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Designing and simulation of the controlling mechanism for the inland shipping water pollution

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ABSTRACT

In china river shipping not only contribute to the development of the economy, but also damage the environment waters. It is very important to design effective mechanism and policy for controlling water pollution. This paper designs a effective mechanism to control river shipping water pollution through process controlling as angle of view based on the analysis of the reason and characteristic of water induced by river shipping pollution. In order to validate the effect of the mechanism this article also simulate the controlling mechanism and policy based on system dynamics model by using tree-structure methodology. The results are helpful to the sustainable development planning between river shipping and water environment.

KEYWORDS

River shipping; Water pollution; Mechanism and policy; Designing and simulation.

INTRODUCTION

In china river shipping not only contribute to the development of the economy, but also damage the environment waters. Inland shipping water pollution mainly include: crew sewage and garbage, oily bilge water and ballast water and chemical toxic liquids. According to statistics[1], in the Yangtze River Basin, inland vessels produce about 90, 000 tons of waste oil, 200, 000 tons of garbage per year, and sewage displacement with a medium-sized city fairly. At the same time, it can not be ignored problem about oil pollution and toxic chemicals pollution due to the emergency accidents.

In order to control pollution caused by inland shipping, currently a series of laws and executive orders have been promulgated. However, the current regulations and executive orders are still inadequate and ineffective in practice. According to actual survey, a lot of garbage and oily wastewater almost without any treatment directly discharged into the water bodies.

Currently there are two main ideas about how to control the water pollution : the first is direct administrative regulation (including environmental regulations and standards of various enforcement); the second category is a market-based economic instruments (including pollution taxes, emissions trading and so on).

Direct administrative regulation is the means by regulatory agencies to develop appropriate laws and regulations on environmental pollution intervene directly, such as limiting emissions of pollution, enacted environmental standards, the permit system with decontamination equipment and requirements and so on. Kathuria V[2] proposed to apply direct regulation to control pollution in developing countries. Tan B, Jiang H[3] studied how to strengthen legislation to control water pollution. Bernhard L, Beroggi GEG, Moens M R[4] proposed to apply Comprehensive administrative regulation methods to control pollution. Pargal S, Wheeler D[5] analysis the Characteristic of some Various administrative means. But Stranlund, J.K[6] think the cost of Monitoring and Enforcement is very high. For how to control inland shipping water pollution, currently many scholars carried out relevant research from the perspective of the legislative and administrative in China. Jin Jianzhong[7], Chen Mian[8] proposed to accelerate the standardization process for inland vessels. Leng Qinghui[9], Deng Libiao advised[10] it is essential to improve the environmental awareness for the crew. Li Fang[11] proposed to strictly control the ship visas and qualifications check, prevent the occurrence of contamination from the source. Mei Hong, Chen Zhiying[12] believes that lack of emergency response fund security system directly affects the ship pollution emergency response capabilities. Yuan Xue[13] thinks that it is necessary to inland ship pollution accident liability require more strict obligation, and the scope of compensation for pollution damage shall be expanded. Administrative control has a positive effect, and its advantage is mandatory, authority and clarity. But for inland shipping pollution, since the mobility of the ship, and the same number of operating vessels involved in the waters, combined with the impact of hydrological conditions, it is difficult to determine the actual sewage situation specific ship. The means of implementing administrative controls need to have a lot of information, management costs are higher, but the effect is not significant. Many scholars have proposed market-based economic instruments such as pollution taxes, emissions trading rights and Sewage charges system.

Since the 1970s, many countries levy environmental taxes in accordance with the principle of "the polluter pays", including air pollution, water pollution taxes, noise, garbage tax and so on[14,15]. It is significant to improve environmental situation. For the economic externalities, as early as 1920, British economist Pigou puted forward the ideas of environmental taxes in his book "welfare economics"[16]. Pigou thinked the government must take appropriate economic instruments (environmental taxes) to control economic externalities. But for inland shipping pollution, according to "Pigou tax" theory, environmental pollution loss can be effectively added to ship operators cost, and better guiding the ship operators to strengthen environmental awareness.

