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PRIMARY EVALUATION OF THE ECONOMIC LOSSES CAUSED BY WATER POLLUTION IN SHANGHAI BY CLASSIFICATION APPROACH

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Abstract: The primary evaluation of the economic losses caused by water pollution in Shanghai in the year 2009 is made by classification approach in order to provide basis for decision of the relative water management policy. The result shows that the portion of water pollution losses in GDP of Shanghai was 2.7%, which was still lower than the average level of whole China despite of the local high population density and the scale of industry, suggesting to some extent the continuous attention in water protection paid by Shanghai government.

INTRODUCTION

Because of the self-purification effect, water has been mistakenly regarded as not only inexhaustible resource, but also natural waste treatment location in the world for a long time. On the one hand, water belongs to public goods or quasi-public goods [1] and the whole world faces the over-exploitation of water resource nowadays. On the other hand, in many countries water resource has not sufficient market price, the damage of water pollution is recognized mainly from the aspect of mechanism, but hardly from the aspect of economical losses by water pollution.

Through the evaluation of economical losses by environmental pollution, the GDP index could be modified into ecological GDP (EGDP), which is suitable for the description of real economic output. In 1973, Japanese government proposed the index of Net Nation Welfare, according to which the pollution treatment fee must be deducted from GDP, thus in that year the growth of GDP in Japan was 8.5%, but actually it was 5.8% by the new index [2]. The research on water pollution losses requires many kinds of knowledge. Ofiara (2001) pointed out that the research needed many non-economics majors [3], such as biology, ecology, environmental law even public policy, when he focused on assessment of economic losses from marine pollution. Guan and Hubacek (2008) calculated the optimization of water exploitation in North China by taking the water pollution losses into consideration [4]. The accurate estimation of water pollution losses could help government implement environmental policy. Reddy and Behera (2006) assessed the economic costs of water pollution (industrial) in the rural communities in southern India in order to manifest compensation fair [5]. Shanghai is the most developed province in China and has experienced a tremendous progress in its economy. As a result, there exists need to quantify the economical losses by water pollution in Shanghai, which could let the value of water resource be better understood, it also could provide important basis on decision of the relative water policy for local government.

METHOD OF EVALUATION FOR WATER POLLUTION LOSSES

The existing econometric models for estimation of water pollution losses

It is comparatively late for Chinese to initiate the research of water pollution losses. The first similar research in China is made by Zhu (1983), and in his paper it was estimated that there was about 2% of GNP loss from water pollution in one chosen northern city [6]. There are two famous models for evaluation of water pollution losses from econometric aspect. The first one is a classical model [7, 8] as the following:

$$R=1/(1+A\exp(-BC/C_0)) \tag{1a}$$

$$R_t= \Sigma K_i R_i/\Sigma K_i \tag{1b}$$

R (dimensionless parameter) represents the rate of loss by certain pollutant in water, A and B are the dimensionless parameters to be decided, C and C_0 separately represent the concentration and permitted concentration of the certain pollutant (mg/L); R_t and R_i separately represent the total and certain rate of loss in water (dimensionless parameter), K_i is the value of certain function of water (*yuan*/cubic meter). The other one is a simplified equation [9, 10]:

$$F=RQ(W-W_p)^k \tag{2}$$

F represents the estimated economic losses by water pollution (billion *yuan*), Q represents the quantity of contaminated water (billion cubic meters), W is the quantity of pollution substance in water (million ton), W_p is the permitted quantity of pollution substance in water (million ton), R is the coefficient representing value of water resource versus pollution loss (billion *yuan*/million ton·billion cubic meters), and k is the dimensionless parameter to be decided.

The model (1) uses environmental mechanism, but there are too many parameters to be decided. As for each specific pollutant, the specific parameters A and B in equation (1a) must be determined, which requires enormous research on every possible pollutant. Therefore, the calculation of water pollution losses using model (1) seems not practical. The requirement of model (2) only includes the local water pollution and economic development, but the physics mechanism in the model is not so clear, and in many circumstances the calculation of parameters must be simply handled, decreasing the credibility of the result.

