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Abstract: It is well-known that the water pollution of the Yangtze River basin is significant. Studies have shown that from the upper river to the lower river, the water volume decreases, the intensity of development is higher, and the pollution is more profound. Studies also find that pollution is even more significant in transboundary areas at the intersection of provinces and large cities. The Yangtze Estuary lies at the end of the lower river of the Yangtze River, where the waters flow directly into the East China Sea. The location is also at the transboundary cross-section of Jiangsu Province and Shanghai. Consequently, the water pollution in this region is the most serious. The Yangtze River Estuary not only provides drinking water to a vast number of people, but it also serves multiple other functions, including agricultural irrigation, tourism, inhabitation and aquaculture, and plays a pivotal role in local social and economic development and in people’s wellbeing in general. Directly or indirectly, the serious pollution of the aquatic environment in Yangtze River Estuary exerts negative influence on the socio-economic function of the Estuary and the neighboring areas. At the same time, the polluted water flows directly into the East China Sea, causing serious pollution and damage to the marine environment. In order to help policymakers and stakeholders have a better appreciation of the heavy economic loss and damage caused by rapid economic development, this paper uses ChongMing County of Shanghai as the study area, applying the concentration-loss model developed by James. We assess the economic losses caused by water pollution in the Yangtze Estuary from 2005 to 2013. We find that the economic sector most significantly affected by various pollutants is tourism, while the pollutant causing the greatest damage to the various functions of ChongMing County is chemical oxygen demand (COD). Based on this assessment and considering Shanghai’s strategic plan to designate ChongMing County as an “ecotourism county” and the “garden of Shanghai”, we point out that the county has already suffered significant economic loss as a result of the water pollution in the Yangtze Estuary. According to the estimated loss rate, the county has lost almost all of its tourism function and life water function. The inhabitation function also exhibits very severe damage. The loss of these functions also inhibits the development of industries such as catering, hospitality, trade and commerce, culture, etc. We conclude that the economic development of the upper river has brought with it tremendous economic cost and losses suffered by ChongMing County. This will impede significantly the realization of the current strategic goal of Shanghai. Therefore, we offer five suggestions. First, the government should develop a rational management mechanism for the Yangtze Estuary environment. Second, in order to curb with appropriate urgency the pollution of the Yangtze River aquatic environment, the government should develop transboundary compensation mechanisms. Third, researchers in this field should focus on the study of relevant theories and methodologies of assessing economic loss from water pollution. Fourth, educational institutions such as universities should address the needs of society and adjust their curricula to include subjects like environmental statistics, environmental economics, environmental information, environmental management technology, pollutant treatment technology, etc., to train more high-level professionals in relevant fields. Last, professional administration departments should strengthen cooperation with research departments, thus enabling the result of scientific research to play its due part in the real world.

Key words: Assessment; ChongMing County; Yangtze Estuary; water pollution; economic loss

1. Introduction

It is well known that, with the increasing intensity of exploitation of water resources, the pollution of the aquatic environment in the Yangtze River basin is more and more extreme. In the 1970s, the volume of the wastewater discharged into the river was approximately 95 billion tons. More recently, it has increased to 270 billion tons, with an annual increase of 5% (Zhi Wang Shen et al. 2006). Noting the differences in flow, industrial development, and water quality, Li Qian conducted a cluster analysis of pollution in the aquatic environment and arrived at the following conclusions: regarding Shanghai and Jiangsu Provinces, which are at the lower river where the overall flow is diminished and the flow speed is slow, self-purification capacity is poor. In addition, areas along the river are densely populated, with high economic development (Qian Li and Zhang Jian Hui 2011). In terms of the emission of pollutants into the river, these two locations rank highest. Concomitantly, the river registers a significant quantity of pollutants, and the surface water is severely polluted. According to the China Marine Environment Quality Bulletin, from 2004 to 2012, the Yangtze River has historically been the greatest source of pollution for the East China Sea.

There are many factors that have led to the extreme deterioration of the aquatic environment in the Yangtze River basin, with transboundary pollution among the most significant. The lack of rigorous monitoring mechanisms, the existence of a large number of construction projects in the region, and the discharge of wastewater without treatment both within and across the boundary are the primary factors causing the pollution (Zheng Shou Ren 2004). In 1998, the Bureau of Water Resources Administration under the Yangtze River Water Resources Commission established 35 monitoring points at cross-sections along the river. By 2003, the number had grown to 53. From the monitoring results, we can see that the most serious pollution takes place at the cross-sections (Yuan Li Yuan 2006).

The Yangtze River Estuary (Fig.1-1) is located not only at the end of the lower river, but also at the cross-section of Jiangsu Province and Shanghai. Consequently, this location has the most serious pollution and the greatest impact on the marine environment of the East China Sea.

Scholars and administrators are actively exploring effective solutions to the problem of cross boundary pollution, and the mechanism of cross boundary compensation is considered to be a relatively effective approach (Zhou Hai Wei and Tang Zhen 2007).The design and implementation of such a compensation mechanism is a very complicated systematic project, however, which involves not only the defining of responsibilities, but also includes ecological compensation and cross boundary economic compensation. Cross boundary economic compensation is a key initiative in internalizing the external costs of environmental pollution, and calls for the assessment of cross boundary economic losses in advance (Yu Hou 2012).

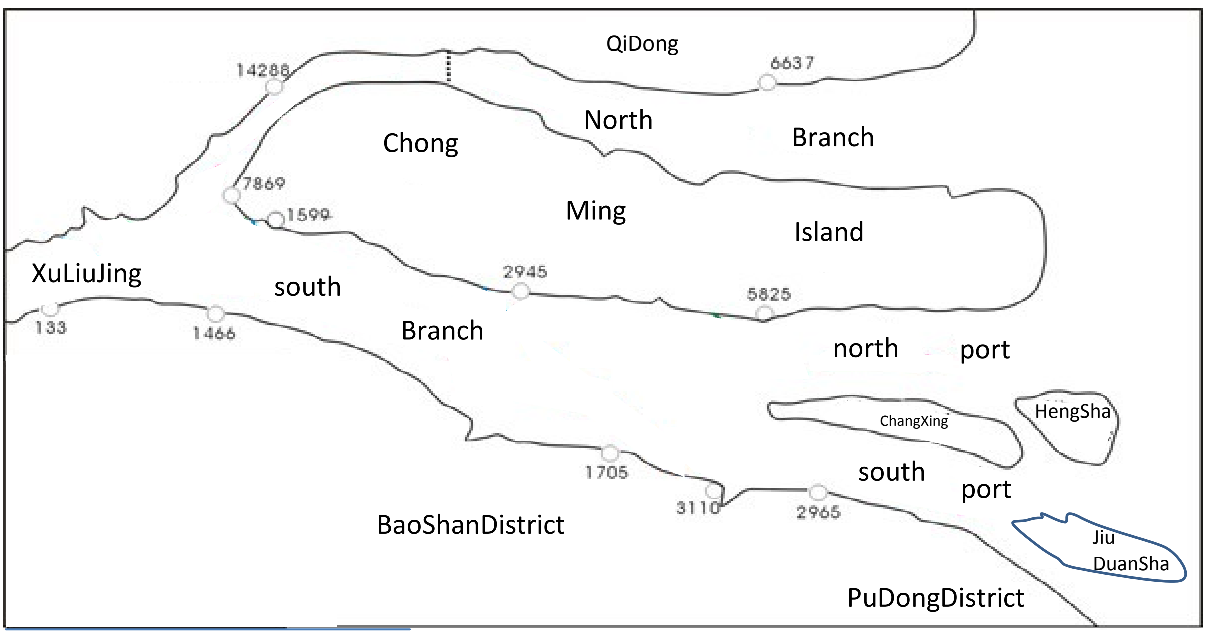


Figure 1-1. Yangtze Estuary

Most of the recent studies of Yangtze Estuary focus on the environmental change caused by pollutants, the composition of sediment, and the change in the sediment content, etc. Few researchers engage in the study of cross boundary compensation of economic losses caused by water pollution in the Yangtze Estuary. There are few studies on the assessment of economic loss from cross boundary pollution. To solve the problem of cross boundary water pollution and eliminate the cancerous influence on the East China Sea marine environment, the mechanism of cross boundary compensation is key. However, in order to design an effective cross boundary compensation mechanism, it is necessary to assess the economic losses caused by water pollution of the Yangtze Estuary.

ChongMing County of Shanghai is located at the center of the Yangtze Estuary and is surrounded by the waters of the lower river. Over the years, it has been affected the most by the pollution of the aquatic environment of the Yangtze Estuary. Therefore, we focus on the assessment of economic losses suffered by the county as a result of water pollution in the Yangtze Estuary. We hope to raise the awareness of authorities, polluters, and stakeholders, so that policymakers can develop relevant policies and management mechanisms that can be replicated and promoted to improve the quality of the aquatic environment in Yangtze Estuary and the entire East China Sea.

Articles in the literature about the Yangtze Estuary number no more than 5900 in the China Academic Journals full-text (CNKI) database. If we search within the above results using the keyword "pollution," there are only 14 citations that relate to Yangtze Estuary pollution. Within these 14 citations, researchers mainly focused on the reasons for the Yangtze Estuary pollution, on the damage to the environment of the Yangtze Estuary (especially to fish), on the assessment of eco-environmental risk of the Yangtze Estuary, and so on。We did not find any research about the assessment related to economic loss from water pollution in the Yangtze Estuary.

