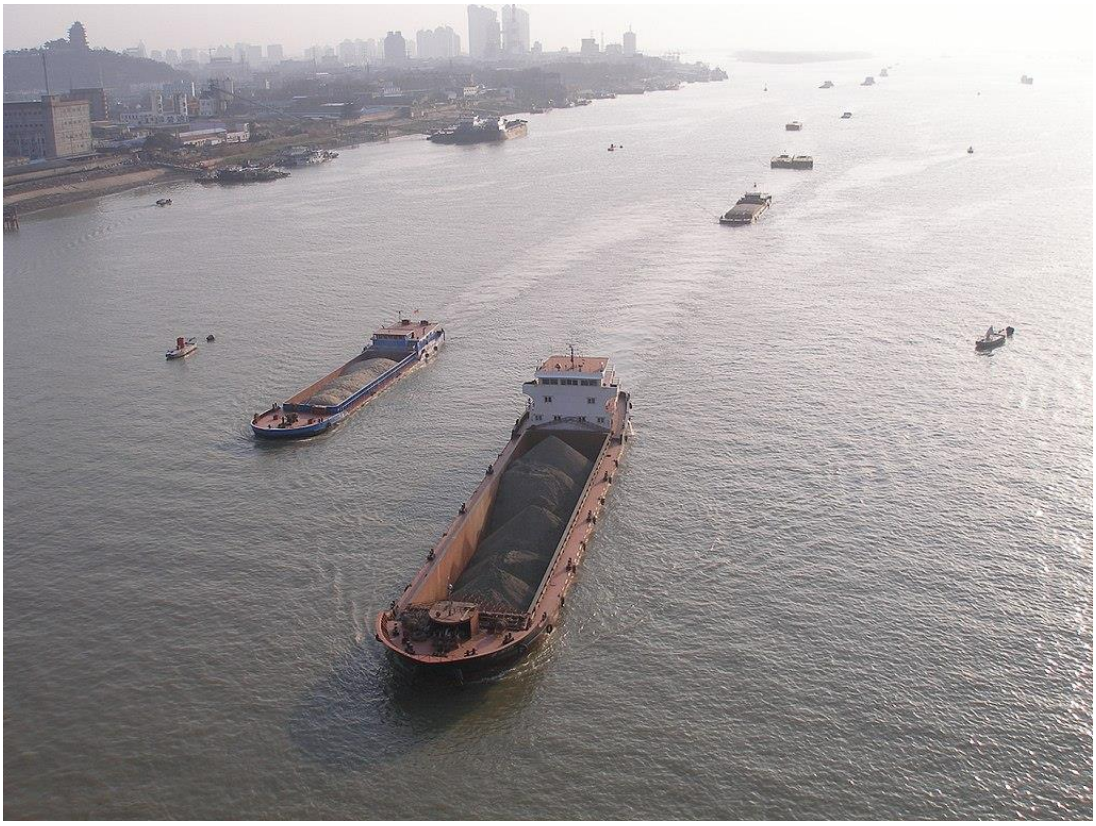

Eutrophication in the Yangtze River Delta

Integrated Water Resources Management

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1. Introduction

1.1 General description

Clean and reliable freshwater supply is essential for both natural and socioeconomic systems. Yet, the water systems in the world face formidable threats. Human impacts have already adversely affected the freshwater and coastal wetlands. The deterioration of water quality not only affects the economic and social development, but also the sustainability of ecosystems and biodiversity.

The Yangtze River with a total length of 6,387 kilometers, which ranking the third longest river in the world, longest river in both China and Asia [1](Figure 1) The main stream of the Yangtze River extends from west to east, it originated from the Tanggula Mountains on the Qinghai-Tibet Plateau, the main stream flows through a total of 11 province, then into the East China Sea, the elevation from 6621 m to sea level.

It supply 40% of Chinese freshwater resources, however, recent years it suffering from enormous environmental deterioration from industrialization[2], especially facing the challenge of water quality deterioration. As the most important river of China, with a basin area of 1.8 million square kilometers, it sustain the water demand of 33% of total national population (459 million people)[3] , among them, the Yangtze River Delta in the middle and lower reaches is the most densely populated and economically developed area in China, and it will be the main research object of our case study.

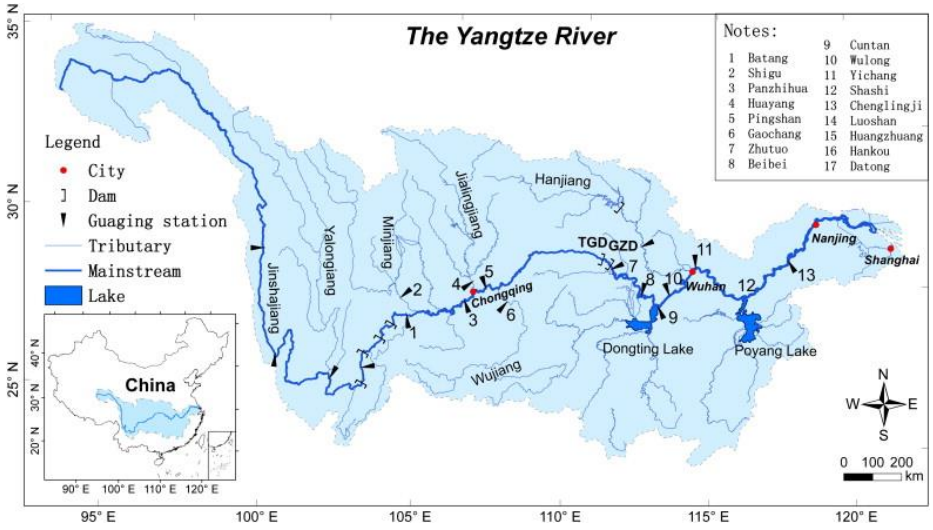

Figure 1. Map of the Yangtze river [1]

For the Yangtze River Delta, numerous national-level ecological sensitive areas are scattered in the river basin and construct the vital ecological barrier of China[3]. However, Great changes have taken place in the water environment of Yangtze River since 2000 and have attracted great attention[4].

Although water quality status is often determined by physical, chemical and biological indicators, an understanding of biophysical causes and their corresponding impairment alone is not sufficient to develop sustainable water management policies. An interdisciplinary tool – the Drivers–Pressures–State–Impacts–Responses (DPSIR) framework provides an overall mechanism for analyzing environmental problems, with regards to sustainable development[5].