Emissions trading rights system is a pollution control measures based on Coase theory[17], the main idea is the operator can (usually presents in the form of emission permits) legally purchased pollution emissions, emission rights can be traded like commodities, thereby controlling pollution emission material. Stavins[18], Gangadharan, L[19] discussed transaction cost of the controlling pollution based on “Coase theory”. Van Dyke, Brennan[20], Godby

R[21] studied to apply market power to control pollution according to “Coase theory”. Barry D Solomon[22], Van Egteren[23] made some research about emissions trading systems from the angle of the equity market. Rosegrant M W[24], Prabodanie R A[25] studied how to use “Coase theory” to improve the controlling efficiency of Water pollution. In recent years, many scholars put forward to levy sewage charges for Ship operators to control inland shipping water pollution, such as Resour J W, Manage P [26], Montgomery, David[27], Neil W O, David M, Moore C, et al[28]. Chen Hu, Yin Jun[29,30] proposed to levy sewage charges according to the type of ship in order to translate economy externalities of Ships Pollution to economy internalities. Charging system is based on the "polluter pays" principle, in accordance with national laws or regulations impose sewage charges to polluters, in essence, forcing polluters add environmental damage caused by emissions into their cost of production being. But for inland shipping pollution, since the mobility of the ship, many operators in order to avoid pollution charges, will ship to the waste-water pollutants. In addition, charging system is paying after pollution, pollution behavior has happened before in its charges, but the water quality of the environment has been compromised. Therefore, for inland shipping pollution, sewage charges has some shortages of low operational efficiency, environmental protection lag and other defects.

Therefore, it is urgent to design effective mechanism and policy to solve and control the inland river shipping water pollution in order to achieve sustainable development of river shipping and the environment

However, it is still obviously insufficient about the current study of the controlling mechanism for inland river water pollution. The studies are only limited to the generic statistical description and simple comparative analysis. It is not deep enough and too general for the study of the controlling mechanism design, mechanism and policy relationship, mechanism

and policy implementation effect analysis and so on. So, it is very important to put forward research in theory and statistical test level further ahead.

According to the reason and characteristics of water pollution of inland river shipping this paper designs the controlling mechanism from process controlling perspective and puts forward the innovative countermeasures. At the same time, in order to further verify the effect of controlling mechanism and policy, to the Yangtze River Basin as an example, this article simulate the controlling system based on system dynamics model and rate variable fundamental in tree modeling method.

DESIGN OF THE CONTROLLING MECHANISM OF THE INLAND SHIPPING POLLUTION

The reason of water pollution of inland river shipping

Low technical level of the Inland river shipping vessels

In china many inland shipping vessels are small and the technical level are low and oar ship s account for more than 50% of the total number of vessels. Many shipper owners often build small oil tankers in the towns shipyard for the pursuit of economic efficiency regardless of the Environmental problems. Due to the low technical level and he poor worker skills of those towns shipyards, those oil tankers can not meet the relevant national norms and technical standards. Even some ship owners change the dry cargo vessels into oil tankers in order to save money, so those oil tankers are not qualified for operation and cause the serious hidden danger.

The low quality of inland crew

According to the survey, Inland crew has lower degree of education about 80% of the inland transport crew are high school level and 40% only primary school culture level, also the crew in many family owned ship still belongs to the illiterate. It is difficult to monitor the sewage behavior because the ship is floating point source, so the crew lack of awareness of environmental protection and discharge the pollutants for convenient. In addition, because the low degree of education level of the crew and without training of safety operation knowledge, many crew also can’t operate anti pollution equipment. So usually the oily sewage and garbage is discharged directly into rivers and lakes.

Lack of effective pollution accident emergency response system

Because of the risk of accident probability, effective pollution prevention policy can not completely eliminate the pollution accidents. Traffic accident will cause great pollution to the water environment in a short time, therefore effective emergency response mechanism for pollution control is very important. But at present in china inland river shipping is also lack of corresponding perfect plans in emergency. Especially lack of the emergency command and expert decision support system. Therefore it can not effectively carry out the work and clear water environment pollution

The lack of effective mechanism of compensation for damage

Because the hazards of toxic oil and chemicals, once the accident happened it not only cause serious casualties but also damage to water quality and resulting in huge economic and ecological loss. In order to protect the interests of victims of pollution effective compensation mechanism of pollution is very import. But in China the ship does not have the capacity to pay clean-up costs or not timely payment, causing great pressure to the relevant maritime authorities and directly affect the cleaning effect. Most inland ship pollution accidents loss can’t be effectively compensated and lead the situation of "who cleaning who unlucky", so it greatly influence the cleaning effect and causing serious environmental pollution problems.

