zn two heavy metal elements is moderate to the water environment of Yanma reservoir. Cr's I_{geo} is the average of 0.38, As's I_{geo} average value is 0.81, the Pb element I_{geo} average value is 0.67, three kinds of elements I_{geo} were between 0-1. Therefore, the pollution degree of three heavy metals, Cr, As and Pb, on the water environment of Yanma reservoir were from zero to medium.

According to the picture analysis shows (see Figure 2.）, the mass concentration of heavy metals in the sediments of Yanma reservoir is arranged as follows: Zn>Cr>Cu>Pb >As. During the period of 1953-1994, the metal elements were obviously enriched, indicating that the heavy metal elements in sediments had a greater impact on the water environment, and the water quality of the reservoir deteriorated significantly, the main reason was as the rapid development of industry and transportation around the Yanma reservoir, people's ideas and traditions and do not pay attention to the management of the production process as well as excessive use of pesticides and fertilizers in agricultural production. 1994-2010 years, Zn and Cr two elements of the mass concentration is basically stable, the two metal elements on the water environment pollution is less affected, mainly As, Pb and Cu elements affect the water environment. The pollution of water environment in reservoirs is weakened, mainly because of with the economic development, the government advocates environmental protection as well as the strengthening of the environmental concept of local residents. In the future, with the development of Yanma reservoir tourism, if the Yanma reservoir administrative bureau has improved the scientific management of the Yanma reservoir and with the citizens' ecological quality improved, the water environment pollution of the Yanma reservoir will be controlled.

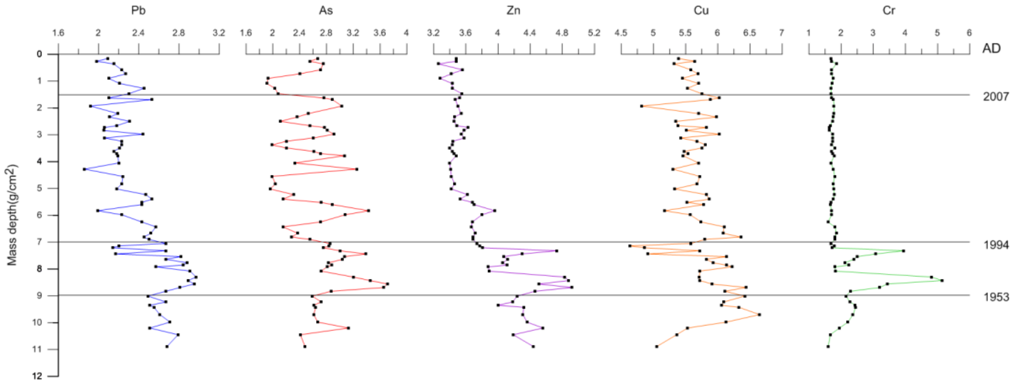

Figure 4. The changes of the heavy metals I_{geo} values in sediments of Yanma reservoir

Table 2. Classification of pollution index of geological accumulation index I_{geo}.

I_{geo}	$I_{geo}<0$	$0\le I_{geo}<1$	$1\le I_{geo}<2$	$2\le I_{geo}<3$	$3\le I_{geo}<4$	$4\le I_{geo}<5$	$I_{geo}>5$
level	0	1	2	3	4	5	6
Class of pollution	No	No-Mid	Mid	Mid-Heavy	Heavy	Heavy-More	More heavy

Table 3. I_{geo} average of heavy metal elements.

Heavy metal elements	Cr	Cu	Zn	As	Pb
I_{geo} value	0.38	1.92	1.33	0.81	0.67

5. Conclusion

The main heavy metal pollutants in Yanma reservoir are Zn and Cr, followed by Cu, Pb and As. Since the establishment of the reservoir in 1958, the water environment has been gradually polluted. During 1993 -1997, the metal elements were obviously enriched, and the maximum contents of Zn and Cr reached 196.6 kg/mg and 308.1kg/mg respectively, and the water quality of the reservoir deteriorated obviously. The pollution of the reservoir was most serious during the 5 years. During the 1994-2010 years, the content of Zn and Cr metal elements remained stable, and the content of Cu and Pb metal elements decreased relatively. The water pollution in reservoirs decreased, and the water environment was improved effectively. If there is no great change in the water body and the human factors can be effectively controlled, the water environment of the Yanma reservoir in the future may be maintained.
Risk assessment of heavy metals in sediments of reservoirs is a very complex task, involving heavy metals content, speciation, bioavailability and effectiveness. There are many researches on heavy metals in rivers and lakes in China. But the theory and technology of sediment research in water bodies of reservoirs are relatively weak, and few researches on Yanma reservoir have been done. This paper mainly studies the evolution characteristics of five heavy metal elements, Cr, Cu, Zn, As and Pb, the investigation of the heavy metal pollution in the reservoir did not involve the risk assessment of heavy metal pollution in the water sediment, the enrichment of the heavy metals, the occurrence form, toxicity and other aspects. We hope that the future can according to the purpose of evaluation, using the geoaccumulation index and risk prediction combined evaluation method and enrichment index method etc. to make a comprehensive evaluation of Yanma reservoir water environment and gain a comprehensive and accurate evaluation results. The spatial distribution characteristics of heavy metals in sediments of Yanma reservoir are less studied, it can be studied the spatial distribution characteristics of heavy metals in sediments of Yanma reservoir and make a research of the whole water environment of Yanma reservoir from two aspects of micro and macro and learn to analyze problems from multiple

perspectives. In addition, other metal elements such as Hg, Cd and W, which affect the sediment of Yanma reservoir, should be paid enough attention. The related results not only can be extended to the study of heavy metal pollution control in the sediment of Yanma reservoir, but also can provide reference for the establishment of management system.

Acknowledgments
We thank for Professor Yanghao and his group members in Nanjing Nomal University, China for their technical support. The study was supported by the Special Fund for Hotel Management Specialty of Zaozhuang University.

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