In this report, we will apply this tool to figure out whether the changes of the water quality lead to the ecological and socioeconomic impacts or not., and evaluate the current response. Analysis will be conducted through following steps:

1. General understanding of the Yangtze River Delta region, including the physical features and the hydro-social system.
2. Define the key problem and involved stakeholders of water quality in the perspective of the natural and socioeconomical interaction.
3. Apply the DPSIR framework to analyze the integrated cause and effects related to the changes.
4. Evaluate the effectiveness of response that planned and/or implemented by various stakeholders.

1.2 Physical aspects

1.2.1 Geography

The Yangtze River Delta is in the middle and lower reaches, located at the confluence of rivers and seas, it is the alluvial plain formed before the Yangtze River enters the sea, with an area of 358,000 km^2(≈12 areas of Belgium). This area including Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, with a population of 227 million people (2009) (≈20 populations of Belgium)[6] (Figure 2).

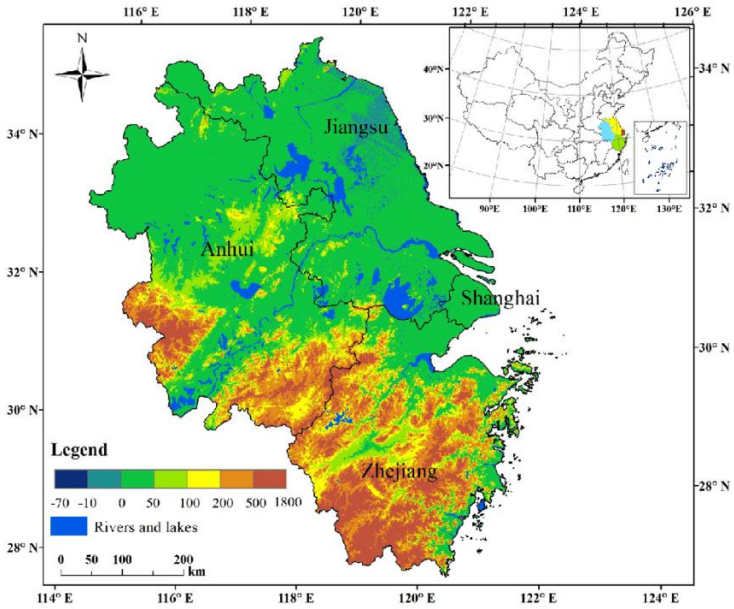

Figure 2. The geographical map of the Yangtze River Delta [6]

1.2.2 Topography

The Tai Lake Plain is the main body of the Yangtze River Delta. The Tai Lake Plain is shaped like a large plate with Tai Lake as the center, and the terrain is high in the week and low in the middle. The apex of the Yangtze River Delta is in Nanjing City and Yangzhou City (Gaoyou). The altitude is mostly below 10 meters, with low hills scattered in between, 200-300 meters above sea level. The Yangtze River has an average annual sediment transport volume of 400 to 900 million tons. In general, 28% of the sediment is deposited in the Yangtze River, and as high as 78% in individual years, the delta continues to extend to the sea.

1.2.3 Hydrography

The region has a high density of river networks, developed agriculture, dense population, and numerous cities. Due to the low-lying terrain, floods have been extremely serious in history. In order to change this situation, the state invested in the construction of water conservancy projects.

1.2.4 Climate

Basin climate type: Subtropical monsoon climate is dominant, with four distinct seasons, with hot and humid summers, cool and dry winters, and warm spring and fall. with an average annual temperature of 16～18℃, the highest temperature in summer is about 40℃, and the lowest temperature in winter is about minus 4℃, but sometimes the large temperature fluctuation can occur.

1.3 Hydro-social-economic analysis

1.3.1 Ecosystem analysis

Yangtze River is famous for the high biodiversity in the world. There are more than 400 species and several distinctive species. Although some of the species has survived in the river for hundreds of years, they are decreasing in a fast speed in the past few decades. One of the reasons is building dams which hinder the way of their reproductive migration. There are also many waterfowl living in the river or wading birds staying in the wetlands of the river. However, the number of these birds is reducing because of a major reason of water pollution. Furthermore, the fast-paced urbanization leads to a reduction of the habitats for many aquatic animals.

1.3.2 Society analysis

Due to the large population and enormous area of Yangtze River watershed, both of traditional culture and modern culture influence the lifestyle of local people. The traditional way of living is more popular among the residents in the upper reaches than the middle and lower reaches. Because the upper reaches are in a low level of urbanization. Even nowadays many people live in rural area and stick to the original & natural lifestyle. Another lifestyle is using more machines and mostly replying on the industrial products like foods and washing agents. There is an inevitable problem that each lifestyle has its pros and cons. As for the pollution impact of the two, the

traditional life is more eco-friendly than the urban life. While considering the access to have safe drinking water, people usually obtain drinking water from the river without enough treatment to remove the harmful chemicals in it. However, people living in cities will acquire clean and safe drinking water easily.

1.3.3 Economical activities

Yangtze River Economic Belt plays an important role in the economic development of China. It covers up to 11 provinces and municipalities of China including Shanghai City, Jiangsu Province, and Zhejiang Province. Besides, Shanghai is one of the most developed cities in China. The area is about 205.0000 km^2, which accounts for 21.4% of the whole China[7].

However, either the creatures living in Yangtze River or the stakeholders of the area found the river was suffering from a lot of problems like water pollution and animal distinction. Therefore, the government focus on giving a new method to solving the problems and ensure the people's health there. In the September of 2016, a strategy named The Plan for The Development of Yangtze River Economic Belt was launched to public. The mainly target of this plan is to reorganize the strategy for building an environmental-friendly industry system in the Yangtze River Economic Belt.

The population and the GDP of the Yangtze River Economic Belt have contributed more than 40% in the total amount of China in 2020. It has three major area which are the east, the west and the middle from almost one side of China to the other side. Besides, Yangtze river is expected to build developed industries in the west and middle area in the future, which can help to make a balance in the economics between each area.

An unbalanced development in the economics between the separated area became obvious to see from 1992. The delta and the lower area of Yangtze River built factories and attracted a lot of workers settling in that area. These factories lead to a huge emission of polluted water without a proper treatment. In the upper area, there are seldom factories in the last century, and the pollution in those parts is not as severe as the delta of Yangtze River.