Analysis of the characteristics of inland river water pollution

The physical characteristics of inland river shipping pollution

Unlike the fixed point pollution, Inland river shipping water pollution is floating and not easy to be monitored In special water area, because the sewage of many ships is cross each other and the geographical, meteorological, hydrological conditions influence on the pollutant transformation, so it is difficult to monitor emissions of a single ship. Strictly speaking single Ship pollution can also identify and monitor, we can use remote sensing (RS), geographic information system (GIS) to monitor and simulation the ship’s pollution, but we should bear too high management costs.

Economic characteristics of inland river water pollution

Because the water resource is a public goods, public goods means that everyone can get the benefits of it, and one of its consumption will not reduce another person's consumption. Therefore, the economic characteristic of inland shipping pollution is externality.

Economic externality refers to the operators cause the external environmental loss to the other economic entities indirectly, the external environmental loss can’t be added to the operators actual cost, it is the social costs. Because waters are public resources, and if the inland shipping operators do not add environmental loss to its operating costs, it will result to economic externalities. In order to control the economic externalities, generally two methods will be used: one is directly to control the operations by executive order and external policies; in additional through market mechanisms to control economic externalities.

Social characteristics of inland river shipping pollution

Inland river shipping pollution also have certain social characteristics, including moral hazard and adverse selection problems. Because sometime the information between regulatory authorities and operators is distorted, so it will lead to the "adverse selection" and "moral hazard" behavior of operators. For the inland shipping, it is more difficult to monitor the real situation of the sewage emission. The information between ship operators and regulatory authorities is asymmetric, and ship operators reluctant to report the real situation of sewage. So it is very important to design a contract based on incentive regulation theory to incentive ship operators to protect water environment voluntarily.

The controlling mechanism and policy design of inland river water pollution

The controlling mechanism of inland river shipping water pollution is the " regulation and control of water pollution according to the basic rules and the mechanism of the effect way of shipping on the water environment" In essence. Among it controlling mechanism is the theoretical basis of policy and policy implementation mechanism.

Therefore based on the above analysis, we can design integrated control linkage controlling mechanism "source control, process control and outcome control " from the perspective of the process controlling. From this controlling mechanism, we can effectively supervise and control the inland river shipping pollution to water environment in whole process and dynamic. At the same time effective controlling mechanism must be embodied and implemented by the relevant policy.

For source control, Implementing the inland river shipping operating license is a important controlling policy. Ship operators must have the appropriate ship technical condition and cleaning equipment for inland river shipping activities, the crew must go through training and assessment to obtain operating permits. On the basis of empirical research, combining foreign advanced experience and the situation of china to study the operating license content, nature, ways of implementation.

For process control, the river shipping environmental tax policies is a important controlling policy. The environmental taxes is a regulation mechanism including two parts "environmental tax levying+ rebateing incentive". firstly levying environmental tax for all operating vessels in related waters. Environmental taxes include the overall environmental taxes and the environmental taxes of single ship. Firstly, the relevant administrative departments estimates the value of environmental damage in related waters due to the inland shipping pollution in a certain period of time (usually one year) as the overall environmental taxes. Then, assigning the overall environmental tax for each single ship according to vessel operating indicators (tonnage, working days, crew numbers, equipped with pollution treatment facilities, etc.). secondly according to ship's actual emissions of pollutants in the specified station to carry incentive rebate, rebate system is conducive to achieve efficiency and social equity. Ships that finished paying environmental taxes can discharge waste oil and waste water in special pollution station, Pollution station or other relevant administrative departments directly to give a certain percentage of rebates to the ship based on the amount of pollutants discharged registered. This will not only constrain the behavior of the operator, but also provides a continuous incentive to ship operators to protect water environment.

For outcome control, the emergency response level directly affects the decontamination effect. Therefore emergency response standard and level is important to outcome control. At the same time, the compensation system, legal and operational control is important for water pollution. Pollution compensation as the last line of pollution control, according to the deficiency of compensation system in the division of labor, fund system and the integration of the resources to design domestic oil pollution fund as expression of policy.

