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The calculation of economic losses of China's coastal water pollution

Xuelian Zhou*
School of Business, Chengdu University of Technology, Chengdu 610059, Sichuan Province, (CHINA)
E-mail: zhouxuelian2012@163.com

ABSTRACT

In recent years, with the rapid development of China's city economy and booming population, the total amount of environmental pollutants discharge increases constantly, resulting in deterioration of quality of Chinese coastal waters, meanwhile restricting the development of China social and economy. That to what extent marine pollution is influencing China's industrial economy, and how to effectively evaluate the value losses caused by ocean water pollution, is the basis of the marine environment protection countermeasures and policy definition. Therefore, in this paper, with the value loss-concentration calculation method, the economic losses of water pollution in coastal waters is evaluated for China in 2010~2013. Compared with others, this method is succinct, accurate and easy to run, and it's not only able to estimate the loss caused by single environmental element, but also capable of comprehensive evaluation of various environmental factors, thus better reveal the relationship between pollution and economic losses.

KEYWORDS

Value loss-concentration calculation; China's coastal water pollution; Economic losses; The marine industry; Pollutant.

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INTRODUCTION

For a long time, the exploitation on marine resources without restriction, as well the marine ecological damage, has caused over exploitation of marine environment and resources. Therefore, in order to fully reflect the value of marine resource and ecological environment, and correctly evaluate costs and benefits of marine development activities, it's necessary to scientifically calculate the economic losses of environmental pollution. The calculation of the economic losses caused by pollution is also the basis for water environment planning and water environmental policy definition. Back in 1920, America biologists and demographers, Pearl and Reed uncovered the function of growth curve in the research of biological reproduction, which is mainly applied to describe the process of growth of industry and organisms[1]. Then James declared economic losses caused by some pollutants in water can be calculated with "loss-concentration curve", but failed to further explore the economic losses caused by various pollutants. In 1993 Zhu Faqing, Gao Guanmin believed that the real water pollution was rarely caused by single pollutant, therefore should first "standardize" all kinds of pollutants to get the comprehensive pollution index, and then established the method of concentration-value loss rate, and the quantitative relationship between water pollutants and economic losses[2]. For the first time, this paper makes use of value loss-concentration calculation, to calculate, in a more objective way, the economic losses caused by China's coastal water pollution. The purpose of this paper is to evaluate the value loss caused by China's coastal water pollution, and how to avoid the marine environment disruption caused by unplanned exploit of tourism resources, fishery resources.

METHODS

The model of pollution loss rate

Generally sewage contains oxygen, nutrients, heavy metals and other toxic and harmful substances which greatly influence the water quality, and in turn the fisheries, tourism, industry and other industries, causing losses due to a reduction in yield and quality. James deems[3], there is no linear relationship between the economic losses caused by the water pollutants and concentration of pollution, but similar to the biological growth curve, often appears as a "s" type nonlinear trend[4] (see Figure 1).

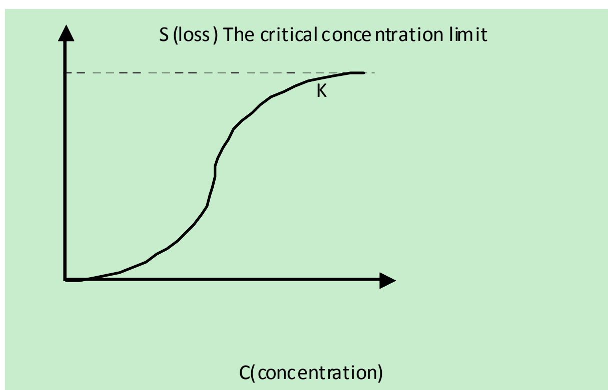

Figure 1 : Relationship between economic losses and pollutant concentration

Suppose some environmental factors i in the environment, and there are n pollutants, and the pollution loss regarding to environmental factors i and caused by pollutant j is. In order to get the rate of pollution loss, creation of differential equation for the concentration of pollutants and environmental resources value loss of economic value is needed :

$$\frac{dS_i}{dC_j} = \beta_{ij}\frac{S_i}{K_i}(K_i - S_i) \quad \textbf{(1)}$$

Where:

C_j: the concentration of pollutant j for the environment factor i ;
S_i: when the concentration of pollutant is C_j, the economic value loss of the environmental factor i;
K_i: the economic value of environmental factor i when its function is complete;
β_{ij}: a proportional coefficient, namely the relative loss rate of economic value of environmental factor i.
On the (1) type of integral solution to:

$$S_i(C_j) = \frac{K_i}{1+a_{ij}\cdot \exp(-\beta_{ij}C_j)} \quad \textbf{(2)}$$

$$r = \frac{S_i}{K_i} = \frac{1}{1+a_{ij}\cdot \exp(-\beta_{ij}C_j)} \quad \textbf{(3)}$$

Let $X=C/C_0$, correct (3) as:

$$R = \frac{S_i}{K_i} = \frac{1}{1+A_{ij}\cdot \exp(-B_{ij}X)} \quad \textbf{(4)}$$

Where:
R: the pollution loss rate;
C_0: a contaminant concentration tolerable by the environment, defined by the local and state water quality regulations;
C: the concentration of water pollutants in some cases.
Thus the problem is transferred to solving the pollution loss rate of R, and the single pollution economic losses value can be expressed as:

$$S = K_i \times R \quad \textbf{(5)}$$

This is the basic formula to calculate the evaluation of economic losses of marine pollution.

The determination of parameters

The determination of parameters A_{ij},B_{ij}.

The value of parameters A_{ij},B_{ij} is specific to the nature of pollutants, and generally requires pollution toxicology experiment or the actual investigation to the polluted water resources. Generally water has some capability of self purification, so only when the water pollutants exceed a certain threshold, it turns out to be the value losses of water[5]. Therefore, the determination of A_{ij},B_{ij} can be based on the background concentration of the pollutant, referring to the approximate description in the relevant state regulations[6]. Suppose the critical concentration of the pollutant J in the environment is A_{0j}, and the corresponding single pollution loss rate is R_{0j}(generally calculated as 1%), and the upper limit when causing serious pollution is C_{mj}, and the corresponding single pollution loss rate is R_{mj} (generally calculated as 99%). In order to facilitate the representation, denoted as:

$$f_i = \ln\frac{R_{mj}(1-R_{0j})}{R_{0j}(1-R_{mj})} \quad \textbf{(6)}$$

$$\text{Then:} A_{ij} = \frac{1-R_{0j}}{R_{0j}}\exp\frac{f_i R_{mj}}{C_{mj}-C_{0j})} \quad \textbf{(7)}$$

$$B_{ij} = \frac{f_i}{C_{mj}-C_{0j}} \quad \textbf{(8)}$$

In the formula (6), the critical concentration is determined according to the national standard of water environment, and the water function, and the limit concentration is set to 5～10 times what's in water quality standards, also referring to and the increasing amplitude of different kinds of water quality standards. Due to the toxicity of pollutants is the invariant of location and time, the calculation of parametersA_{ij},B_{ij} is universal in different areas.

The total loss rate of water pollution. Usually there are more than one pollutants in the water, and the comprehensive loss rate is not the algebra sum of individual pollution loss rates, but in a intersection form. Suppose there are pollutants A and B in the water, and the loss rates are P(A)= Ri1 and P (B) = Ri2 respectively, then the comprehensive loss rate:

$$P(A \cup B) = P(A) + P(B) - P(AB) \quad \textbf{(9)}$$

Generally P(AB) and not calculated by P (A) and P (B), but when A, B are independent:

$$P(AB) = P(A) \cdot P(B) \quad \textbf{(10)}$$

So the formula (4) can be expressed as:

$$R_i^{(2)} = P(A \cup B) = P(A) + P(B) - P(A) \cdot P(B)$$

$$= R_{i1} + R_{i2} - R_{i1}R_{i2} = R_{i1}^{(1)} + (1 - R_{i1}^{(1)}) \cdot R_{i2}^{(1)} \quad \textbf{(11)}$$