The method used for calculation in this paper

Classification approach, according to which the calculation of each item of water pollution loss is made before summed up, seems much more feasible and dependable than the two econometric models. Therefore, in this paper, the method of classification approach has been adopted to primarily evaluate the economic losses caused by water pollution in Shanghai. Water pollution has direct and indirect influence on economy. Direct influence could decrease the product of fish and grain, also contaminate the water and make it undrinkable. Therefore, the direct losses from water pollution include plantation, fishery, water supply, and wastewater treatment. When it comes to water pollution, government must invest in relative infrastructures to protect water resource from being contaminated. Water pollution could deteriorate the landscape and decrease the revenue of tourism somehow. Another very important indirect influence of water pollution is damage of human health. Therefore, the indirect losses of water pollution include investment in water environment protection, the decrease of ecological landscape, and human health damage. The categories of water pollution losses can be described as Fig. 1:

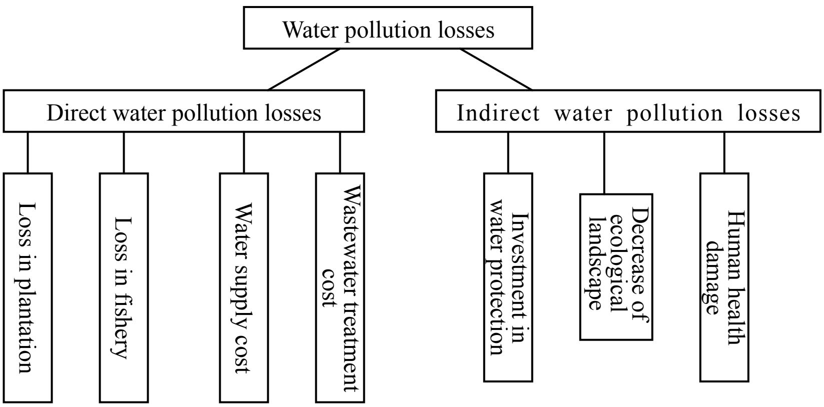

Fig. 1. The categories of water pollution losses

ASSESSMENT OF DIRECT WATER POLLUTION LOSSES IN SHANGHAI

Loss in plantation caused by water pollution

The contaminated land has a decrease of about 210 kilograms grain/ha according to the research of China Agriculture Environment Protection Research Bureau cited by Hong (2007) [11]. Because most rivers in Shanghai have been contaminated to a different extent, and there are 202.3 thousand ha arable land in Shanghai in 2009 [12], so the loss of plantation by water pollution is 42.483 thousand tons, about 3.5% of total output of plantation. As the total output of plantation in Shanghai in 2009 was 14.753 billion *yuan*, so the loss in plantation (LP) by water pollution is 0.516 billion *yuan*.

Loss in fishery caused by water pollution

According to the research of Environment Bureau of Jiangsu Province, the loss in fishery from water pollution is about 5% [13]. For the reason that Shanghai is located near *Taihu*

Lake, the loss in fishery from water pollution in Shanghai could also be regarded as 5%. The output of fishery in Shanghai in 2009 was 5.48 billion *yuan* [14], so the loss in fishery (LF) caused by water pollution is 0.274 billion *yuan*.

Water supply cost

In 2009, the domestic water consumption (DWC) of Shanghai was 1.847 billion tons and industry water consumption (IWC) of Shanghai was 0.559 billion tons [12]. The price of domestic water supply (PDWS) and the price of industry water supply (PIWS) in Shanghai in the year 2009 are as the data showed in Table 1. On June 20th 2009, Shanghai experienced reform of water price, because June 20th is near the middle of the year, so the arithmetical average value could be regarded as the price of year 2009. The water supply cost (WSC) in Shanghai in 2009 is calculated using the equation (3):

$$\mathrm{WSC}= \mathrm{DWC}\times\mathrm{PDWS}+\mathrm{IWC}\times\mathrm{PIWS} \tag{3}$$

After calculation, the total water supply cost is 3.102 billion *yuan*.