2. Key-problem

Human activities in agriculture and industry efficiently increasing the rate of the inorganic salt (such as N and P) enter the water biosphere compared to pre-industrial levels[8]. In recent years, harmful algal blooms (HABs) has become a global phenomenon, affecting almost every country around the world, as a country with rapid development in population and economy, the impact of increased nutrient input in the Yangtze River Delta is an example that cannot be overlooked.

HABs are aquatic algae, nutrients (N, P) and sufficient sunshine are essential factors for their growth. Eutrophication is one of the most likely factors to induce HABs, eutrophication may not only increase the prevalence of HAB, but also have an immeasurable impact on natural resources and the coastal economy[9]. So which phenomenon will induce the presence of eutrophication? The main reason is the excess nutrients (mainly nitrogen and phosphorus P) into the water body. In another word, the increase in human activities in recent years has led to a sharp increase in anthropogenic N and P, is one of the reasons why the water bloom phenomenon is getting worse [8].

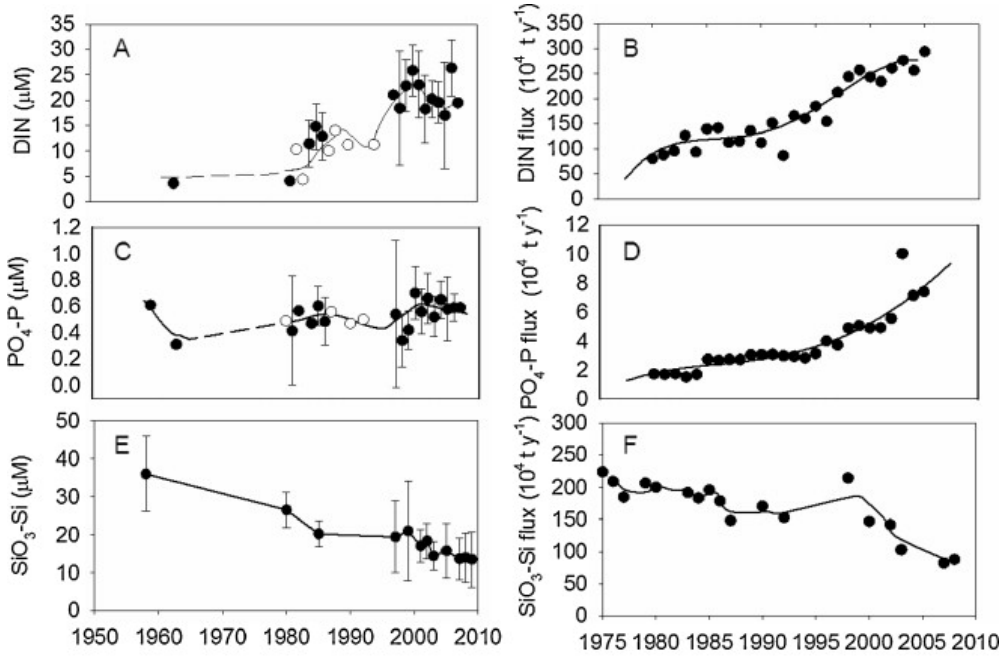

Figure 3. Annual variations of the nutrients (DIN, PO_4-P, SiO_3-Si) and their fluxes in the Yangtze River delta area [9]

The annual changes and fluxes of dissolved inorganic nutrients (DIN[1], PO_4-P, SiO_3-Si) in the Yangtze River Delta (Figure 3) were analyzed using the data in recent decades. From 1960 to 1980, the annual DIN concentration showed a basically stable trend, but since 1980, both the DIN concentration and its flux have increased sharply to a new level. Around 2000, it rose to a new high and remained Increased year after year. Besides, the Yangtze River also emits a large amount of phosphorous to the study area. The concentration of PO_4-P did not fluctuate much in the first 50 years, but the increasing trend became greater after 2000 [9]. In contrast, silicon dioxide clearly declined after 2000, which may be due to the decrease in SiO_3-Si concentration caused by the impoundment of the Three Gorges Dam.

This finding indicates that as the DIN flow increases, the DIN concentration is mainly affected by the ground discharge. The high content of chemical fertilizers used along the Yangtze River since 1980 and the existence of chemical plants can explain this phenomenon [9].

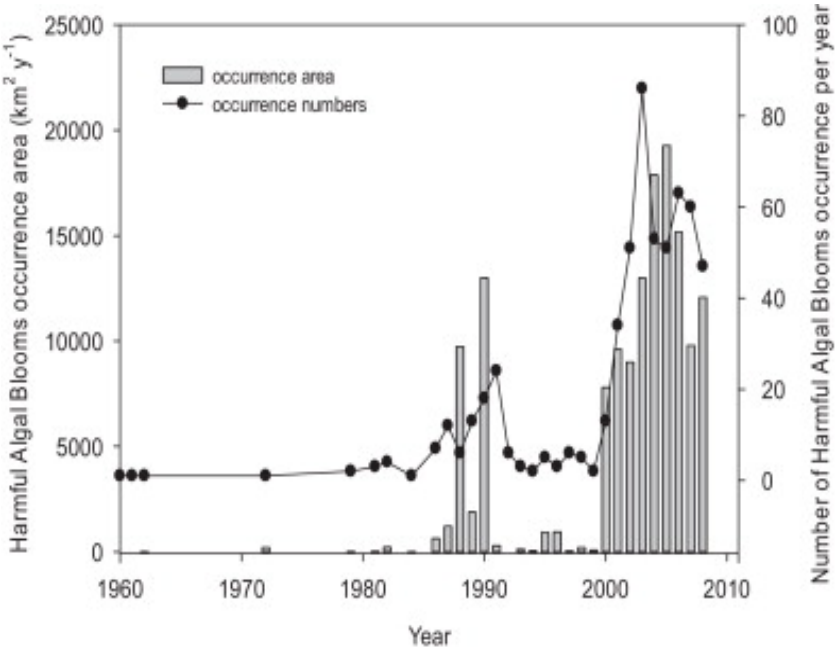

Figure 4. Annual variations of HABs in the Yangtze River delta [9]

In the meantime, the frequency, occurrence area and the outbreak timing of HAB in the Yangtze River delta area are also analyzed (Figure 4). Overall, there was a significantly increase since 2000, this phenomenon could conclude in 2 reasons: The first is the increase in HAB incidents caused by the deterioration of marine water

[1] DIN (=nitrate (NO_3-N) + nitrite (NO_2-N) + ammonium (NH_4-N))

quality, especially eutrophication, and the second is the increase of alien species, which should catch special attention due to their harmful effects on biodiversity, these may be the cause of the complexity of HAB behavior.