So the controlling mechanism of inland river shipping water pollution from the perspective of the process controlling can be expressed by the Figure 1 as follows:

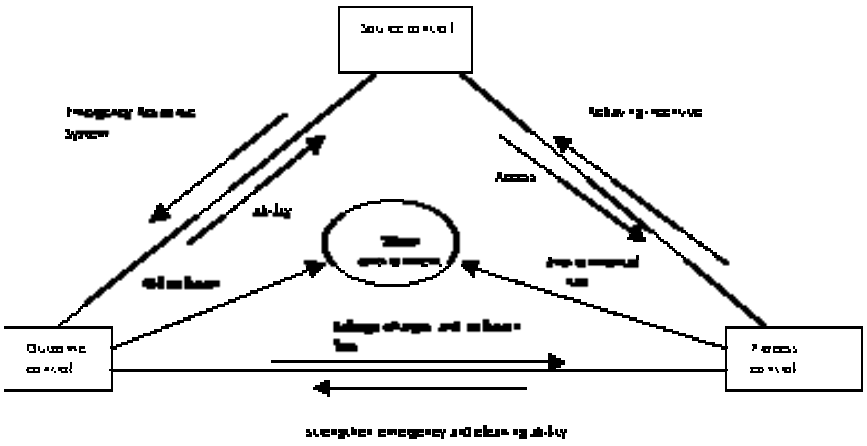

Figure 1 : The controlling mechanism of inland river shipping water pollution

THE SIMULATION EXPERIMENT OF CONTROLLING MECHANISM OF INLAND RIVER SHIPPING WATER POLLUTION

Build the system dynamics model based on rate variable in tree

The mechanism of Controlling pollution essentially is a collaborative interaction process of the social, economic, resource, environment factors With nonlinear, open, dynamic characteristics. But it is not intuitive and if we use traditional system dynamics model to analysis complex system. Professor Jia Renan[12,13] put forward the rate variable fundamental tree modeling method that can transform the complex network structure of the flow graph into a tree structure model In order to solve the problem of dynamic analysis of complex structure feedback system.

Through the investigation of the pollution in Yangtze area and macro-control policy, the pollution and anti-pollution process can be listed as follows.

The economic development of the Yangtze area not only contribute to the development of the shipments, but also the growth of the number of the ships. The waste oil, waste water and solid waste discharged by these vessels make a large effect on the environment. The cost of pollution caused by the shipping pollution have some side effect on GDP which continue to affect the investment of the anti-pollution fund as well as the development of freight volume. At the same time, we should control and manage the anti-pollution action to reduce the lost, which will further affect the pollution discharge. Therefore the main target is to make the concentration of water quality close to the standard.

According to the above analysis, we can divide the main control system into five subsystems which including the concentration of water quality and shipping, the lost of pollution and concentration of water quality, the lost of pollution and macro-control policy, macro-control policy and development of shipping, the lost of pollution and GDP. We can use the SD Rate Variable Fundamental In-tree Model.

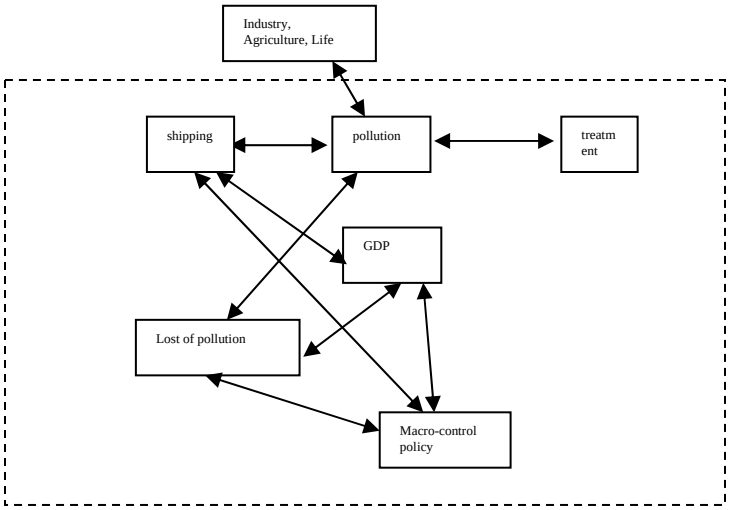

Figure 2 : Main structure of pollution of environment waters and macro-control system

Flow and flow rate

Basing on the research and analysis, we can build the flow and flow rate system and other variable, control parameter.