Similarly there may be n independent pollutants, thus the comprehensive loss rate of $R_{in}^{(n)}$ formula:

$$R_{in}^{(n)} = R_{in-1}^{(n-1)} + (1 - R_{in-1}^{(n-1)}) \cdot R_{in}^{(1)} \quad \textbf{(12)}$$

This is the quantitative relationship between the loss rate of single pollutant and the comprehensive loss rate of various pollutants. Obviously it satisfies the commutative law and $0 \leq R_{in}^{(n)} \leq 1$, and the practical significance is: When adding a pollutant of loss rate of R_{in}, the increased loss rate is the product of the rest and R_{in}, and the its total loss rate is or the original loss rate plus the additional loss rate.

Strictly speaking, the pollutants are not completely independent to each other, and there may be antagonistic or synergistic effect between them. Regarding to common contaminants, there is no precise report for such effects, so it's ignored. Zhu and Lv considered that the process of eutrophication are mainly caused by TN, TP contents, and TN:TP ratio limit[7]. When the TN:TP ratio is higher than the basic ratio, phosphorus is more restrictive, otherwise nitrogen is. Therefore, TN, TP are not independent of each other, and shall be taken as:

$$R_{i1}^{'} = \min\{R_{i1}, R_{i2}\}, R_{i2}^{'} = 0 \quad \textbf{(13)}$$

Formulas (4) and (12) can be applied to calculate the comprehensive loss rate caused by water pollution when there are co-existing pollutants.

The calculation of China's coastal water pollution losses

Chinese marine environment survey

Statistics shows in 2013 Chinese marine GDP is 5431.3 billion Yuan, with an annual growth rate of 7.6%, accounting for 9.5% of GDP, in which the marine industry added value is 3196.9 billion Yuan, and the added value of marine related industry is 2234.4 billion Yuan[8]. The added value by the first, second and third industry takes the share in gross ocean GDP is 5.4%, 45.8% and 48.8% respectively. In 2013, the national sea water quality level is generally normal, and the main factors exceeding the standard are inorganic nitrogen (28.6% above) and active phosphate (15.6% above), some the ocean petroleum (2% above) and chemical oxygen demand (1% above). For the 200 rivers under surveillance, water quality level I ~ III takes 46% and 68.8% water meets the standard at the ocean entry[9]. The main pollution factors in water worse than Class III are the chemical oxygen demand, ammonia nitrogen and total phosphorus. Pollutants exceeding the standard produce great negative impact on the fishery production, tourism, industrial and marine transportation. Therefore, we select the main standard exceeding factors in 2010~2013 China offshore water, namely TN PO4-P, COD and petroleum pollutants, as a reference for evaluation.

TABLE 1 :China's coastal water quality (mg/L)

Year	TN	PO4-P	COD	Petroleum
2013	0.299	0.017	1.02	0.016
2012	0.300	0.016	1.00	0.017
2011	0.274	0.014	0.99	0.017
2010	0.360	0.016	1.03	0.016

(Data sources: China marine environmental monitoring, http://www.mem.gov.cn/)

Determination of the pollution loss rate

The values of parameters Aij, Bij. The environmental function of China's coastal water includes fisheries, marine transportation, industrial and coastal tourism. The critical concentration of pollutants is determined according to the national standard of water environment and water function, so based on the Sea Water Quality Standard of China(GB 3097-1997) classification, Class II is selected as the critical concentration for fishery, and Class III is selected as the critical concentration for marine transportation, industrial and tourism[10]. According to the Formulas (7) and (8), the reference values of pollutants Aij, Bij are calculated (TABLE 2).

TABLE 2 : Value of parameters about Aij,Bij

Marine Functions	TN		PO4-P		COD		Petroleum	
	A	B	A	B	A	B	A	B
Fishery	160.6	0.4837	160.6	0.4837	622.1	0.6127	368.0	1.3129
Transportation	160.6	0.4837	160.6	0.4837	274.9	0.2042	200.8	0.7095
Tourism	622.1	1.838	622.1	1.838	274.9	0.2053	622.1	1.838
Industry	274.9	1.0211	274.9	1.0211	274.9	0.2053	799.4	2.0887

Pollution loss value calculation. According to the quality data in TABLE 2, Formulas (12) and (13) are applied respectively, and then China's offshore single index of pollution loss rate and total loss rate are calculated for various functions in year 2010~2013. The calculation results are shown in TABLE 3.