2. Defining the Area, Function Analysis, Selecting the Method, and Collecting Data for the Study

2.1 Defining the Area for the Study

The cross boundary pollution of the Yangtze River Estuary involves three administrative units of Shanghai city in the lower river region. They are the Baoshan District, the Pudong New District, and ChongMing County. While relying on the Yangtze River Estuary for resources, these three areas have a large population and a very prosperous local economic development. Baoshan District and Pudong New District have a certain number of dwellings and businesses along the river, but they also have a considerable number of social economic activities that are far from the river and the coast. The social and economic activities are either not directly affected by the waters of the Yangtze River, or the influences are too complex to separate from one another to conduct an individual study. ChongMing County is made up of three islands that are all located in the middle of Yangtze River Estuary: ChongMing, ChangXin, and HengSha, with a total area of 1,411 square kilometers and a 2012 household population of 688,000 people (data are from Year Book of ChongMing County in 2013). The polluted water from the estuary flows along the coast surrounding the area and into the East China Sea. All of its water resources depend on the waters of the Yangtze River, so it is most seriously affected by the pollution of the river. At the same time, over the years, the Municipality of Shanghai has focused on making the county into an ecological county and the garden of Shanghai. In addition, ChongMing County is also a regulator for the balance of ecological systems in Shanghai. Based on all of the above reasons, we selected ChongMing County as the research object.

2.2 Function Analysis about the Yangtze Estuary in ChongMing County

The waters of the Yangtze River Estuary serve the following functions in supporting ChongMing County: (1) Agricultural irrigation: Every year, the waters of Yangtze River Estuary support tens of thousands of hectares of irrigated area in the county, making it a significant agricultural county of Shanghai and an important provider of grains and vegetables. In 2013, the county had an agricultural output value of 6.1 billion Yuan, of which, 3.14 billion Yuan are from farming, 1.04 billion Yuan are from animal husbandry and 120 million Yuan are from forestry (data are from agricultural committee of ChongMing County). (2) Aquaculture: Supported by the resources of the Yangtze River, ChongMing County has always been ideal for producing aquatic products. ChongMing crab is renowned in China and abroad. Historically, the Yangtze River Estuary has been the migratory passage of many species. It plays an important role in the county’s fishery production. In 2013, the value of fishery output in ChongMing County reached 1.62 billion Yuan, with 60,740 tons of annual output of aquatic products, of which 43,261 tons were inland aquatic products and 17,479 tons were inshore fishing output, providing a very rich source of animal protein for the city of Shanghai (data are from agricultural committee of ChongMing County).(3) Tourism: Over the years, Shanghai has made great efforts to make ChongMing County an ecotourism area, so the county is committed to the development of Dongping National Forest Park, the Dongtan Wetlands and Migratory Birds Protected

Area, as well as Sanmin Cultural Village 4A Level Scenic Spots, Pearl Lake, Gao Jia Manor and other major leisure agricultural eco-tourism villages. The ecological leisure tourism industry with special characteristics of the county is developing steadily. In 2013, the county enjoyed 4,303,000 tourists, with an operating income of 630,000,000 Yuan (data are from Tourism Bureau of ChongMing County). (4) Housing: ChongMing County was formed by the accumulation of sediments of the Yangtze River. Over the years, due to its relatively excellent ecological environment and rich natural resources, the county attracted many residents to live and settle its banks. As the housing price in other districts of Shanghai remains very high, and with the recent building of the Yangtze River Tunnel Bridge, the high-end residential and villa market is beginning to boom. (5) Drinking water: Because of the serious pollution of the Yangtze River Estuary, although the people of Shanghai live near the river, their water has always been supplied by several large reservoirs. QingCaoSha Water Source is located to the north of ChangXin Island and the center of Yangtze River Estuary. With a total area of nearly 70 square kilometers, designed effective capacity of 435 million cubic meters, daily water supply scale of 7.19 million cubic meters, total investment of 17 billion Yuan RMB, it provides water to 10 million people and is currently the world's largest river estuary reservoir (data are from Water affair Bureau of Shanghai City).

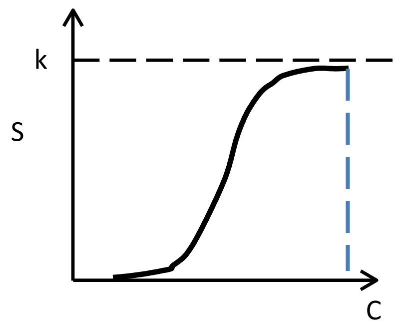
It should be noted that, despite the fact that the county is located at the center of the river and is surrounded by water, it does not realize the swimming function of the presumably advantageous location. The primary reason is that the water at the estuary flows too fast, and the water along the bank is generally more than 2 meters deep. For the sake of safety, swimming in the river is prohibited, so this function is not taken into consideration.

2.3 Selecting Method for Study

Based on the comparative analysis of many methods (James L.D. 1984; Zhu Qingfa 1996) of assessing economic losses, we chose the "concentration - loss curve" developed by L. D. James (1984). According to the curve, when the pollutant concentration is low, the damage to the environment is not significant, but with the increase in the dose of pollutants, the extent of damage to the environment increases dramatically. However, when the pollutant concentration reaches a certain point, the increase in the damage of the concentration of pollutants to the environment slows down, until it reaches the limit, when the increase in concentration no longer increases the damage. The trend is often expressed as an S shape nonlinear equation. The equation can be seen in (2-1):

$$\frac{dS_i(C_j)}{dC_j} = b_{ij} \cdot \frac{S_i}{k_i}(k_i - S_i) \tag{2-1}$$

The function can be expressed as the following:



Equation 2-1 James' Concentration-Loss Curve

In Equation 2-1, C represents the concentration of pollutants while S represents the economic loss from those pollutants. Many pollutants affect the economic value of water resources, so when assessing the economic losses of water resources, the common practice is to calculate the economic losses of water resources from one pollutant, and then calculate sequentially the losses from a variety of other pollutants. If there are n kinds of pollutants in an aquatic environment affecting the quality of the environment, the pollution rate from pollutant type j is R_j. In order to calculate the pollution rate, we must first establish the differential equation between pollutant concentration and the economic losses of environmental factors like (2-1):

R_{ij} refers to the ratio between the economic losses caused by the pollutant and functional value K_i under a certain concentration of C_j. It is called the loss rate of the function caused by the pollutant, which can be called pollution loss rate. If i represents different functions, and j represents different pollutants, we have the following equation:

$$R_{ij} = \frac{S_i}{k_i} = \frac{1}{1 + a_{ij} * \exp(-b_{ij} * C_j)} \quad . \tag{2-2}$$

In general, the pollution loss rate of the function i caused by pollutant j can be formulated as:

$$R_{ij} = \frac{1}{1 + a_{ij} * \exp(-b_{ij} * C_j)} \quad . \tag{2-3}$$

As a_{ij} and b_{ij} are only parameters associated with the characteristic of the pollutant and water use function, they cannot be arbitrarily selected and are somewhat objective. In addition, as the toxicity of pollutants does not vary with the change of time or place, once determined, a_{ij} and b_{ij} can be applied to any lake or river. When there is more than one kind of pollutant in the water, the interactions among them should be subtracted from the simple summation of the comprehensive loss. If the synergistic and antagonistic effects between different pollutants are ignored, when there are n kinds of pollutants that are independent of each other, when the interactions are subtracted, the comprehensive losses $R_i^{(n)}$ will be as follows:

$$R_i^{(n)} = R_i^{(n-1)} + [1 - R_i^{(n-1)}]R_{in} \quad (2\text{-}4)$$

2.4 Collecting Data for Study

2.4.1 The collection of data

Many annual statistical data used in this study are mainly from Shanghai Statistical Yearbook compiled by the Shanghai Municipal Bureau of Statistics, ChongMing County Statistical Yearbook compiled by ChongMing County Bureau of Statistics, data of water price in Shanghai from http://www.h2o-china.com/, data related to fisheries, agricultural irrigation area and other relevant data of ChongMing provided by the Agricultural Commission of ChongMing County (Zhang XiaoLi et al. 2014: 108).

2.4.2 The Collection of Monitoring Data

This research mainly focuses on the economic loss from the pollution of the Yangtze River Estuary, so the data related to the pollution of the Yangtze River Estuary is required. These data are from the Water Environmental Monitoring Station of the Estuary Station of the Yangtze Water Resources Administration Bureau (Zhang XiaoLi et al. 2014: 76-77).

2.4.3 Questionnaire

In the assessment of the functional value of dwelling and tourism, the travel cost method and consumers' willingness-to-pay method are used respectively, both of which need questionnaires to obtain the needed information, so we designed and distributed questionnaires to collect data(Zhang XiaoLi et al. 2014: 101-107).

2.4.4 Experts Consulted

The method of expert investigation is used many times in this research. First of all, this method is used in determining the recipients and the locations for questionnaire distribution. Secondly, in the designing process, some questions were confirmed by expert opinion surveys. In addition, valuable information was obtained from experts in the ChongMing County Tourism Bureau and Sports Bureau concerning the swimming function of the river. When determining the parameters a and b in the research method of "loss-concentration" curve, Professor Zhu Qingfa was consulted (Zhang XiaoLi et al. 2014: 76-77).

3. Principles of Assessment

3.1 Principle of Theoretical Support

To have an authentic, accurate, and objective assessment of objective reality, we need relevant theoretical research which can objectively reflect reality and the essence and laws of matter as the foundation and support. Theoretical study is the authentic and objective reflection of things and their internal laws, and it is the abstraction of the nature of things. Only with a theoretical basis can we obtain the factors causing the current situation under assessment and the influence mechanisms. We can design and choose the methods and elements of assessment based on the information.

Assessment without theoretical support is not reliable, and may even be wrong.

3.2 Availability of Data

A large amount of data which reflect the objective phenomena is needed in conducting any assessment. When there is no objective and sufficient data available, however advanced the methods of assessment we choose, the effectiveness of assessment will be compromised. The result of assessment will be questioned, and it may even lose its guiding function in the policy-making process. Therefore, the data needed for the assessment should be available.