By analyzing the relationship between nutrients, flux and HAB parameters, we can clearly find that eutrophication plays a critical role in the development of HAB in the Yangtze River Delta. Due to the annual and seasonal variations of the inorganic nutrients such as nitrogen and phosphorus, the phytoplankton community composition has changed significantly in recent years. It is not difficult to analyze that the biggest culprit causing such changes in the water environment is the rapid expansion of human activities in a short period of time, which lead to the Yangtze River delta has undergone such seriously eutrophication and deterioration of environmental for more than 30 years. Some scholars believe that in the next 50 years, the region will develop more densely populated agriculture. Therefore, reducing and restricting human activities to suppress eutrophication is one of the most important issues for human beings [9].

The human activities we mentioned, is include many kinds, such as increasing population, the high degree of urbanization, Overfishing, frequent sailing, and excessive fertilization in agriculture. Especially in China's Yangtze River Delta and its surrounding waters. At present, the untreated sewage treatment system and excessive use of fertilizers are main sources of nutrients for the surface water of the Yangtze River [8]. This has destroyed the coastal ecosystem, and then affected the ecological environment, drinking water quality, fisheries, tourism maritime trade and other aspects of production and life, which we will describe separately later.

3. Stakeholder analysis

Stakeholders are distinguished mainly in two groups. One is the governmental entities. The other is the non-governmental entities. Following graphs explains detailed stakeholders contained in each group. The stakeholder matrix was composed according to their importance and influence (Figure 5).

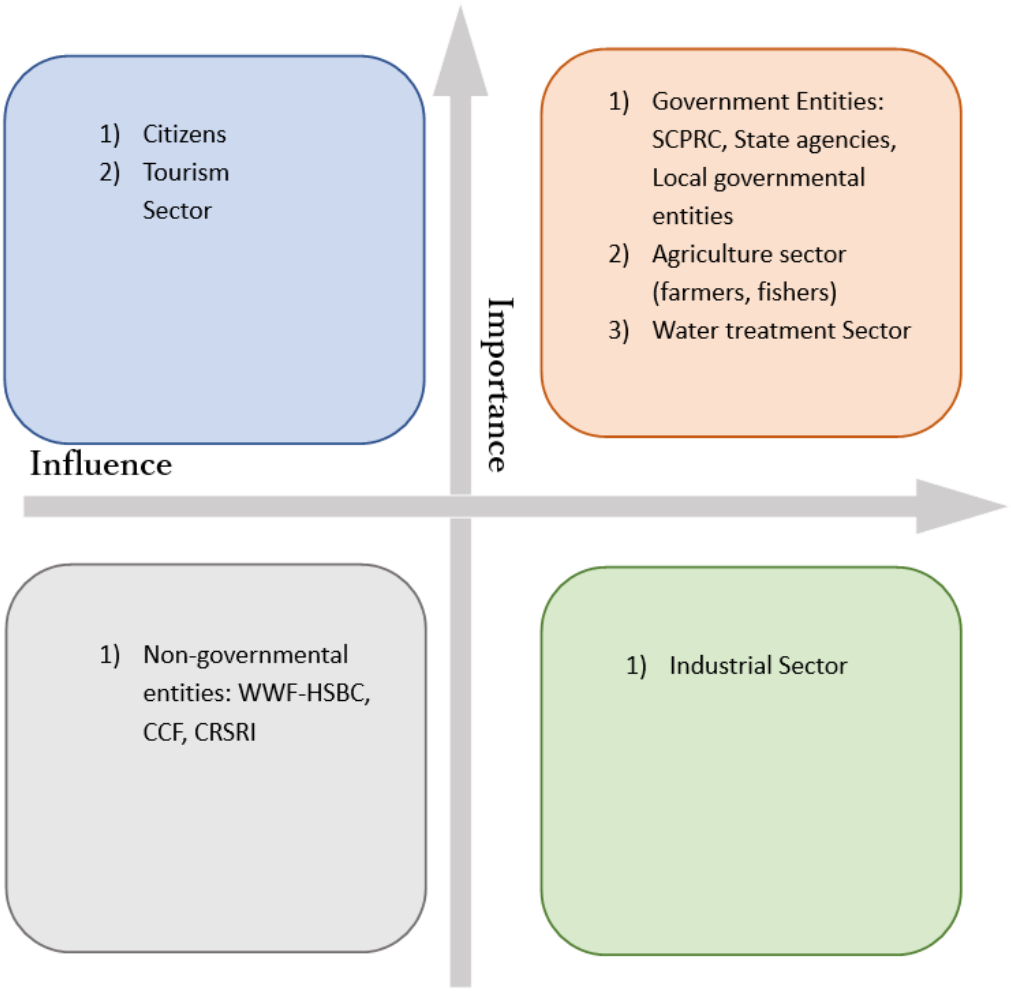

Figure 5. Stakeholders matrix

3.1 Governmental Entities

As the Yangtze river basin involves a total of 19 provinces, municipalities and autonomous regions, the collaboration among different municipal entities and law enforcement units under a clear and visionary blueprint is highly required. Consequently, governmental entities involved will be classified into two level – the

national level and the local level. The entities in national level are responsible for developing the sustainable water management frameworks and setting scientific standard to evaluate the water quality, while entities in local level need to localize these frameworks and give feedbacks to the national governmental entities.

State Council of People's Republic of China: There are overall 26 departments in the State Council. Ministry of Ecological and Environment (MEE) is the lead department improving the water quality of Yangtze River basin, and other 14 departments are involved, including: Ministry of Natural Resources, Ministry of Water Resources, National Development and Reform Commission, Ministry of Public Security, Ministry of Human Resources and Social Security, Ministry of Housing and Urban-Rural Development, Ministry of Agriculture and Rural Affairs, Ministry of Justice, Ministry of Industry and Information Technology, Ministry of Transport, Ministry of Finance, Ministry of Emergency Management, Ministry of Commerce, Ministry of Education.

As the core ministry, MEE cooperating closely with other departments conduct following contents: 1) formulate national ecological environment policies and plans, draft laws and regulations; 2) formulate and supervise the implementation of ecological environmental planning and water function zoning for key areas, river basins, sea areas, and drinking water sources; 3) monitor ecological environment in the basin and unifying the law enforcement; 4) supervise and manage the national emission reduction targets; 5) organize the implementation of ecological environmental protection publicity and formulating the outlines of public education; 6) carry out international cooperation and research.