TABLE 3 : Multirate of pollution of China sea area during 2010~2013（%）

Year	Marine Functions	TN	PO4-P	COD	Petroleum	Total Loss
2013	Fishery	0.7144	0.6239	0.2993	0.2767	1.1955
	Transportation	0.7144	0.6239	0.4460	0.5012	1.5630
	Tourism	0.2777	0.1656	0.4465	0.1653	0.7757
	Industry	0.4912	0.3688	0.4465	0.1292	0.9418
2012	Fishery	0.0107	0.6193	0.2994	0.2771	0.5863
	Transportation	0.7148	0.6236	0.4442	0.5015	1.5612
	Tourism	0.2782	0.1653	0.4447	0.1656	0.7739
	Industry	0.4917	0.3684	0.4447	0.1294	0.9398
2011	Fishery	0.7109	0.6230	0.2940	0.2771	0.8976
	Transportation	0.7109	0.6230	0.4433	0.5015	1.5597
	Tourism	0.2653	0.1647	0.4438	0.1656	0.7724
	Industry	0.4789	0.3676	0.4438	0.1294	0.9381
2010	Fishery	0.7357	0.6193	0.3012	0.2767	1.1928
	Transportation	0.7357	0.6236	0.4469	0.5012	1.5636
	Tourism	0.3106	0.1653	0.4474	0.1653	0.7763
	Industry	0.5226	0.3684	0.4474	0.1292	0.9423

Further calculation according to year 2010~2013 China marine economic output shows: the loss value of functions of Chinese offshore water increases gradually year by year (see TABLE 4). The loss value of 2013 is the highest, as 101.5 billion Yuan, and the loss rate is 4.48%; even in 2012 with the lowest loss rate, is still 3.86%, and the total pollution loss value as big as 69.5 billion Yuan.

TABLE 4 : Economic losses assessment of marine pollution in 2010~2013(100 million Yuan)

Year	Marine Economy	Fishery	Transportation	Tourism	Industry	Total Loss	Loss Rate%
2013	22681	271.15	354.50	175.94	213.61	1015.20	4.48
2012	20574	120.63	321.20	159.22	193.35	794.40	3.86
2011	18760	168.39	292.60	144.90	175.99	781.88	4.17
2010	15531	185.25	242.84	120.57	146.35	695.01	4.48

CONCLUSIONS

In Year 2010~2013 China's coastal waters pollution loss rate remains at a stable level, while the loss of economic value increases year by year, and reaches the maximum in 2013, above 100 billion Yuan. Obviously, with the development of China's economic and the further utilization of marine resources, marine environment quality is being compromised; resulting in China's coastal area environment quality loss increases year by year. According to above conclusion, the environmental protection departments should take measures to prevent the occurrence of red tide; which is conducive to enhance the vigilance of people's environmental awareness and the government's alert on environmental pollution; and take positive measures to reduce the pollution loss of value, such as control of water pollution, industrial waste water discharge, in order to achieve the sustainable development of China's marine economy.

"Value loss-concentration calculation" is mainly applied to evaluate the economics loss caused by surface water and groundwater pollution. The precision depends on the calculation of the water pollution loss rate R and the total economic value K of the same water unpolluted. Precise detection of the water pollution level is the key to accuracy of R, including the investigation on hydrogeological conditions and calculation parameters. The evaluation accuracy of the economic value of polluted waters, on the other hand, is the key to the accuracy of K, involving the related resources economic evaluation theory and method. This paper takes the calculation parameters which are overall pollutants concentration averaged by year, so the result is not accurate enough, and also lacks of adequate verification model. Therefore in this paper, the result of

China's economic loss assessment result of the offshore marine areas can be used as a reference for related research and theory, meanwhile the improvement of the method is still needed.

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