3.3 Principle of Practicability

The assessment methods we choose should be practicable. Sometimes we may have very advanced assessment theories, and under the guidance of such theories, we may also choose very good assessment methods, but if such theories and methods cannot guide the practice, and have no practicability, then we will not be able to conduct effective assessment.

3.4 Principle of Consistency

In the assessment, many indicators and time series data of many years are used. In order to have a dynamic display and objective comparison of the assessment results of the same object over the years, the selection of the time series data must be dynamically consistent; otherwise the assessment results cannot be compared in the time series, and will also affect the guiding function of the assessment results to practical decision-making.

3.5 Principle of Optimal Synthesis

Our assessment involves a lot of trivial links, while the links also involve many methods and schemes. In order to ensure the validity of the assessment, under the premise of practicability, we have to try to ensure the selection of optimal schemes in every link and to then accomplish the objective of assessment with the optimized synthetic scheme.

4. Empirical Assessment of Economic loss in ChongMing County

To calculate the value of the various functions of the Yangtze Estuary in ChongMing County (Table 4-1), we used a variety of methods. We refer the reader to the references to examine the process in detail (Zhang XiaoLi et al. 2014: 45-49).

Table 4-1. Value of Various Functions in ChongMing ($V_{i;}$ unit: 100 million Yuan)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fisheries	7.25	7.18	7.31	8.82	7.84	7.3	7.74	8.16	8.13
Water for Life function	0.665	0.671	0.661	0.656	0.684	0.643	0.908	0.892	1.05
Value of function	3.94	4.28	5.06	5.6	13.15	21.52	16.18	18.32	21.41
Housing function	2.55	2.59	2.61	2.62	2.75	2.81	2.811	2.808	2.91
Agricultural irrigation function	43.79	44.88	46.18	49.87	50.56	52.78	55.33	58.66	61.05

4.1 Primary Assessment Results

For the convenience of narration, we copy Equations 2-3 and 2-4 and renumber them here:

$$R_{ij}=\frac{1}{1+a_{ij}*\exp(-b_{ij}*C_j)} \tag{4-1}$$

$$R_i^{(n)}=R_i^{(n-1)}+[1-R_i^{(n-1)}]R_{in} \tag{4-2}$$

The relevant parameters in Equations 4-1 and 4-2 and their definitions have been discussed in conjunction with Equations 2-2 and 2-3, and we will not repeat them here.

In order to assess the economic loss of ChongMing County, we collected data of the concentration of the various pollutants in Yangtze River Estuary (Zhang XiaoLi et al. 2014:77) and the relevant parameters a_{ij}, b_{ij} (Zhang XiaoLi et al. 2014: 78).

4.2 Calculating the Direct Loss Rate R_{ij} and Comprehensive Loss Rate $R_i^{(n)}$

Following the process of assessment discussed above, we calculate initially the direct loss rate of various pollutants R_{ij} and then the comprehensive loss rate $R_i^{(n)}$ according to Equation 4-2. The results are shown in Tables 4-2 and 4-3 (Zhang XiaoLi et al. 2014: 108).

Table 4-2.The Direct Loss Rate Rij
(Unit : %)

Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Fisheries	2005	0.211272390969	0.00768870571087	0.00643069753641	0.00161077970254	0.00363373223335	0.000106816780526	0.00683995828596	0.00101699606136
	2006	0.454175261054	0.00736358602994	0.00643069753641	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101676266074
	2007	0.492339406457	0.00745250312356	0.00643069753641	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101559646007
	2008	0.560960529806	0.00753524763693	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101536338033
	2009	0.515309519911	0.00709628490426	0.00646167669079	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101513035403
	2010	0.507655208726	0.00753163116365	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101559646007
	2011	0.424005722985	0.00756061124863	0.00652408048963	0.00161077970254	0.00363373223335	0.000106816780526	0.00683995828596	0.00101513035403
	2012	0.285155422306	0.00704534557214	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101443159563
	2013	0.226992675739	0.00716133330013	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101443159563
Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Water for life	2005	0.901391548052	0.00489491156746	0.00300924902685	0.00363188424102	0.00102003514448	0.000486456367504	0.00618813368525	
	2006	0.989716804176	0.00435176226767	0.00300924902685	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2007	0.992497831803	0.00449631506522	0.00300924902685	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2008	0.995754570232	0.00463352098863	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2009	0.99379334856	0.0039349811725	0.00304889669783	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2010	0.99338831273	0.00462746976263	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2011	0.986775974599	0.00467610067242	0.00312976108754	0.00363188424102	0.00102003514448	0.000486456367504	0.00618813368525	
	2012	0.954344810251	0.00385854178291	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2013	0.917105800784	0.0040339732531	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Tourism	2005	0.941590427025	0.00320520445414	0.00147626091324					
	2006	0.995181150583	0.00265738434814	0.00147626091324					
	2007	0.996581144064	0.0027994343324	0.00147626091324					

	2008	0.998158566111	0.00293679753637	0.00157157456107					
	2009	0.997218017432	0.00226348866122	0.00150737288237					
	2010	0.997020092289	0.00293068780737	0.00157157456107					
	2011	0.99366104105	0.00297992270182	0.00157157456107					
	2012	0.975304810771	0.00219382500452	0.00157157456107					
	2013	0.951977492822	0.00235490632411	0.00157157456107					

Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Housing	2005	0.786662151034	0.00489491156746	0.00300924902685					
	2006	0.965945288903	0.00435176226767	0.00300924902685					
	2007	0.973937352294	0.00449631506522	0.00300924902685					
	2008	0.983969674638	0.00463352098863	0.00312976108754					
	2009	0.977822866817	0.0039349811725	0.00304889669783					
	2010	0.97659507903	0.00462746976263	0.00312976108754					
	2011	0.957895126824	0.00467610067242	0.00312976108754					
	2012	0.883062338821	0.00385854178291	0.00312976108754					
	2013	0.8131097905	0.0040339732531	0.00312976108754					

Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Agriculture irrigation	2005	0.016664694254			0.00363188424102	0.00363373223335	0.00366156480747	0.00362452006889	0.00919940849064
	2006	0.0198658202356			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00919731451507
	2007	0.0203422394477			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918685171826
	2008	0.0212281424963			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918476057438
	2009	0.0206334426913			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918266990208
	2010	0.0205359243339			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918685171826
	2011	0.0194925710424			0.00363188424102	0.00363373223335	0.00366156480747	0.00362452006889	0.00918266990208
	2012	0.0177270621854			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00917640071362
	2013	0.0169041610944			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00917640071362

Table 4-3. Comprehensive Loss Rate of Various Functions $R_i^{(n)}$
(Unit :%)

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture
2005	0.232597893297	0.90327389979	0.94186359304	0.788345265185	0.0398111853786
2006	0.468757497356	0.989907558615	0.995201051093	0.966195520051	0.0429313906648
2007	0.50594573358	0.992638066861	0.996595747921	0.974132614525	0.0433864966131
2008	0.572803347589	0.995835006068	0.998166859481	0.984093890107	0.0442495436357
2009	0.528145404562	0.993906175061	0.997228498411	0.97797748314	0.0436668136785
2010	0.520934270627	0.99351354132	0.997033494891	0.976776297434	0.0435756254956
2011	0.439558662004	0.987027126041	0.993689863118	0.958223175435	0.0425563226781
2012	0.304093918458	0.955174941117	0.975397712883	0.883878122438	0.0408227183396
2013	0.247559990511	0.918627367467	0.952203403521	0.814446262753	0.0400191656801

4.3 Calculating the Comprehensive Loss of Various Functions Caused by All Pollutants

When the values of various functions calculated (V_i) are multiplied by the comprehensive economic loss rate $R_i^{(n)}$ of various functions caused by various pollutants, we can calculate the comprehensive economic loss of various functions caused by various pollutants as below (Zhang XiaoLi et al. 2014: 106-107).

Table 4-4. Comprehensive Loss Rate of Various Functions $R_i^{(n)}$
(Unit :%)

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture
2005	0.232597893297	0.90327389979	0.94186359304	0.788345265185	0.0398111853786
2006	0.468757497356	0.989907558615	0.995201051093	0.966195520051	0.0429313906648
2007	0.50594573358	0.992638066861	0.996595747921	0.974132614525	0.0433864966131
2008	0.572803347589	0.995835006068	0.998166859481	0.984093890107	0.0442495436357
2009	0.528145404562	0.993906175061	0.997228498411	0.97797748314	0.0436668136785
2010	0.520934270627	0.99351354132	0.997033494891	0.976776297434	0.0435756254956
2011	0.439558662004	0.987027126041	0.993689863118	0.958223175435	0.0425563226781
2012	0.304093918458	0.955174941117	0.975397712883	0.883878122438	0.0408227183396
2013	0.247559990511	0.918627367467	0.952203403521	0.814446262753	0.0400191656801

Table 4-5. Comprehensive Economic Loss of Various Functions over the Years V *R (n)

(Unit: RMB100 million)

Year	Fisheries (pctg)	Water for Life (pctg)	Tourism (pctg)	Housing (pctg)	Irrigation for Agriculture (pctg)	Total Economic Loss in ChongMing County	Annual Economic Loss (pctg)	Gross Increase of Annual Economic Loss in ChongMing County
2005	1.686334726/17	0.600677143/6	3.710942557/38	2.010280426/21	1.743331808/18	9.75156666	0.101897248276	95.7
2006	3.365678831/26	0.664227972/5	4.259460499/33	2.502446397/20	1.926760813/15	12.71857451	0.117438361127	108.3
2007	3.698463312/27	0.656133762/5	5.042774484/36	2.542486124/18	2.003588414/14	13.9434461	0.113545978013	122.8
2008	5.052125526/31	0.653267764/3	5.589734413/34	2.578325992/16	2.206724741/14	16.08017844	0.116776894989	137.7
2009	4.140659972/18	0.679831824/2	13.11355475/57	2.689438079/12	2.2077941/10	22.83127873	0.133829300879	170.6
2010	3.802820176/12	0.638829207/4	21.45616081/69	2.744741396/9	2.299921514/7	30.9424731	0.159169100309	194.4
2011	3.402184044/13	0.89622063/3	16.07790199/63	2.693565346/11	2.354641334/9	25.42451334	0.113451643641	224.1
2012	2.481406375/10	0.852016047/3	17.8692861/69	2.481929768/10	2.394660658/9	26.07929895	0.110365209268	236.3
2013	2.012662723 7	0.964558736/3	20.38667487/72	2.370038625/8	2.443170065/9	28.17710502	0.111680955291	252.3
Accumulated Economic Loss	29.64233568/16	6.605763086/4	107.5064905/58	22.61325215/12	19.58059345/11	185.9484349		