Other state agencies: Supreme People's Court, Supreme People's Procuratorate, guarantee and strengthen the joint force of the supervision of the environmental protection and the administrative law enforcement. These iron fists can control the pollution, investigate and punish illegal sewage discharge, illegal disposal of solid waste, by means of fine, detention, production restriction and production suspension. With the participation of these law enforcement, the judicial forces related to water quality and be well constructed.

Another important state agency is the "Leading Group for Promoting the Development of the Yangtze River Economic Belt". Core leaders are from the Party Central Committee and the State Council. Governors of 11 provinces and municipalities along the middle and lower sections of Yangtze River serve as members. This agency establishes a vertical communication tunnel and facilitates the administrative efficiency.

Local governmental entities: Local government of the 19 provinces, municipalities and autonomous regions are the essential parts localizing and implementing administrative regulations and enforcement formulated by state entities. Meanwhile, their feedbacks can promote the effectiveness of the whole process. Formulating the detailed action plan which is suitable for local municipal system and culture is the key factor to guarantee the substantial improvement of water quality.

3.2 Non-governmental entities

Agriculture: The agriculture of the Yangtze River is divided into three areas, which are the Qinghai-Tibet area, the Southwest area, and the middle & delta area. As for the Qinghai-Tibet area, the weather in that area is very cold and not suitable for plants growing. Besides, the oxygen level in the air is lower than average due to the high altitude of Qinghai-Tibet region. Therefore, the forest is the most important agriculture resource. The south-west part is in the subtropical zone. The major crops there are rice & wheat, rapeseed and sugarcane. Furthermore, the production of tobacco, tea, orange and silkworm in this area are among the top in China. The agriculture in the middle & lower area is more intensive than the other two areas. The land is rich and fertile. Besides, the water resources are abundant because of a huge number of lakes and tributaries. This leads to the fact that rice becomes the main crop rather than wheat [10].

Tourism: Yangtze River has been famous for sightseeing sites along the river since hundreds of years before, and one of the well-known poems said “Along the Yangzi River, apes moan ceaselessly. My boat ’s passed ten thousand mounts briskly.” In the ancient periods, the wonderful ecosystems and some amazing architectures formed the rare scenery along Yangtze River. Although there are some pollutions which makes the good views disappearing, many tourists still come and hope to have a glance at the old scenery and architectures along the river.

Local groups: Citizens, farmers, and fishers: The recent population of Yangtze River Area is over 440,000,000 [11]. In the upper and middle area, most of the population work as farmers and fishers. Famers need water to cultivate crops and sometimes may release the polluted water with chemical fertilizers into the river.

The over-fishing causes several fish species endangered [12]. However, as the biggest city in the lower area of Yangtze River, workers related to the industry and advanced technology increases in a fast speed due to the development of the economics in China.

WWF – HSBC: The HSBC Water Program has been started since 2012. The first aim of the organization is to provide the local people and animals with sufficient and safe water. Besides, the second target is to keep rivers and wetlands with ecosystem sin good conditions. Yangtze River is among the five priority freshwater places on the plan. WWF has contributed to protect the ecosystems of Yangtze River by developing tools which can identify the water risks and opportunities in business.

CCF - Yangtze River(Changjiang) Conservation Foundation: This is a local foundation which mainly focus on the protection of finless porpoises living in freshwater since this species is critically endangered.

CRSRI – Changjiang River Scientific Research Institute: The CRSRI is a national public research institute for providing scientific suggestions and technology support for the decisions of government. The topics on their research include the strategies of protection for the environment of Yangtze River Area and the construction design of architecture in the area.

4. DPSIR

With the reference of the DPSIR flow chart (Figure 6), we have a better understanding