Table 1. PDWS, PIWS, PDWT, PIWT in Shanghai, 2009 (unit: *yuan*/ton)

	PDWS	PIWS	PDWT	PIWT
Before June 20th	1.03	1.30	0.90	1.20
After June 20th	1.33	2.00	1.08	1.80
Average value	1.18	1.65	0.99	1.50

Wastewater treatment cost

In 2009, the domestic wastewater discharge (DWD) of Shanghai was 1.893 billion tons and industry wastewater discharge (IWD) of Shanghai was 0.412 billion tons [12]. The price of domestic wastewater treatment (PDWT) and the price of industry wastewater treatment (PIWT) in Shanghai in the year 2009 experienced the same reform of water price as PDWS&PIWS, so the method of dealing with the data is the same. The data of PDWT and PIWT in year 2009 is showed in Table 1. In 2009, the treatment rate of wastewater (α) was 78.9% [15], so the wastewater treatment cost (WTC) in Shanghai in 2009 could be calculated using the equation (4):

$$\mathrm{WTC}=\alpha\times(\mathrm{DWD}\times\mathrm{PDWT}+ \mathrm{IWD}\times\mathrm{PIWT}) \tag{4}$$

After calculation, the total wastewater treatment cost is 1.966 billion *yuan*.

ASSESSMENT OF INDIRECT WATER POLLUTION LOSSES IN SHANGHAI

Investment in water environment protection

Shanghai government has accelerated investment in environment protection. Investment in environment protection (IEP) includes the following items: investment in basic infrastructure for environment (IBIE), investment in pollution source treatment (IPST), investment in ecological construction (IEC), investment in technology for environment protection (ITEP), investment in maintenance of infrastructure for environment (IMIE), and investment in other environment items (IOEI). For the reason that only water pollution losses are focused in this paper, the investment in water environment protection (IWEP) should be calculated as:

$$\mathrm{IWEP}=\beta\times\mathrm{IEP} \tag{5a}$$

$$\mathrm{IEP}=\mathrm{IBIE}+\mathrm{IPST}+\mathrm{IEC}+\mathrm{ITEP}+\mathrm{IMIE}+\mathrm{IOEI} \tag{5b}$$

The coefficient β represents the portion of investment in water environment protection compared to the whole investment in environment protection. It was reported in People's Daily newspaper [16] that in the near future Shanghai would invest in the environment protection more than 60 billion *yuan*, half of which would be invested in water environment protection. Therefore, β is estimated as 0.5. The values in the year 2009 in (5b) were separately 28.274 (IBIE), 9.927 (IPST), 1.22 (IEC), 0.23 (ITEP), 3.877 IMIE), 2.514 (IOEI) (unit: billion *yuan*) according to Shanghai Statistical Yearbook of 2010 [12]. With equation (5a) and (5b), investment in water environment protection (IWEP) was calculated as 23.021 billion *yuan*.

The decrease of ecological landscape caused by water pollution

The decrease of ecological landscape caused by water pollution could be calculated using the equation (6) according to Hong [11]:

$$\mathrm{DEL}=\zeta\times\mathrm{OTR} \tag{6}$$

DEL stands for the decrease of ecological landscape, which could be regarded as decrease of tourism revenue; ζ for the rate coefficient (usually taken as 0.106); and OTR for the output of tourism revenue, which is 100.708 billion *yuan* [15]. Therefore, the decrease of ecological landscape (DEL) is calculated as 10.675 billion *yuan*.

Human health damage from water pollution

About 25% of many cancers, such as stomach cancer, liver cancer, and esophagus cancer are caused by water pollution according to the research by China Environment Press [17]. The proportion of cancer is 0.13% of population, among them stomach/liver/esophagus cancer occupy 62% according to Statistics of Hygiene Ministry of China [18]. The average fee for treatment of cancer is 125000 *yuan* and the average length of hospital stay is 69 days and the average hospital stay fee per day is 150 *yuan* [18]. The population of Shanghai is 19.213 million [12]. Therefore, the human health damage from water pollution could be calculated using equation (7):

$$\mathrm{HHD}=\mathrm{PS}\times\mathrm{PC}\times\mathrm{CO}\times\gamma\times(\mathrm{ATC}+\mathrm{ALHS}\times\mathrm{AHSF}) \tag{7}$$

HHD stands for human health damage from water pollution, PS stands for population of Shanghai, PC for proportion of cancer, CO for the proportion which the discussed cancers occupy, γ for the rate of cancers which is caused by water pollution, ATC for average treatment cost, ALHS for the average length of hospital stay, and AHSF for average hospital stay fee. As a result, the human health damage (HHD) from water pollution is calculated as 0.92 billion *yuan*.