We can first choose the concentration of water quality as the parameter of flow caused by the pollution. Shipping is a macro concept, so we can choose some index to be the state variable including the number of ships, mainly include freight volume, the quality of seamen and the situation of using anti-pollution technology. Controlling mechanism of anti-pollution is a systematic engineering with internal connection whose main components are safe prevention system, emergency reaction system and compensation for damages system. We set the tax system of environmental concentrations, the daily management of seamen and the management of technical specification as the parameter in prevention system, the ability of emergency reaction as the parameter in emergency reaction system, the improvement of compensation scheme and ratio of compensation for damages as the parameter in compensation for damages system.

According to the above analysis, we can build the main structure of the flow and flow rate system as follows.

{(L1(t), R1(t)), (L2(t), R2(t)), (L3(t), R3(t)), (L4(t), R4(t)), (L5(t), R5(t)), (L6(t), R6(t)), (L7(t), R7(t))}

The flow and flow rate:
L1(t), R11(t), R12(t)——concentration of water quality(L)and its varianceR11(t)(L per year)
L2(t), R2(t)——the number of ships and its variance
L3(t), R3(t)——the freight volume in Yangtze river(MT)and its variance(ton per year)

L4(t), R4(t)——the quality of seamen(0-1)and its variance(0-1/per year)
L5(t), R5(t)——the technical condition of ships(0-1)and its variance (0-1 per year)
L6(t), R6(t)——GDP in that area(Yuan)and its variance(Yuan/year)
L7(t), R7(t)——lost caused by pollution(Yuan)and its variance(Yuan/year)
Exogenous variable and the macro-control parameter:
E0(t)——the investment of pollution abatement, a0(t) related macro-control parameter
E1(t)——tax for environmental centration, a1(t) related macro-control parameter
E2(t)——daily management for seamen, a2(t) related macro-control parameter
E3(t)——management for technical specification of ships, a3(t) related macro-control parameter
E4(t)——the level of pollution compensation, a4(t) related macro-control parameter
E5(t)——capability for pollution emergency, a5(t) related macro-control parameter

SD Rate Variable Fundamental In-tree Model

We can build SD Rate Variable Fundamental In-tree Model for the influence and control system of environment water pollution based on the flow and flow rate system and SD Rate Variable Fundamental In-tree Model.

The growth in concentration of water quality R11(t) is influenced by the industry, agriculture, life and shipping which is reflected by the number of ships L2(t), the freight volume in Yangtze river L3(t), the quality of seamen L4(t), the technical condition of ships L5(t), while the reduction in concentration of water quality R12(t) is affected by the investment of pollution abatement E0(t). Therefore we can get the SD Rate Variable Fundamental In-tree of water quality in Yangtze river T1(t):

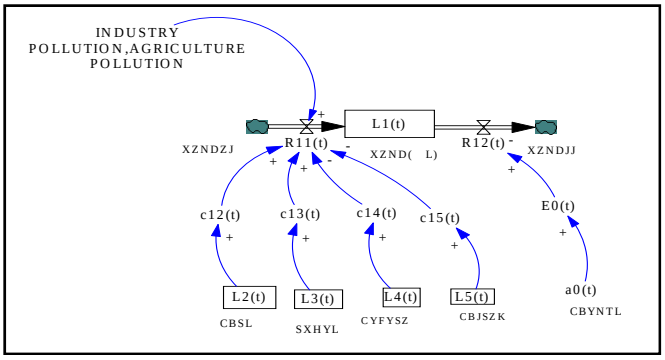

Figure 3 : SD Rate variable fundamental in-tree of water quality in Yangtze river T1(t)

With the same principle, we can get other SD Rate Variable Fundamental In-tree, and then we can transfer them to the general plan of whole system:

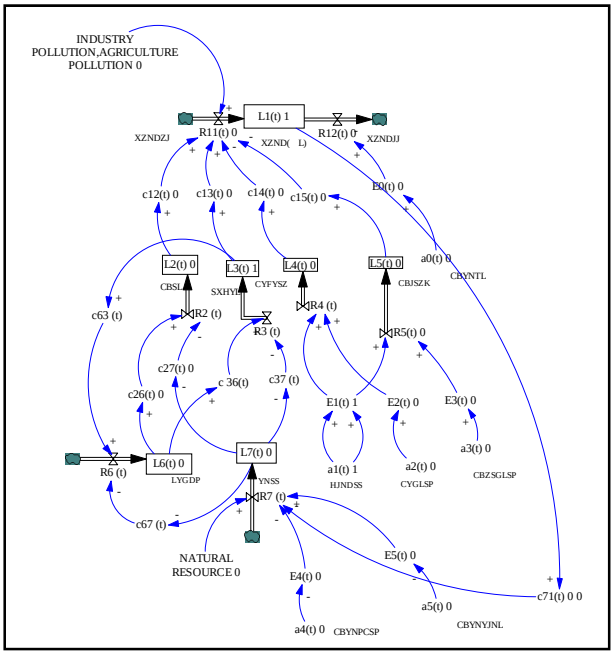

Figure 4 : SD Rate Variable Fundamental In-tree of water quality in Yangtze river T1(t)

The explanation for main formula and parameter in the leading structure of the flow rate

Parameter can be estimated through many ways. The single parameter can be used a non-aggregate way to estimate, such as the investigation for the past and present, the advice from specialists, historical record and reasonable speculation from experience. Some nonlinear parameter should be provided by TABLE function which is described by a couple of Figures. Dependent variables can be defined through certain endpoint, value and gradient of the intermediate point and faired curve. However, it is more difficult to define those parameter than single parameter which is covered in this model.

For example,

R12(t)= investment level of pollution abatement*influence factor

R2(t)= L6(t)*influence factor on GDP in those area-L7(t)*influence factor of lost caused by shipping pollution

R3(t)= L6(t)*influence factor on GDP in those area-L7(t)*influence factor of lost caused by shipping pollution

R4(t)= a1(t)*E1(t)*influence factor of tax regulation*0.6+a2(t)*E2(t)*influence factor*0.4

R5(t)= a1(t)*E1(t)*influence factor of tax regulation+a3(t)*E3(t)* influence factor

R6(t)= L3(t)*influence factor for freight volume-L7(t)*influence factor for lost caused by pollution

Model simulation and policy analysis

Data needed in system analog including the condition for concentration of water quality in stream of the Yangtze river, the variation of freight volume, the variation of average ship tonnage, GDP for Yangtze area, GDP for per freight volume, which can be found in statistic yearbook[12-14].

All the SD model can be run on computer. The VENSIM[15] software provide the function of compile and error detection and test the validity of expression, the rationality of the model. The better goodness-of-fit statistics can be reached through the comparison between the simulation value of historical state variable and historical statistical data, and then test the availability of the model.

Decision maker can use a system simulation to adjust the decision variable in the model and make the results. The slider on human-computer interface is a convenient and intuitive decision process tools provided for the decision maker. The decision variable include:

C—the compensation ratio for damage ;

R— emergency reaction capacity for shipping pollution;

T— tax for environmental concentration;

M—daily management level of seamen;

T—technical management level for ships;

I—investment for contamination;

The following chart(Figure 5) shows the forecast result in present policy (the compensation ratio for damage is 13%, tax for environmental concentration is 0%, daily management level of seamen is low, emergency reaction capacity for shipping pollution is medium, technical management level for ships assumed medium and investment for contamination covering 4% of GDP.

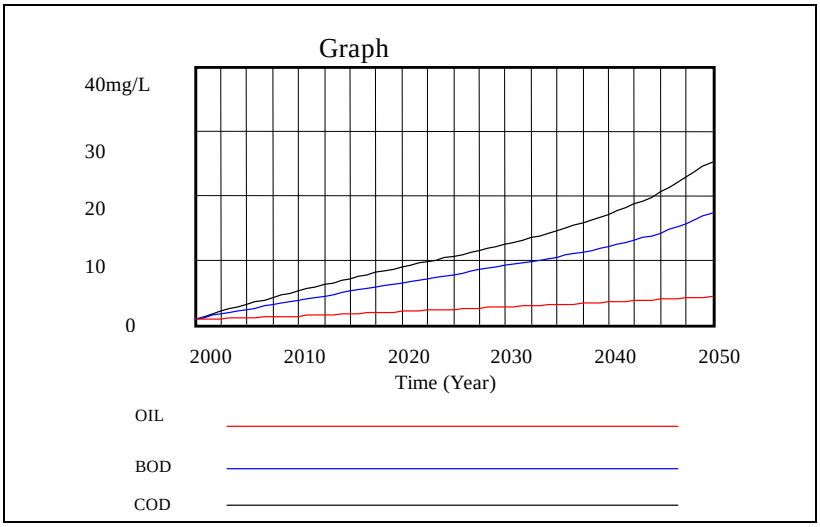

Figure 5 : Simulation of concentration of water quality of Yangtze river in present policy