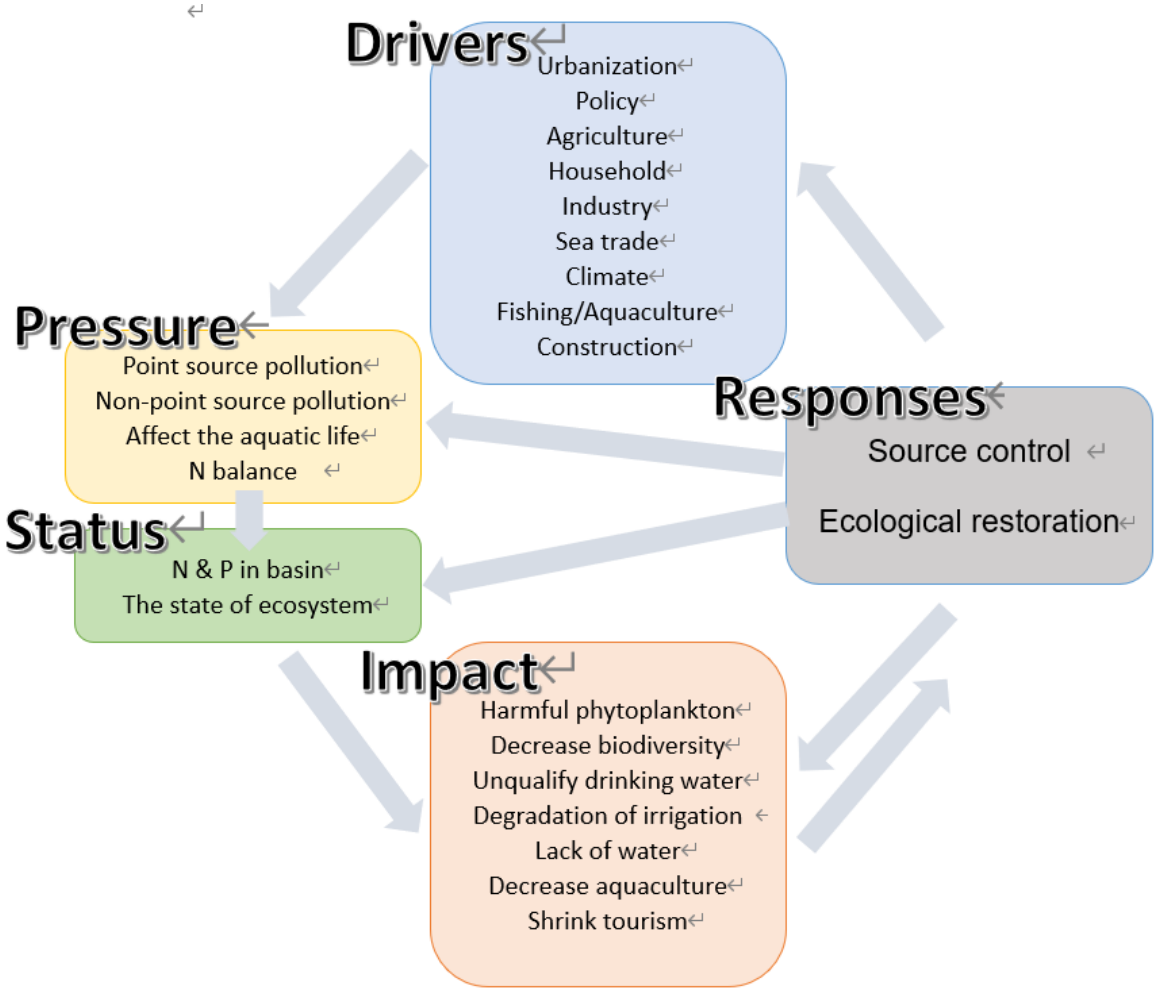

Figure 6. DPSIR flow chart

of the cause, current situation of eutrophication. Responses of different stakeholders were also be displayed and evaluated.

4.1 Drivers

Urbanization: The Yangtze River Delta is the mos densely populated and industrialized area in China, and it is also the most economically developed area. It is an important area for waterways in the country [13]. The urbanization level of here came up to 85.3% which is higher than the middle area and the upper area of Yangtze River.

Policy: Due to its superior geographical location and natural conditions, it was one of the earliest special economic zones developed in China (1985), and it is worth mentioning that due to the constraints at the time, China was actually on the road of "pollution first, treatment later" [13]. As a developing country, China chose the former between industrialization and environmental protection, which also condoned the continuous deterioration of environmental quality in the region over the past few decades. The situation has not been improved until the past decade.

Agriculture: Agriculture of Yangtze River delta plays an important role to the food production and cash crop production. This area has 120 million acres of arable land, in 2016, the cultivation land of Yangtze watershed accounted for about 1/3 of the whole in China. According to the survey, the proportion of agricultural sources in the total phosphorus and total nitrogen of Dongting Lake in this area is 86% and 65% respectively. It can be concluded that the agricultural sources in this area have a great impact on the water [13]. In addition, the basin is also used for farmland irrigation water environment.

Household: Discharge of substandard domestic sewage has always been one of the main reasons for the eutrophication of water bodies. As of 2019, there are a total of 298 urban sewage treatment plants in the region, with an operating load rate of 79.6%. The processing capacity of some sewage cannot meet the needs, and the supporting pipeline network is relatively lagging, generally failing to achieve rain and sewage diversion [13]. At the same time, the Yangtze River estuary is also an important water supply source for surrounding provinces and cities [14].

Industry: The factories in this area are relatively concentrated, and most of them are industries with low technology such as chemicals and metals, which are difficult to deal with waste water, so the proportion of pollution is high. The industrial parks along the river highlighted the characteristics of structural pollution in the basin.

Sea trade: There are many types of ships in the basin, and the density of ships in the channel is high, so there is a high risk of water pollution, due to the pollution treatment equipment is insufficient, so mostly pollutants cannot be treated in a timely and comprehensive manner.

Climate: Meteorological conditions such as temperature, rainfall and sunshine are known to be the necessary conditions for the outbreak of cyanobacteria. In recent years, the warming of the climate in the region will also lead to the intensified the outbreak of cyanobacteria [15].

Fishing/aquaculture: The fishery resources of Yangtze River watershed are the most abundant area in China, it rovides the critical environment for the reproduction of four major fish species and many distinctive species [16]. Since the 1980s, the local freshwater aquaculture industry has developed rapidly and has gradually become the main source of freshwater aquatic products in the area. However, high-intensity aquaculture is accompanied by a large amount of feed input.

Construction: As the river with the largest flow in China, we have built many water conservancy projects in the basin in recent years. Among them, the Three Gorges Dam built in 1994 is the world's largest dam. Its main profits are flood control, water supply, power generation and shipping. However, the intense construction may also resulted the negative influence to the biodiversity and water quality [17].

4.2 Pressure

The fact is that many farmers living in the rural area move to the cities and work in the factories. This caused two changes in the area. On one hand, the mode of agriculture becomes intensive and automatic, which means they use more machines and fertilizers than ever. In addition, there are a wide range of livestock breeding sites. Most of the waste in the breeding is discharged into the water body without treatment, which leads to eutrophication of the water body [18]. At the same time, due to the large amount of aquaculture in the area, the nitrogen and phosphorus in the feed that fish cannot consume are retained in the water body, the eutrophication is further increased [19].

On the other hand, those farmers moving to the city ensure the need for labor force of factories and contribute to the enlarged scale of industries, which also contributes to the population explosions in cities. The large population in the cities consume a big amount of water not only for drinking but also washing and cleaning. However, the water treatment facility in China is not completely capable for all kinds of pollutants as well as such a huge amount. The polluted water which are emitted directly into Yangtze River without any treatment was more than 80% according to an article stated in 2006. The water for washing will eventually come back to the river together with a lot of pollutants, This contains a lot of phosphorus that causes eutrophication of water bodies. For example, Tai Lake, a lake in the south of Yangtze River Delta, has experienced the algae bloom which is related to the polluted water which contains laundry powder with phosphorus [20].

The influence of human activities including over-fishing, building dams, and increasing travelling boats on the river could not be ignored as for the reasons of the decreasing of fish varieties and speed. The sharp decreasing of one kind of fish might lead to the balance of ecosystem broken in the partial area of Yangtze River [21]. Except human activities, the nature is also the keen reason of the algae bloom. Due to the climate in this area become more extreme these years, the summer is more arid, less rainfall and high temperature, which lead to the intensified the outbreak of cyanobacteria. Among them, atmospheric deposition has also had a great impact on the increase of nitrogen and phosphorus concentrations. For example, the TN and TP obtained through wet deposition in Lake Tai every year account for 7.3% and 16.5% of the input of TN and TP into the rivers of the lake [15].

4.3 Status

4.3.1 N &P in basin

With the rapid development of population and social economy along the Yangtze river basin, especially along the middle to lower reaches where the most developed cities allocated, high concentration and large amount of nutrients such as nitrogen and phosphorus loads in its mainstream and tributaries were observed by different studies. On the other hand, the natural topology has been largely changed due to the urbanization and the construction of hydro-power stations, the flux of nutrient loads were also be influenced.