RESULTS AND DISCUSSION

Assessment of the total water pollution losses in Shanghai

The water pollution losses (WPL) is the sum of loss in plantation (LP), loss in fishery (LF), water supply cost (WSC), wastewater treatment cost (WTC), investment in water environment protection (IWEP), decrease of ecological landscape (DEL) and human health damage (HHD):

$$WPL=LP+LF+WSC+WTC+IWEP+DEL+HHD \tag{8}$$

Thus, WPL in 2009 could be calculated as 40.474 billion *yuan*.

The analysis on the portion of water pollution losses in GDP of Shanghai

The Shanghai GDP in 2009 is 1504.645 billion *yuan* [12]. Therefore, the portion of water pollution losses (WPL) in GDP is 2.7%. In Table 2, the comparison among separate regions of China are manifested.

Table 2. The WPL portion in GDP of separate regions of China

Region	WPL portion	Reference
Jiangyin (in *Jiangsu* Province)	2.4%	[11]
Heilongjiang Province	2.7%	[19]
Chongqing Shi	3.0%	[20]
Liao River valley	4.4%	[21]
Huai River valley	4.7%	[21]
Zhu River valley	1.8%	[21]
Southeastern rivers	2.2%	[21]
Southwestern rivers	0.7%	[21]
Whole China	3.1%	[21]
Shanghai	2.7%	[in this paper]

From the data shown in Table 2 [11, 19, 20, 21], *Huai* River valley and *Liao* River valley suffer the most serious water pollution in China, probably because of the local high population density and the scale of industry [22]; while southwestern rivers have the least water pollution, because of local low population density and the low-developed industry. It could also be found out that the WPL portion of Shanghai is still lower than the average level of whole China though Shanghai has high population density (nearly 19 million in only 5.8 thousand square kilometers in 2009 [12]) and a large scale of modern industry, the reason may be correlated with the continuous attention to water environment protection from local government.

In fact, there definitely exists variance in estimating WPL because of subjectivity. It must be remembered that many other scholars enormously underestimate or even ignore the IWEP (investment in water environment protection) item in the whole WPL, which is regarded as a kind of indirect loss from water pollution in this paper, suggesting that WPL portion of Shanghai would be lower if calculated in the ways of other scholars.

CONCLUSIONS

The portion of water pollution losses in GDP of Shanghai in 2009 was about 2.7%, which is in the normal range compared to other regions of China and still lower than the average level of whole China, therefore there is not necessary to worry too much about the water pollution in Shanghai. As far as the high population density and industry scale in Shanghai are concerned, it could also be concluded that local government paid much attention to water protection.

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APPENDIX

Table 3. Abbreviation List

Abbreviation: word Meaning
AHSF average hospital stay fee
ALHS average length of hospital stay
ATC average treatment cost
CO the proportion which the discussed cancers occupy
DEL decrease of ecological landscape
DWC domestic water consumption
DWD domestic wastewater discharge
HHD human health damage from water pollution
IBIE investment in basic infrastructure for environment
IEC investment in ecological construction
IEP investment in environment protection
IMIE investment in maintenance of infrastructure for environment
IOEI investment in other environment items
IPST investment in pollution source treatment
ITEP investment in technology for environment protection
IWC industry water consumption
IWD industry wastewater discharge
IWEP investment in water environment protection
LF loss in fishery
LP loss in plantation
OTR output of tourism revenue
PC proportion of cancer
PDWS price of domestic water supply
PDWT price of domestic wastewater treatment
PIWS price of industry water supply
PIWT price of industry wastewater treatment
PS population of Shanghai
WPL water pollution losses
WSC water supply cost
WTC wastewater treatment cost

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