After adopting the macro-control policy as TABLE 1, we'll get the result as Figure 6:

TABLE 1 : Description for curves in different macro-control policy

	Compensation ratio for lost	emergency reaction capacity for shipping pollution	Tax rate for environmental concentration(%)	Daily management level for seamen	technical management level for ships	investment ratio for contamination (%)
Curve4(policy 4)	80%	0.8	70%	0.85	0.85	20%
Curve3(policy 3)	70%	0.7	60%	0.7	0.7	15%
Curve2(policy 2)	50%	0.4	45%	0.55	0.55	10%
Curve1(policy 1)	30%	0.3	35%	0.40	0.40	5%

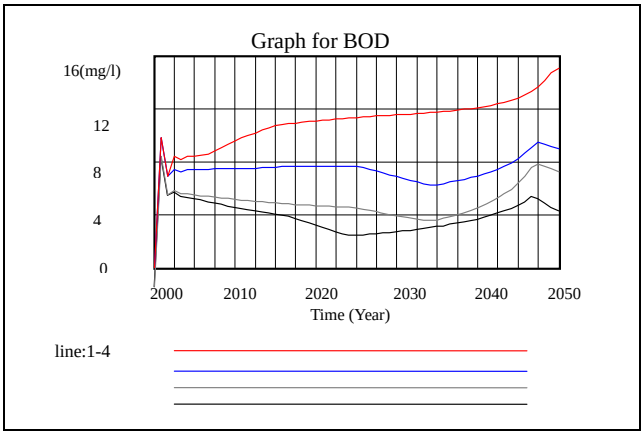

Figure 6 : Variance of BOD in different macro-control policy

The analysis of simulation results

Through the analysis of the above policies, we can get the conclusion as follows:

Firstly, it is quite important to implement the macro-control policy for shipping pollution whose effect is quite obvious. We can find that the pollution in Yangtze area will become more serious under the present condition and biochemical oxygen demand(BOD_5) and COD (one of the important parameter of symptomatic water quality condition)will above 10mg/l and 30mg/l. While after the implementation of macro-control policy, the future BOD_5 will reach the type II water quality standard (3~6mg/l). Nowadays, the fast developing petroleum potency which closely related to the shipping can be controlled under 0.5mg/l.

Secondly, it is not necessarily more rigorousness will get the better result. When we apply the policy 4 which is a more severe way, such as the higher level of compensation reaching 80% of the lost compared with 13% in present policy, the concentration of water quality can be controlled better. But in a long run way, we can also find that both policy 3 and policy 4 will reach more better results which can make the water quality maintain level II-III. Therefore, moderate control can reach a better result because of the higher cost in higher level of control.

Last, different macro-control policy will lead to different effect and function. Through analysis about different simulation curves in different control policies, collecting tax for environmental concentration, compensation ratio for lost caused by pollution and capability of emergency reaction, we can find all of them will play a vital role in the sustained development of shipping.

CONCLUSION

Inland shipping promote the china economic development, but also caused serious environmental pollution. This paper designs a effective mechanism to control river shipping water pollution through process controlling as angle of view based on the analysis of the reason and characteristic of water induced by river shipping pollution. In order to validate the effect of the mechanism this article also simulate the controlling mechanism and policy based on system dynamics model by using tree-structure methodology. The research results indicate that the effective mechanism and policy are helpful to the sustainable development planning between river shipping and water environment.

This paper presents three basic viewpoints about the mechanism and policy of inland river water pollution control:

(1)Inland river shipping water pollution has physical characteristics (mobility), economic characteristics (external) and social characteristics (public resource).

(2)Pollution controlling mechanism include "source control, process control and outcome control " from the perspective of the process controlling.

(3)Mechanism is the basis of the policy, the policy is manifestation of mechanism. The policy is proposed according to mechanism such as improving the level of crew and vessels, levying environmental tax policies and enable domestic fund as pollution compensation Supplement.

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