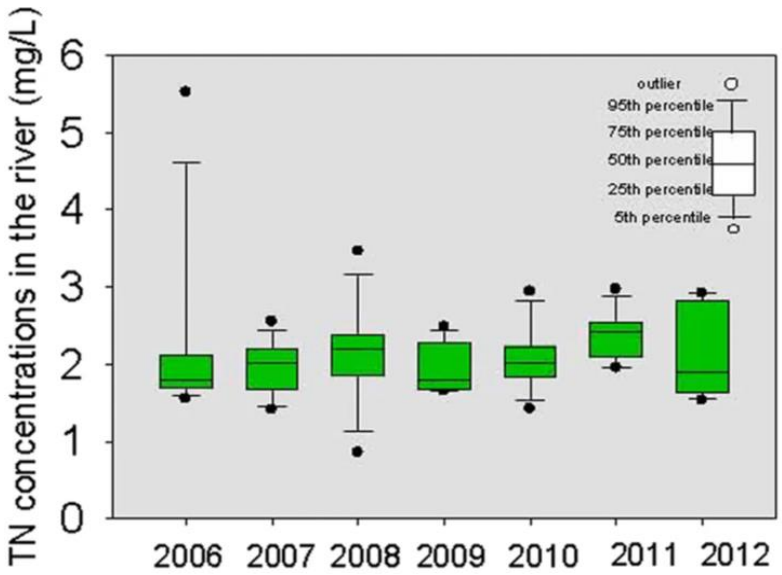

Figure 7. TN concentrations in the rivers from 2006 to 2012 [23]

From 2006-2014, the total nitrogen TN and total phosphorus (TP) were monitored and recorded in Yangtze river basin by different researchers. An increasing trend of TN concentrations were observed (Figure 7). The yearly TN discharge was 1.35×10^5 tons in 2006 and surged to 2.44×10^5 till 2012 [22]. In the Jinshajiang River (the upper sections of the Yangtze river, location see (Figure 7) the annual concentration of TN almost doubled, from 0.37 mg/L in 2006 to 0.68 mg/L in 2012. In the lower section, the annual TN concentration also shew an obvious increase, from 1.41 mg/L in 2006 to 1.90 mg/L in 2012 [23].

The annual discharge load and concentration of TP also increase in the period 2006-2014. In 2006, the discharge of TP was 1.22×10^5 tons and it reached 2.38×10^5 tons in 2012. With regard to the TP concentration [23]. Comparing the TP concentration of the main city along the mainstream, an obvious increase trend can be observed from 2006 to 2014 (Figure 8) [24]. Spatially, the TP concentration tended to decrease from upper-middle stream to downstream, and there is a sharp increase in the stream around Three Goreges Dam. The process of phosphorus entering the river is mainly through particulate phosphorus (PP)[25]. The content of PP is mainly adsorbed in fine suspended solids. Due to large-scale soil and water conservation and upstream construction and operation, it dropped sharply from 1986 to 2003 to 2015. The reservoir of the Three Gorges Dam intercepted more than 75% of upstream PP input by intercepting suspended solids.

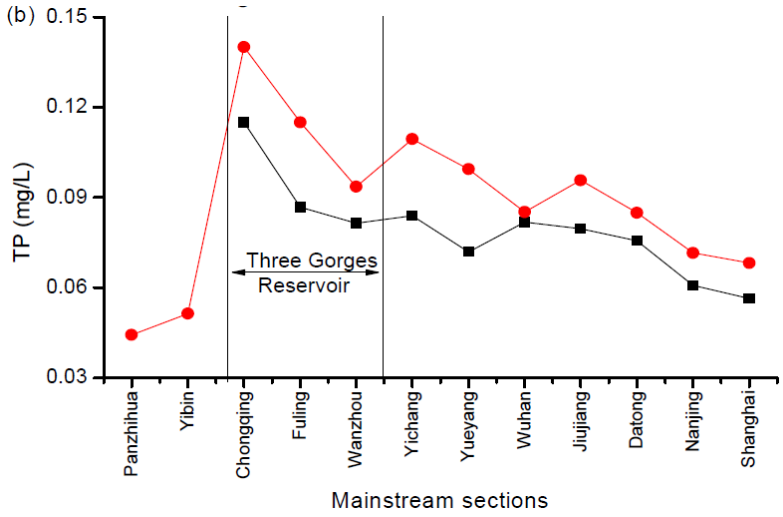

Figure 8. total phosphorus (TP) concentrations along the main stream sections in 2006 and 2014 [24]

4.3.2 The state of ecosystem

In addition to pollution from external point sources and non-point sources, the aquatic organisms in the Yangtze River Delta are also suffering from external influences. The drivers mentioned previously, like sea trade, fishing and construction, even if they do not directly produce nutrients such as N and P that cause blooms, fishing and contruction will artificially affect the organisms in the water body。 For example，fishing reducing their types and numbers , To break the ecological balance,;the high-intensity hydro-grade development of the main and tributary streams in the upper and middle reaches of the Yangtze River has resulted in the isolation of river habitats and the decline of biodiversity, thereby accelerating the formation of water blooms [17].

4.4 Impact

As mentioned previously, the rapid increase of population, the lack of wastewater treatment system in cities and industries, the exceed use of fertilizer in agricultural, the increasing aquaculture in the water body all lead to the increase load of nutrients (especially N and P), which will pose impact on both natural system and human society.

4.4.1 Impact on natural system

Harmful phytoplankton: Sufficient supply of nutrients and hydrodynamic process such as slow water flow and long hydraulic retention time are among the main reasons stimulate Eutrophication. Eutrophication was indicated as the most urgent problem in the basin. Harmful algal blooms (HABs) are the most obviously result of eutrophication [33]. The rapid increase in nutrient load in the Yangtze River is considered to be the main cause of HABs in the Yangtze River Delta. From 2006 to 2012, HAB occurred about 500 times in coastal waters of China, of which 313 occurred in the region [9], from here we can see the importance of the Yangtze River Delta and the severity of pollution.

Decrease in aquatic biodiversity and density: The rapid eutrophication of the Yangtze delta basin lead to the problem of the degradation of water quality. Data shows that the coastal waters in delta area are seriously polluted, and the water quality exceeds four categories (2001). It is a red tide-prone area, which directly leads to a large number of wild and farmed fish, shrimp, crabs and shellfish. And the breeding industry caused serious damage [18].