（Note：Total economic loss = mathematical expectation of economic loss of the value of every function）

Table 4-6 Direct Economic Loss Caused by Various Pollutants over the Years V_i*R_{ij}
(Unit: RMB100 million)

Year	COD	Nitrogen	Phosphorus	Volatile Phenols	Cadmium	Lead	Mercury	Arsenic	Total Direct Economic Loss
2005	10.58259591	0.085895039	0.061264742	0.174350248	0.186485728	0.161600801	0.214495565	0.410215319	11.87690335
2006	13.66102384	0.07996952	0.061818451	0.178005601	0.190192135	0.165584429	0.217967495	0.420075831	14.9746373
2007	15.61630469	0.087304388	0.064957408	0.182931267	0.195388372	0.17035835	0.223568566	0.431672822	16.97248586
2008	18.18144985	0.103986538	0.078273786	0.19874711	0.21428378	0.184030817	0.247271382	0.466999515	19.67504278
2009	32.30388071	0.119099607	0.093352349	0.199674892	0.213229998	0.186452617	0.243069141	0.472234412	33.83099373
2010	48.69490219	0.18574518	0.118396118	0.206861249	0.219334668	0.194523609	0.247421998	0.492295888	50.3594809
2011	37.50197551	0.15962553	0.104482297	0.217051474	0.230199527	0.203907599	0.259674106	0.515934235	39.19285028
2012	40.05625079	0.14173031	0.11394875	0.229577744	0.243826023	0.216145473	0.274616541	0.546565428	41.82266106
2013	44.55823153	0.163092702	0.140236491	0.238200886	0.252401631	0.224893408	0.283073945	0.568466592	46.42859719
Total	261.156615	1.126448814	0.836730392	1.825400471	1.945341862	1.707497103	2.211158739	4.324460042	275.1336524

In Table 4-5, the economic losses of various functions caused by one pollutant are added up, and the result is the total direct economic loss of various functions caused by certain pollutants. The formula it adopts is $\sum_{i=1}^{n} V_i R_{ij}$, in which i stands for the types of function, j stands for the types of pollutants, R_{ij} stands for the economic loss of I kinds of functions caused by j kinds of pollutants.

The comprehensive economic loss of various functions in Table 4-4 covers the comprehensive economic loss indirectly caused by different kinds of pollutants or the interaction of those pollutants. The formula adopts the comprehensive loss rate shown in Equation (4-2).

4.4 Forecasting

In order to project the development of trends of likely losses in the coming years, we make some forecasts regarding the losses caused by all the various kinds of pollutants, using the horizontal method and the regression analysis method. To enhance the accuracy of the forecasts, we average the weighted number of the forecasts from the two methods, and then take the average of the forecasts as the rate of economic loss (Zhang XiaoLi et al. 2014: 106-107).

Table 4-7. Projected Equal Weighted Average Number of Predictive Value of the Economic Loss of All Functions (Unit: RMB100 million)

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture	Total
2015	1.496836	1.033687	28.85176	2.787565	2.665879	36.83572
2020	1.174802	1.32423	64.5654	2.0874.25	3.181254	70.24569
Total	2.671638	2.357917	93.41716	2.787565	5.847133	107.0814

Table 4-8. The Equal Weighted Average Number of Predictive Value of the Economic Loss of All Pollutants (Unit: RMB100 million)

Year	COD	Nitrogen	Phosphorus	Volatile Phenols	Cadmium	Lead	Heavy Metals	Arsenic	Total
2015	60.8917	0.194429	0.162807	0.254608	0.269568	0.241369	0.250002	0.659066	62.92355
2020	119.4124	0.27168	0.245924	0.302657	0.318666	0.279494	0.350247	0.729083	121.9102
Total	180.3041	0.466109	0.408731	0.557265	0.588234	0.520863	0.600249	1.388149	184.8338

4.5 Empirical Analysis Regarding Primary Assessment Results and Forecasts

4.5.1 Comprehensive Economic Loss Rate of Various Functions Caused by Various Pollutants: Table 4-3

The results shown in Table 4-3 are derived using Equation 4-2. First, we look at the functions of water for life and tourism, which have the greatest loss rates. The data in the table show that the waters in ChongMing County have effectively lost all water for life function because the loss rate (i.e., above 90%) is absolutely not suitable for inhabitants' water needs. In addition, serious pollution has caused the loss of nearly all of the tourism function, again with a loss rate above 90%. Because the water quality is so poor, even if it were to be developed as a potential tourism resource, the economic benefit would likely not be forthcoming. This fact will seriously constrain Shanghai's implementation of a strategic plan to develop ChongMing County into an ecotourism county.

Second, in terms of the housing function, which also suffers serious loss, as the data in the table show, the pollution of the waters of the Yangtze River Estuary has caused serious economic loss, with the loss rate at nearly 80%. This implies that the economic benefit of developing real estate on the coast near ChongMing County would not be prudent and the real estate industry will unlikely be able to feature houses with a sea view.

Third, in terms of economic loss rate of fisheries, the loss rate is largely between 30% and 50%, which means the current fisheries output is only about half of its potential, and about half of its output is lost as a result of environmental costs. This does not take into account the indirect loss in the form of damage to people's health caused by the poor quality of fisheries. Therefore, waters like this are absolutely not suitable for fisheries production and culture.

Finally, in terms of the irrigation function, the loss rate is relatively small and stable, at approximately 4%. This is primarily due to the fact that when the concentration levels are low, some pollutants have a positive effect on agricultural production. But this does not take into account the indirect net loss caused by the decline in the quality of agricultural products as a result of the excessive discharge of various pollutants, as well as the decline in the quality and quantity of agricultural production caused by sedimentation of pollutants in the soil. Therefore, even though the measured loss is relatively small, agricultural quality is not acceptable and should not be left unchecked.

(n)

4.5.2 Comprehensive Loss Rate of Various Functions R_i: Table 4-4

Table 4-4 shows the comprehensive economic loss of various functions calculated according to the direct loss rates seen in Table 4-3 and the value of various functions in ChongMing County. The calculation takes into account not only the economic loss rate caused by pollutants, but also the value of various functions.

First, considering the total comprehensive economic loss over the years, from 2005 to 2013, the comprehensive economic loss caused by the pollution of the Yangtze River Estuary accounts for more than 10% of the annual economic growth of ChongMing County. If we put the average annual income in Shanghai in the year 2012 at 56,300 Yuan, the number of the total economic loss of ChongMing County over the years (18.5 billion Yuan) could address the employment problem of 300,000 people. If in 2013 the average disposable income is 13,421 Yuan for rural residents in ChongMing County, as the registered population in the county is 680,000 people, and 390,000 of them are non-rural residents, then the number of the comprehensive economic loss that year will render all the rural population without any income. If in 2012 the per capita living expense of rural residents in ChongMing County affects 12,000 people, then the economic loss caused by the pollution in Yangtze River Estuary could threaten the livelihood of about 90% of the rural population in the county.

Second, in terms of the trend of the economic loss over the years, according to Figure 4-1, from 2005 to 2013, the total economic loss of various functions increases dramatically. Despite a slight drop in 2011 compared with 2010, the general trend is nevertheless obviously climbing upward.

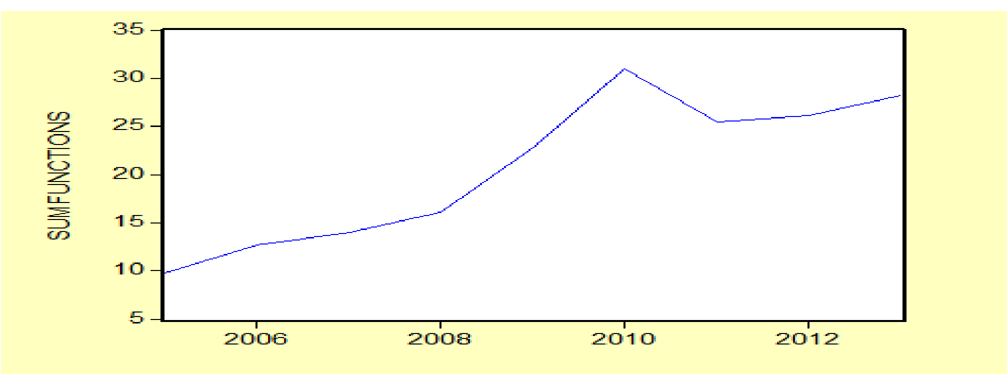


Figure 4-1. The Trend of the Total Economic Loss of Various Functions over the Years in ChongMing County

(Unit: RMB100 million)

Third, in combining Figure 4-2 with Table 4-5, we can analyze the economic loss of the five various functions. Among the five functions of the water resources of the Yangtze River Estuary in ChongMing County, the tourism function suffers greatest economic loss over the years, with the lowest loss in 2006 at 33% to high losses of at least 57% from 2009 on. From 2005 to 2013, the comprehensive economic loss of tourism exceeds 10.7 billion Yuan, approximately half of the annual economic growth of the county. This is mainly because of the deterioration of the aquatic environment in ChongMing County caused by the pollution of the Yangtze River Estuary, which deprives the tourists of the comfort and happiness of enjoying the beautiful scenery, thus greatly decreasing the economic benefit it potentially possess.

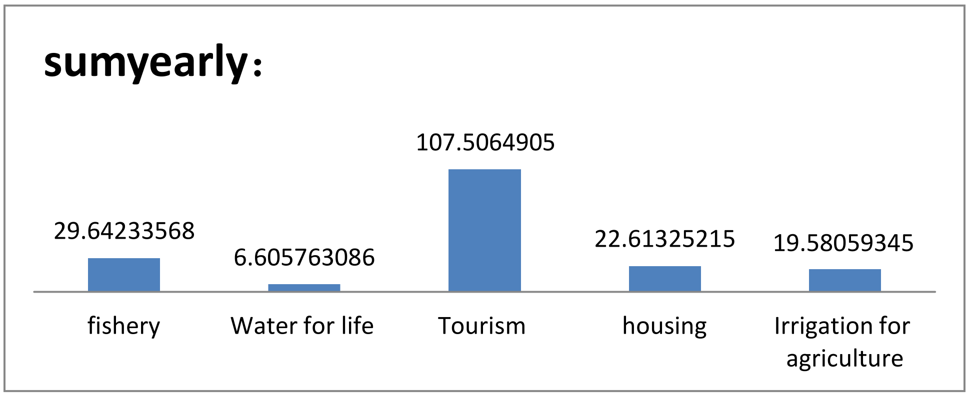


Figure 4-2. Column of the total economic loss of various functions over the years in ChongMing County. (unit: RMB100 million)

In terms of economic loss, next to tourism is the fisheries function. The total loss suffered by fisheries industry is much smaller than that of tourism, and the reasons are as follows: (1) the general functional value of fisheries in ChongMing County is not very high to begin with; (2) it is known that certain concentrations of organic substances in bodies of water such as the Yangtze River Estuary are actually beneficial to the breeding and growth of fish; (3) the current fisheries industry mainly relies on aquaculture instead of wild caught fisheries in the Yangtze River. The water for aquatic culture is from the estuary, but the pollutants in the water are sedimented and filtered before they reach the farms; (4) the indirect loss in the form of harm to consumers' health caused by the deterioration of fisheries quality is not taken into consideration here.

The economic loss of the housing function ranks third. Because the aquatic environment along the coastal of ChongMing County is damaged, the related "life and leisure" function featuring "houses with a sea view" is certainly compromised, but not to the degree as that suffered by tourism. This is mainly because the population density in ChongMing County is relatively small when compared with the city center. In the center of the county, there is still a large area of plain, where the vegetation coverage rate is high, and the ecological environment is beautiful, with a high function of life and leisure. So, for the residents of ChongMing County, the life and leisure function suffers far less from water pollution than does the tourism function.

The economic loss suffered by irrigation function ranks fourth. The reason is that there are rich nutrients like nitrogen and phosphorus in the polluted waters of the Yangtze River Estuary. At certain concentrations, these pollutions can increase the growth rate and thus agricultural output of the region. Therefore, in this sense, the irrigation using the polluted water resources has some positive effects on the agricultural production. Therefore, according to the result of our assessment, the total loss is relatively low. On the other hand, the excessive concentration of pollutants in water resources will surely contaminate the soil, crops, and groundwater, which will inevitably cause a certain degree of economic loss. However, in this study, the pollution of soil, crops, and groundwater are not taken into consideration, not to say that there is no degree of indirect harm to public health with concomitant economic loss.

The economic loss suffered by the function of domestic water ranks at the bottom of the list because the absolute amount of this loss remains the smallest. This is because the population in ChongMing County is small and the price of life water is low, so the total value of life water function is relatively low. In Table 4-3 we saw that the loss rate of the water for life function has been calculated at up to 90%, while the actual source of life water for the residents in ChongMing County is from the Qingcaosha water source. Therefore, with a 90% loss of function, the water resources of the Yangtze River Estuary are effectively unable to provide the life water function for the region.

A note about substitution elasticity: this is yet another factor to be considered in assessing the economic loss of the five main functions. If tourists go to ChongMing, they will put too much emphasis on the pollution of the local aquatic environment, so the influence will be bigger. For those who work there, as a result of transport, the substitution elasticity for life and leisure will decrease, so the result of the assessment will be relatively small. The same is true with fisheries and agricultural irrigation.

4.5.3 The economic loss caused by various pollutants in Yangtze River Estuary in different years: Table 4-5

Table 4-5 shows the economic loss caused by various pollutants in the Yangtze River

Estuary over the period 2005 to 2013. The last row shows the total value of economic loss from different pollutants for the period. From the total economic loss, we can see that among all the pollutants, COD causes the greatest economic loss, accounting for more than 94% of total direct economic loss over the period. It is followed by arsenic pollution, accounting for 2%. Together, the two account for about 96% of the total direct economic loss over the years. The rest include lead, cadmium, volatile phenols, nitrogen, and phosphorus.

The sources of pollution in the Yangtze River Estuary are primarily pesticides, chemical plants, and organic fertilizers, whose ingredients contribute to large amounts of COD. The higher the concentration of COD in the river, the more serious is the pollution of organic substances, which means there is large amount of reducing substances in the water. These substances exert a great influence on fisheries, living environment, tourism, water for life, and irrigation. Furthermore, the Yangtze River Estuary is a large tidal estuary with a typical tidal bank. In recent decades, in view of the rapid development of the economy of the Yangtze River Basin region, sewage and waste emissions along the river have increased dramatically. The pollutant flux also increases precipitously, resulting in large amounts of heavy metals like arsenic being discharged into the river. These pollutants have no direct impact on tourism and living, but with long-term sedimentation throughout the food chain, they will have serious effects on people’s health.

According to the last column in Table 4-5, the total value of the economic loss caused by various pollutants over the years grows significantly with time. This tendency is also shown in Figure 4-3. In the chart, “Total” refers to the sum of the economic loss caused by various pollutants in a certain year, T refers to the study years, ranging from 2005 to 2013. Despite a slight decline in 2011 compared with 2010, the total value of economic loss caused by various pollutants shows a tendency of continuously increasing. Therefore, it is a very urgent task to monitor carefully the emission of pollutants into the Yangtze River Estuary and increase both the regulation of and remediation of the COD content in the waters in ChongMing County.

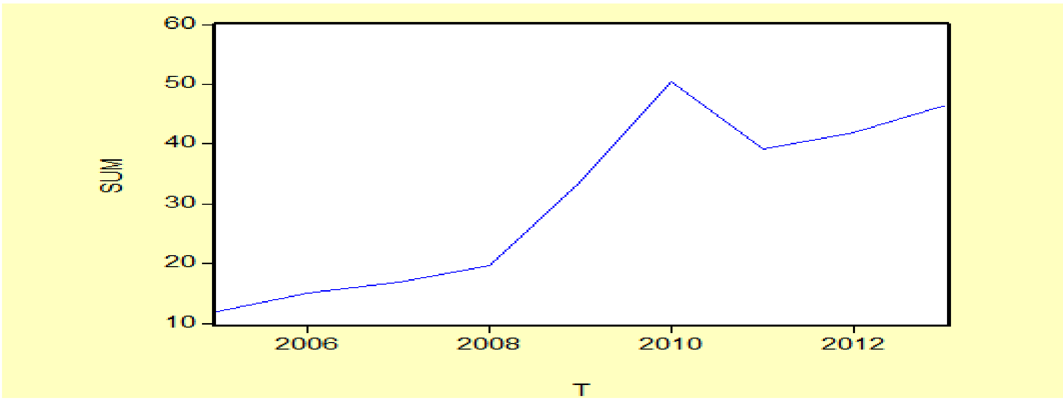


Figure 4-3. The tendency of change over time of the total economic loss caused by various pollutants over the years. See text for definition of units.

4.5.4. Direct Economic Loss Caused by Various Pollutants

In the last section, we saw a very clear picture of the impact of various pollutants and the resulting economic loss of various functions in the Yangtze River Estuary. The available data tell us that the loss is already significant and must be treated urgently. We need a better understanding of whether or not this level of pollution can be addressed effectively. However, in the foreseeable future, (i.e., perhaps three to eight years), the pollution is almost certainly going to cause even greater economic loss.

According to Table 4-6, the total economic loss of various pollutants between 2005 and 2013 will reach 10.7 billion Yuan, which is 60% of the total economic loss in the same period. The forecasts (Table 4-8) of economic loss caused by various pollutants, (i.e., the total economic loss in 2015 and 2020 caused by various pollutants) will reach 18.5 billion Yuan, approximately equal to 67% of the total economic loss from 2005 to 2013. The economic loss caused by COD increases fastest, with the economic loss of the two years accounting for 70% of the total economic loss from 2005 to 2013.

4.6 Analysis of Indirect Economic Loss

by pollution in the Yangtze River Estuary. However, we should note that in the development of the economy in a particular region, all the socioeconomic activities within the area interact with one another and influence one another. Together, they arer synergistic. So the economic loss of one function or one industry caused by water pollution will inevitably cause inestimable and indirect socioeconomic loss to the local socioeconomic development as a whole.

The pollution in the Yangtze River Estuary is mainly a result of COD. Generally speaking, the higher the concentration of COD in the water, the higher the oxygen demand, which ultimately leads to a deficiency of oxygen. The levels of ammonia and nitrates also increase and bacteria and pathogens consequently breed in large numbers, causing an increase in disease-causing pathogens in aquatic products. For tourism, the main negative effect is on scenery, especially when algae thrive vsibly in “blooms” in the water and the water emits a foul smell. If left untreated, many organic pollutants will deposit at the bottom and can exert a lasting toxic influence on aquatic organisms over several years. When the aquatic organisms die in large numbers, the ecosystem in the river is destroyed. If people eat affected aquatic organisms, they will absorb and accumulate the toxins in the organisms, which will lead to cancer, deformities, and mutations. Thus, the cumulative damage involves the quality of aquatic products, effects on public health, and the quality of crops. Although this damage cannot be quantitatively estimated in the short term, the harm is great in the long term.

When the environment is destroyed by COD, it affects not only the tourism function and the housing function, but also the economic development of service industries such as the hotel industry, catering, and businesses and commerce that depend on tourism as the economic driving force. The development of these industries directly determines the industrial structure of ChongMing County (i.e., whether its focus is on primary industries or on related industries). Differing industrial structural arrangements determine the efficiency and speed of the economic development of the region. From this perspective, it is obvious that ChongMing County suffers significant economic loss as a result of the pollution of Yangtze River Estuary.

A rational industrial structural arrangement will speed up the industrial development and improve people’s quality-of-life, which will in turn boost the improvement of soft power and comprehensive power. The pollution of the Yangtze River Estuary checks the development of tourism, living, catering, hotel industry and cultural exchange, seriously affecting the improvement of the county’s soft power and the development of the modern service industry. The damage is both inestimable and enormous.

Finally, the municipal government of Shanghai, while trying to turn ChongMing into an island of ecotourism, also hopes to develop its modern service industry with the focus on tourism by relying on the potential advantage of natural and ecological resources.

In summary, the pollution of the Yangtze River Estuary has caused inestimable losses to ChongMing County, both directly and indirectly. These losses have resulted in considerable unpaid labor for the residents, where in theory, they could have created significant employment opportunities for residents, and could have substantially improved the living standard of the residents. In order to create a beautiful environment of life and work for the people of ChongMing County (and even Shanghai as a whole) and to deter further unnecessary economic losses to the people of the county and the city at the earliest possible time, it is urgent that the pollution of the Yangtze River Estuary be controlled.

5.0 Conclusions

From the analysis of the economic loss, we know that ChongMing County suffers very serious economic loss from the pollution of the Yangtze River Estuary, with the total economic loss continuously accounting for more than 10% of the annual economic growth. Relevant departments and stakeholders should attach great importance to this lasting and significant economic loss. Thus, targeting the many sources of such great loss, we offer several suggestions to relevant departments and stakeholders.

5.0.1 For Government

The Chinese government has formulated and promulgated relevant laws, regulations, and systems to deal with the problem of water pollution in the Yangtze River Estuary, but with little success. The fundamental problem is that the management and implementation systems are not smooth. First of all, the Yangtze River Water Resources Administration Bureau does not have enough power to curb the polluting behavior of the local enterprises in their pursuit of economic development along the river. Second, regarding cross boundary pollution, it is very difficult to define specific responsibilities and rights. In fact, there has been widespread failure of the Yangtze River Water Resources Administration Bureau in managing cross boundary administration. Third, there are no specific and strong management and law-enforcement agencies to enforce authority and implement relevant laws.

Faced with this difficult situation in the management of the water resources in the Yangtze River, the government should, first of all, come to a better understanding and acknowledge that, while this loss is indeed unfortunate, one of the primary causes of the loss is poorly outlined management mechanisms of the region. To rationalize this management mechanism in view of its serious defects, we need to give due consideration to and strengthen the power, function and jurisdiction of agencies like the Yangtze River Water Resources Administration Bureau, so as to curb the pollution and restore the ecological environment along the Yangtze River for the sake of local residents.

Governments at all levels along the river should come to a full realization of the enormous economic loss suffered by themselves, by the people at the lower reaches, and even by future generations as a result of the pollution caused by the enterprises under their jurisdiction. They should enhance their moral awareness and sense of responsibility toward the environment and take immediate action to formulate effective mechanisms for the management of the aquatic environment along the river, devise and lay down relevant policies, systems, laws and regulations, so that the polluters will be punished accordingly, and the economic loss from pollution can be appropriately compensated.

There must be laws to go by, and laws must be strictly observed, lawbreakers must be prosecuted. Only in this way can we restore the ecological environment for the sake of people living along the river.

5.0.2 Companies and Residents along the Coastal Watershed

The pollution of the Yangtze River is very serious and the problem is very difficult to solve. A main cause of this lies in people’s attitudes. The pollution involves not only the polluting enterprises and the victims of pollution and economic loss themselves, but also the residents along the river and local government. For the most part, the local enterprises have not developed an awareness of the necessity of preserving a clean and sustainable ecological environment for the life and work of others and for future generations. They largely lack the basic and necessary moral approach of refraining from polluting the environment for the sake of others, themselves, and future generations. Meanwhile, the residents and local government along the river, when faced with the fact that the ecological environment of their life and workplace is being polluted and destroyed, lack the sense of crisis which should drive them to fight against the pollution which will exert serious influence not only on their mental and physical health as well economic loss, but also on the survival of future generations. With regard to the degradation of the environment, they are seemingly either indifferent or turn a blind eye.

Therefore, we have the following suggestion for the polluting enterprises: (i) They should weigh the economic benefits against the social and ecological costs, that is whether the profits they gain at the cost of the environment can make up for the economic loss they cause. (ii) They should have enough awareness and moral principles to curb their own polluting behavior. If every stakeholder would exercise self-discipline and minimize his/her polluting behavior, the situation would gradually but surely improve. (iii) Every enterprise should have the goal of investing money and energy and cooperating with institutes of scientific research to develop pollution-treatment technologies with associated cost advantages to incorporate into required procedures of industrial production. This requires upfront investment, but will benefit society as a whole. (iv) In the production process, every enterprise should allow open scrutiny of their daily sewage discharge information, which would serve as an important means of self-supervision as well as the supervision of stakeholders as a group.

Regarding victims of economic loss, they should promote the awareness of protecting the environment, the sense of environmental crisis, environmental costs, and economic loss. They should have a clear understanding of the total economic loss and the loss to society caused by others' polluting behavior. They should stand up for their own rights and get organized in monitoring the polluting enterprises.

5.0.3 Researchers

From the perspective of this study, there are several key findings: first, there is no standard for judging the result of assessment. Judging from the existing literature, while up to date, there is still no standard for judging the result of assessments. Therefore, no matter what method is used to conduct the assessment, when it comes to assessing whether the results are reliable or not and how reliable they are, there is still no way to answer these questions definitively. Scholars in relevant fields should focus on this issue and conduct relevant research.

A second issue concerns the selection of parameters used in the concentration-loss curve. At present, the parameters adopted is the number calculated by scholars through experiment, but whether it can cover all the waters including the marine environment, whether the parameters are constant, or whether they will change with the aquatic environment, are questions that require further study.

A third issue concerns the theoretical support of the assessment methods. Among the many research results, there is still no relevant theory obtained from tracking the dynamics of economic loss of certain function caused by different levels of pollution. This is the difficulty and the core issue in the assessment of economic loss from water pollution. The difficulty lies in the fact that the data cannot be analyzed and reliably repeated, and this requires dynamic tracking which lasts a long time. The research has to be a collaborative effort of economists and environmentalists. It requires the cooperation of experts in fields such as agriculture, fisheries, water resources, etc. Its importance lies in the fact that it is the foundation of choosing the assessment method that is scientific and rational.

The fourth issue regards the study of waste water treatment and prevention technology. One of the main reasons why many enterprises are not actively and effectively treating the waste water produced in production is the cost of treatment, while the high cost is in turn caused by the high cost of relevant technology in treating waste water. Therefore, scholars should focus on this urgent and important issue. If the result of research on technologies can minimize the cost of waste water treatment to the point of being negligible, it will surely be a tremendous contribution to the progress of human society.

The fifth point concerns the relevant laws, mechanisms, and policies. Obviously, when dealing with the problem of aquatic environment pollution, the challenge of cross boundary aquatic environment management lies in the fact that the systems and the mechanisms are not smooth. This makes it hard to define rights and responsibilities. There is usually no relevant law to follow, and even when there is a law, it is very hard to follow. Even when the law is followed, the implementation is largely lax. In addition, there is no corresponding authority to carry it out, but even if it is carried out, the key in managing such cross boundary aquatic environment pollution regards standards of implementation. Therefore, scholars should step up efforts in the study of relevant standards of compensation, especially regarding the study of cross boundary water pollution, compensation mechanisms, management mechanisms, and relevant laws and policies.

5.0.4 Educational Institutes

Educational institutes should set up suitable subjects to adapt to this urgent demand for information regarding environmental protection. As far as China is concerned, the main responsibility of education institutes like colleges is to cultivate practical talents with high theoretical caliber. Currently, the field of aquatic environment, be it the Yangtze River, inland rivers and lakes, or the ocean and coastal waters, needs a large number of professional technical talents and researchers with high theoretical caliber to manage the aquatic environment. Relevant colleges and other institutes of education should have a clear appreciation of the enormous demand and try to meet it by adjusting their majors and establishing subjects with both practical value and theoretical guidance, such as environment monitoring, environmental statistical analysis, environmental economic analysis, environmental information, environment law-enforcement supervision, environmental pollution treatment technology, aquatic environment ecological restoration, etc., so as to cultivate high-level professional talents in relevant fields who can meet the urgent need of society.

5.0.5 Practitioners

Practitioners should enhance close cooperation with research institutes. In China, the practitioners and researchers of aquatic environmental management are divorced from one another, which is yet another important reason for the current failures in preserving and improving the aquatic environment. Practitioners, especially enterprises and management departments, need a great deal of latest results of scientific research to guide their practice. For example, they need to know and utilize advanced technologies to lower the cost of pollution and decrease the emission of pollutants. But in reality, they do not actively cooperate with research institutes and share their needs with researchers. While on the part of researchers, they are often busy applying for the big projects like the so-called national 973 and 863 projects. They are largely not concerned with whether their research results can match up with practical departments or whether the results can solve real problems, which then leads to the separation of theory from practice. The accumulated effect is that practical departments lose confidence in the research institutes, assuming that these research results cannot guide practice. On the other hand, researchers, cloistered in the ivory tower, cannot have a full picture of the practical needs of environmental protection. This kind of mutual asymmetry of information leads to the serious waste of scientific, technological, and economic resources. In the meantime, it will also become a huge opportunity cost in the process of environmental pollution and economic development. Therefore, we suggest that a platform and mechanism for the exchange of information should be established, which will pass the information of practical needs to research institutes, as well as enable the results of scientific research to play a key role in practice at the earliest possible time. In the future, this should be the focus of practical departments.

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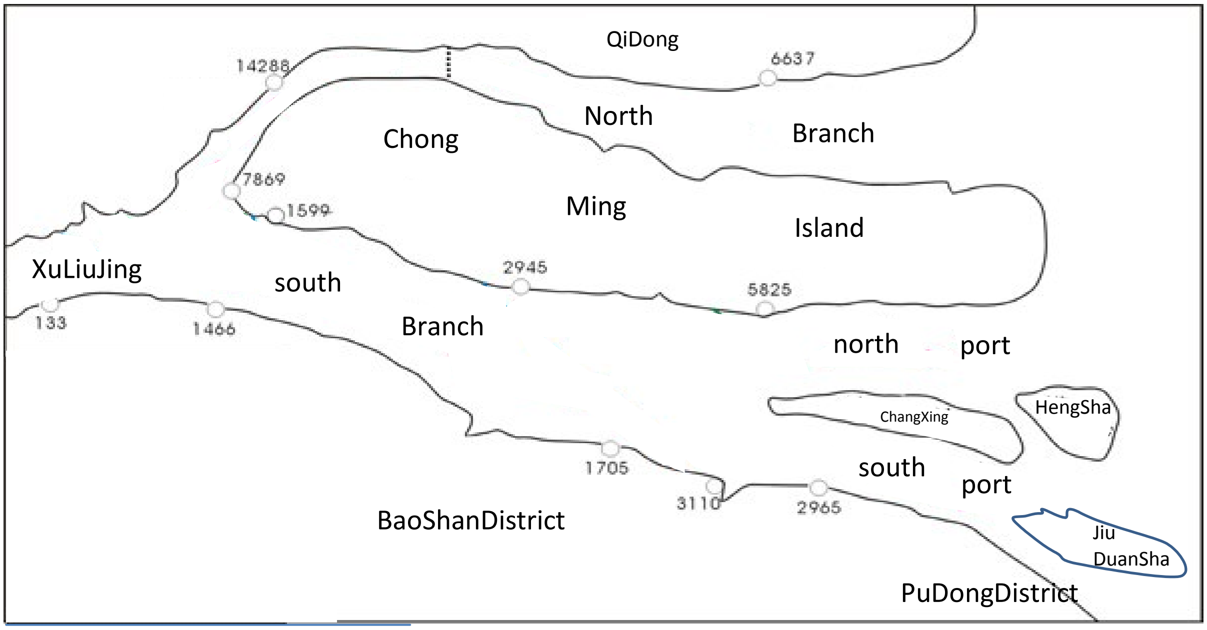

Figure 1-1. Yangtze Estuary

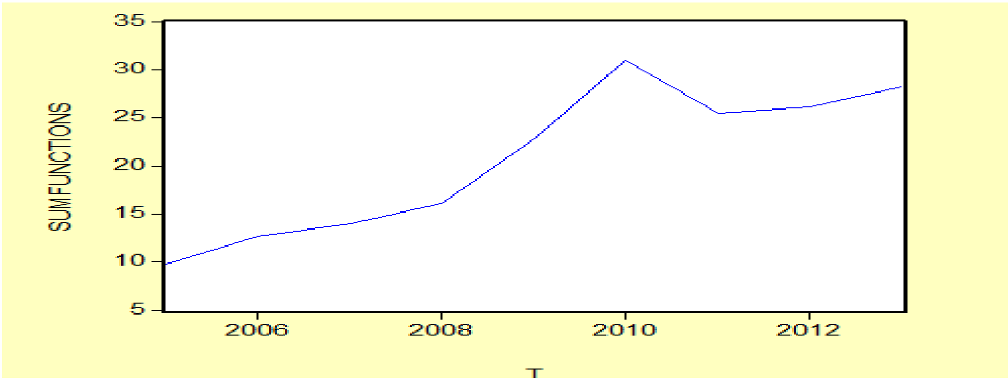

Figure 4-1. The Trend of the Total Economic Loss of Various Functions over the Years in ChongMing County

(Unit: RMB100 million)

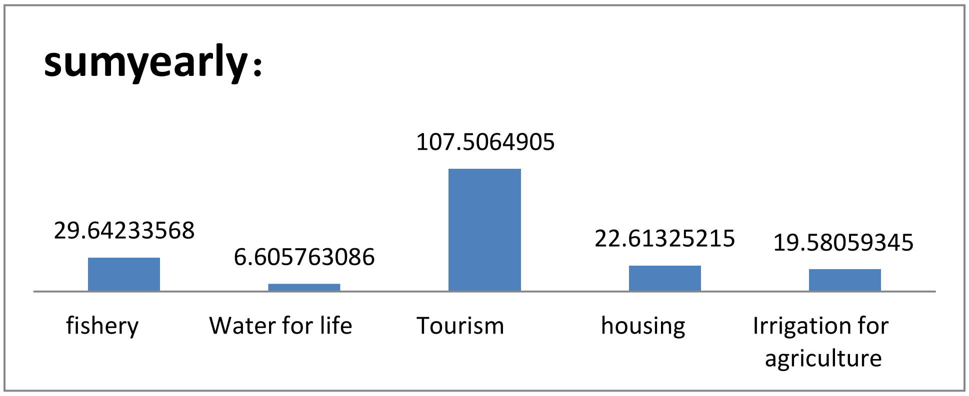

Figure 4-2. Column of the total economic loss of various functions over the years in ChongMing County.
（unit：RMB100 million）

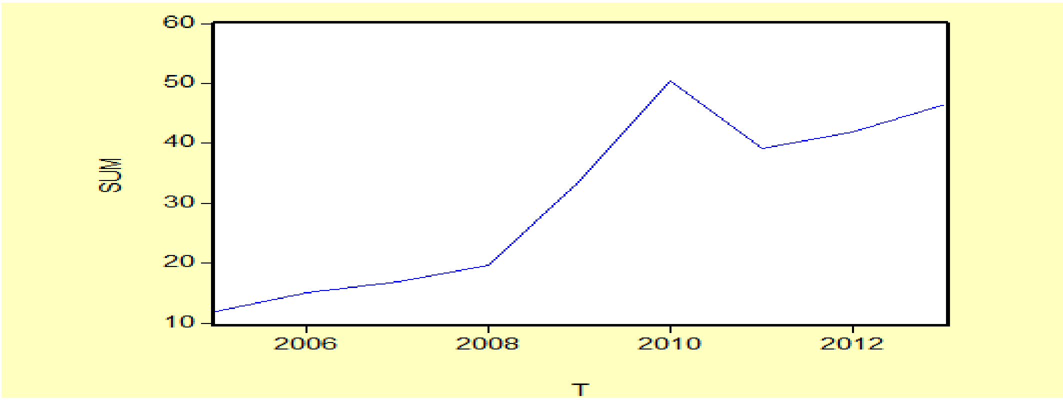

Figure 4-3. The tendency of change over time of the total economic loss caused by various pollutants over the years. See text for definition of units.

Table 4-1. Value of Various Functions in ChongMing ($V_{i;}$ unit: 100 million Yuan)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fisheries	7.25	7.18	7.31	8.82	7.84	7.3	7.74	8.16	8.13
Water for Life function	0.665	0.671	0.661	0.656	0.684	0.643	0.908	0.892	1.05
Value of function	3.94	4.28	5.06	5.6	13.15	21.52	16.18	18.32	21.41
Housing function	2.55	2.59	2.61	2.62	2.75	2.81	2.811	2.808	2.91
Agricultural irrigation function	43.79	44.88	46.18	49.87	50.56	52.78	55.33	58.66	61.05

Table 4-2.The Direct Loss Rate Rij

(Unit : %)

Function	Year	COD	Nitrogen	Phosphorus	Volatile phenols	Cadmium	Lead	Heavy Metals	Arsenic
Fisheries	2005	0.211272390969	0.00768870571087	0.00643069753641	0.00161077970254	0.00363373223335	0.000106816780526	0.00683995828596	0.00101699606136
	2006	0.454175261054	0.00736358602994	0.00643069753641	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101676266074
	2007	0.492339406457	0.00745250312356	0.00643069753641	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101559646007
	2008	0.560960529806	0.00753524763693	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101536338033
	2009	0.515309519911	0.00709628490426	0.00646167669079	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101513035403
	2010	0.507655208726	0.00753163116365	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101559646007
	2011	0.424005722985	0.00756061124863	0.00652408048963	0.00161077970254	0.00363373223335	0.000106816780526	0.00683995828596	0.00101513035403
	2012	0.285155422306	0.00704534557214	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101443159563
	2013	0.226992675739	0.00716133330013	0.00652408048963	0.00160782656436	0.00363373223335	0.000106816780526	0.00683995828596	0.00101443159563
Function	**Year**	**COD**	**Nitrogen**	**Phosphorus**	**Volatile phenols**	**Cadmium**	**Lead**	**Heavy Metals**	**Arsenic**
Water for life	2005	0.901391548052	0.00489491156746	0.00300924902685	0.00363188424102	0.00102003514448	0.000486456367504	0.00618813368525	
	2006	0.989716804176	0.00435176226767	0.00300924902685	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2007	0.992497831803	0.00449631506522	0.00300924902685	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2008	0.995754570232	0.00463352098863	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2009	0.99379334856	0.0039349811725	0.00304889669783	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2010	0.99338831273	0.00462746976263	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2011	0.986775974599	0.00467610067242	0.00312976108754	0.00363188424102	0.00102003514448	0.000486456367504	0.00618813368525	
	2012	0.954344810251	0.00385854178291	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
	2013	0.917105800784	0.0040339732531	0.00312976108754	0.0036281910651	0.00102003514448	0.000486456367504	0.00618813368525	
Function	**Year**	**COD**	**Nitrogen**	**Phosphorus**	**Volatile phenols**	**Cadmium**	**Lead**	**Heavy Metals**	**Arsenic**
Tourism	2005	0.941590427025	0.00320520445414	0.00147626091324					
	2006	0.995181150583	0.00265738434814	0.00147626091324					
	2007	0.996581144064	0.0027994343324	0.00147626091324					

Table 4.2 (cont.)

	2008	0.998158566111	0.00293679753637	0.00157157456107					
	2009	0.997218017432	0.00226348866122	0.00150737288237					
	2010	0.997020092289	0.00293068780737	0.00157157456107					
	2011	0.99366104105	0.00297992270182	0.00157157456107					
	2012	0.975304810771	0.00219382500452	0.00157157456107					
	2013	0.951977492822	0.00235490632411	0.00157157456107					
Function	**Year**	**COD**	**Nitrogen**	**Phosphorus**	**Volatile phenols**	**Cadmium**	**Lead**	**Heavy Metals**	**Arsenic**
Housing	2005	0.786662151034	0.00489491156746	0.00300924902685					
	2006	0.965945288903	0.00435176226767	0.00300924902685					
	2007	0.973937352294	0.00449631506522	0.00300924902685					
	2008	0.983969674638	0.00463352098863	0.00312976108754					
	2009	0.977822866817	0.0039349811725	0.00304889669783					
	2010	0.97659507903	0.00462746976263	0.00312976108754					
	2011	0.957895126824	0.00467610067242	0.00312976108754					
	2012	0.883062338821	0.00385854178291	0.00312976108754					
	2013	0.8131097905	0.0040339732531	0.00312976108754					
Function	**Year**	**COD**	**Nitrogen**	**Phosphorus**	**Volatile phenols**	**Cadmium**	**Lead**	**Heavy Metals**	**Arsenic**
Agriculture irrigation	2005	0.016664694254			0.00363188424102	0.00363373223335	0.00366156480747	0.00362452006889	0.00919940849064
	2006	0.0198658202356			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00919731451507
	2007	0.0203422394477			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918685171826
	2008	0.0212281424963			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918476057438
	2009	0.0206334426913			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918266990208
	2010	0.0205359243339			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00918685171826
	2011	0.0194925710424			0.00363188424102	0.00363373223335	0.00366156480747	0.00362452006889	0.00918266990208
	2012	0.0177270621854			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00917640071362
	2013	0.0169041610944			0.0036281910651	0.00363373223335	0.00366156480747	0.00362452006889	0.00917640071362

Table 4-3. Comprehensive Loss Rate of Various Functions $R_i^{(n)}$
(Unit :%)

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture
2005	0.232597893297	0.90327389979	0.94186359304	0.788345265185	0.0398111853786
2006	0.468757497356	0.989907558615	0.995201051093	0.966195520051	0.0429313906648
2007	0.50594573358	0.992638066861	0.996595747921	0.974132614525	0.0433864966131
2008	0.572803347589	0.995835006068	0.998166859481	0.984093890107	0.0442495436357
2009	0.528145404562	0.993906175061	0.997228498411	0.97797748314	0.0436668136785
2010	0.520934270627	0.99351354132	0.997033494891	0.976776297434	0.0435756254956
2011	0.439558662004	0.987027126041	0.993689863118	0.958223175435	0.0425563226781
2012	0.304093918458	0.955174941117	0.975397712883	0.883878122438	0.0408227183396
2013	0.247559990511	0.918627367467	0.952203403521	0.814446262753	0.0400191656801

Table 4-4. Comprehensive Loss Rate of Various Functions $R_i^{(n)}$

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture
2005	0.232597893297	0.90327389979	0.94186359304	0.788345265185	0.0398111853786
2006	0.468757497356	0.989907558615	0.995201051093	0.966195520051	0.0429313906648
2007	0.50594573358	0.992638066861	0.996595747921	0.974132614525	0.0433864966131
2008	0.572803347589	0.995835006068	0.998166859481	0.984093890107	0.0442495436357
2009	0.528145404562	0.993906175061	0.997228498411	0.97797748314	0.0436668136785
2010	0.520934270627	0.99351354132	0.997033494891	0.976776297434	0.0435756254956
2011	0.439558662004	0.987027126041	0.993689863118	0.958223175435	0.0425563226781
2012	0.304093918458	0.955174941117	0.975397712883	0.883878122438	0.0408227183396
2013	0.247559990511	0.918627367467	0.952203403521	0.814446262753	0.0400191656801

Table 4-5. Comprehensive Economic Loss of Various Functions over the Years $V_i*R_i^{(n)}$
(Unit: RMB100 million)

Year	Fisheries (pctg)	Water for Life (pctg)	Tourism (pctg)	Housing (pctg)	Irrigation for Agriculture (pctg)	Total Economic Loss in ChongMing County	Annual Economic Loss (pctg)	Gross Increase of Annual Economic Loss in ChongMing County
2005	1.686334726/17	0.600677143/6	3.710942557/38	2.010280426/21	1.743331808/18	9.75156666	0.101897248276	95.7
2006	3.365678831/26	0.664227972/5	4.259460499/33	2.502446397/20	1.926760813/15	12.71857451	0.117438361127	108.3
2007	3.698463312/27	0.656133762/5	5.042774484/36	2.542486124/18	2.003588414/14	13.9434461	0.113545978013	122.8
2008	5.052125526/31	0.653267764/3	5.589734413/34	2.578325992/16	2.206724741/14	16.08017844	0.116776894989	137.7
2009	4.140659972/18	0.679831824/2	13.11355475/57	2.689438079/12	2.2077941/10	22.83127873	0.133829300879	170.6
2010	3.802820176/12	0.638829207/4	21.45616081/69	2.744741396/9	2.299921514/7	30.9424731	0.159169100309	194.4
2011	3.402184044/13	0.89622063/3	16.07790199/63	2.693565346/11	2.354641334/9	25.42451334	0.113451643641	224.1
2012	2.481406375/10	0.852016047/3	17.8692861/69	2.481929768/10	2.394660658/9	26.07929895	0.110365209268	236.3
2013	2.012662723 7	0.964558736/3	20.38667487/72	2.370038625/8	2.443170065/9	28.17710502	0.111680955291	252.3
Accumulated Economic Loss	29.64233568/16	6.605763086/4	107.5064905/58	22.61325215/12	19.58059345/11	185.9484349		

（Note：Total economic loss = mathematical expectation of economic loss of the value of every function）

Table 4-6 Direct Economic Loss Caused by Various Pollutants over the Years V_i*R_{ij}

(Unit: RMB100 million)

Year	COD	Nitrogen	Phosphorus	Volatile Phenols	Cadmium	Lead	Mercury	Arsenic	Total Direct Economic Loss
2005	10.58259591	0.085895039	0.061264742	0.174350248	0.186485728	0.161600801	0.214495565	0.410215319	11.87690335
2006	13.66102384	0.07996952	0.061818451	0.178005601	0.190192135	0.165584429	0.217967495	0.420075831	14.9746373
2007	15.61630469	0.087304388	0.064957408	0.182931267	0.195388372	0.17035835	0.223568566	0.431672822	16.97248586
2008	18.18144985	0.103986538	0.078273786	0.19874711	0.21428378	0.184030817	0.247271382	0.466999515	19.67504278
2009	32.30388071	0.119099607	0.093352349	0.199674892	0.213229998	0.186452617	0.243069141	0.472234412	33.83099373
2010	48.69490219	0.18574518	0.118396118	0.206861249	0.219334668	0.194523609	0.247421998	0.492295888	50.3594809
2011	37.50197551	0.15962553	0.104482297	0.217051474	0.230199527	0.203907599	0.259674106	0.515934235	39.19285028
2012	40.05625079	0.14173031	0.11394875	0.229577744	0.243826023	0.216145473	0.274616541	0.546565428	41.82266106
2013	44.55823153	0.163092702	0.140236491	0.238200886	0.252401631	0.224893408	0.283073945	0.568466592	46.42859719
Total	261.156615	1.126448814	0.836730392	1.825400471	1.945341862	1.707497103	2.211158739	4.324460042	275.1336524

Table 4-7. Projected Equal Weighted Average Number of Predictive Value of the Economic Loss of All Functions (Unit: RMB100 million)

Year	Fisheries	Water for Life	Tourism	Housing	Irrigation for Agriculture	Total
2015	1.496836	1.033687	28.85176	2.787565	2.665879	36.83572
2020	1.174802	1.32423	64.5654	2.0874.25	3.181254	70.24569
Total	2.671638	2.357917	93.41716	2.787565	5.847133	107.0814

Table 4-8. The Equal Weighted Average Number of Predictive Value of the Economic Loss of All Pollutants (Unit: RMB100 million)

Year	COD	Nitrogen	Phosphorus	Volatile Phenols	Cadmium	Lead	Heavy Metals	Arsenic	Total
2015	60.8917	0.194429	0.162807	0.254608	0.269568	0.241369	0.250002	0.659066	62.92355
2020	119.4124	0.27168	0.245924	0.302657	0.318666	0.279494	0.350247	0.729083	121.9102
Total	180.3041	0.466109	0.408731	0.557265	0.588234	0.520863	0.600249	1.388149	184.8338