4.4.2 Impact on human society

Brought by the eutrophication, the ecosystem service of the river basin will be affected to a large extent. Sever aspects of the human society, such as drinking water safety, sufficient water supply for agriculture and industry, aquaculture, fishery, ecological tourism will be largely influenced.

Unqualified drinking water quality: The priority is the safety of drinking water. One of the most famous drinking water crisis caused by HAB happened in the Wuxi City which is located in the Yangtze Delta and take Lake Tai as its only water supply of the city [26]. On the morning of May 29, 2007, the residence found the tape water was pungent. Investigators found the massive agglomerate of cyanobacterial genus Microcystis which can produce cyanotoxin and strong odor [26]. With the deep concerning, local residence had to stopped to use the polluted tap water until Jun 4, 2007.

Degradation of Irrigation water: Besides the drinking water problem, the qualified water resources for the agricultural irrigation and manufacturing will be reduced. The rapid eutrophication of the Yangtze delta basin leads to the problem of the degradation of water quality. Relevant department have to applot more financial budget to restore the deterioration of water quality caused by eutrophication [14].

Lack of water: The per capita possession of water resources in the Yangtze River Delta is only 775 cubic meters, which is equivalent to one third of the national level, and the large-scale water pollution has increased the water shortage.

Decrease aquaculture/fishery: One of the characters of the eutrophication is the depletion of oxygen in water. Cyanotoxin during HAB will also be released. Subsequently, aquatic products in or close the eutrophic waterbody will be decreased or even suffer a complete loss. Similarly, the harvest of fisheries will also be largely decreased.

Shrink tourism: Another industry which will be seriously affected is the eco-tourism [14]. The tourism in areas such as Tai Lake, Tianchi (tributaries of Yangtze basin) are an important income for some of local residents. The surface of the water body with bloom problem will be covered with green or brown-red algae layer, which is the disappearance of the landscape effect of the water body [27]. At the same time, some algae are poisonous and harmful, with the frequent occurrence of HAB, and the degradation of natural resort caused by eutrophication, the income will face an obvious shrink.

4.5 Reponses

The prevention and control of eutrophication of rivers and lakes is a systematic project. It must be carried out from the watershed, from the aspects of source control and ecological restoration, that is, to control point sources, non-point sources and lake internal sources in the watershed, and to make extensive use of lakeside sources. Belt ecological restoration technology, terrestrial plant ecological restoration technology, etc. [18].

Focusing on lake areas with serious eutrophication such as Lake Tai, in terms of ecological restoration, dredging of wide and shallow lakes [27], breeding filter-feeding fish. To ensure that the comprehensive nutritional status index is reduced [17]. Conserve vegetation, exert the water purification function of shrubs and aquatic plants, restore the ecology of the lakeside zone, use it as a buffer zone to reduce the nutrients entering the river and the lake, thereby improving water quality [15].

In terms of source control, the pollution into the lake was greatly reduced, especially nitrogen and phosphorus, which can be divided into the following points:

City: Speeding up the construction of urban sewage treatment projects: As the water treatment facilities in this area are relatively lagging, especially the sewage interception pipe network is not matched, which intensifies water pollution; and due to the shortage of water resources in this area, the reuse of sewage should be considered in the design [18]. In addition, it is necessary to advance the design of urban sewage treatment plants, strengthen the treatment requirements for mono-phosphorus removal, and crack down on the direct discharge of sewage into the river.

Agriculture: In response to the phenomenon of excessive use of chemical fertilizers in agricultural breeding, promote the principle of "reducing nitrogen, controlling phosphorus, and stabilizing potassium" as the fertilization principle, and adopt measures such as surface water excavation and storage and drainage and irrigation canal transformation to maximize the control of nitrogen and phosphorus loss ; At the same time, strengthen the comprehensive management of pollution in livestock and poultry farms, and implement ecological breeding methods for aquaculture [18].

Industry: Because the region contains a very complete industry, but generally lacks cleaner production platforms and technologies, it is necessary to establish relevant rules and regulations for the implementation and cleaner production first, and give preferential policies to enterprises that have implemented cleaner production but fail to meet the standards Enterprises will be punished, especially to strengthen the

governance of phosphorus-related enterprises, and encourage advanced treatment and recycling of wastewater from high water-consuming enterprises such as steel, dyeing and weaving, and chemical industries [17]. Encourage the establishment of clean production information exchange platforms within the industry, enhance technology and strengthen cooperation, and establish industrial waste exchange centers between different industries to match the needs of both supply and demand, and strengthen the recycling of industrial by-products [18].

Sea trade: Control the pollution of water bodies by ships and ports, strengthen the reception and disposal of pollutants, and strengthen the management and control of high-dangerous goods transportation risks [17].

Government: Because the basin covers multiple provinces and cities, and various regions affect each other due to water pollution, for avoid transboundary pollution disputes, resources should be concentrated to establish a regional water pollution analysis and early warning system, such as providing water level information in a timely manner. The monthly changes of phosphorus and nitrogen are predicted [18]. Install water quality monitoring facilities upstream, regularly monitor and announce the quality of drinking water to prevent environmental risks of water sources.

Publicity and supervision: Make full use of new media such as Weibo and WeChat to strengthen publicity on water saving and ecological protection. Governments at all levels build information disclosure platforms, promote information disclosure, and actively accept supervision. Broaden public participation channels, guide the development of public welfare organizations, and strengthen environmental education and social practice in primary and secondary schools.

4.6 Evaluate current Response

According to the “Water Pollution Prevention and Control Plan for Key River Basins (2016-2020)” released by the state, by 2020, the proportion of good (class 3) water quality in the Yangtze River as a whole will reach more than 76%, and the inferior Class V will be controlled below 3% (Table 0-1).Table 0-1Table 0-1 The 2020 goal of water quality in the Yangtze River Basin [17]

By 2019, all counties and key towns have sewage collection and treatment capabilities, and the sewage treatment rates in counties and cities will reach about 85% and 95% respectively; By 2020, ensure that the coverage rate of soil testing and formula

fertilization technology promotion reaches more than 90%, the utilization rate of chemical fertilizers is increased to more than 40%, the use of chemical fertilizers for major crops and the total pesticide use in the country have zero growth, and the coverage rate of biological and physical control of major crop diseases and insect pests reaches More than 30%, the coverage rate of specialized unified prevention and control of pests and diseases reached more than 40%, and the utilization rate of pesticides reached more than 40%; the Yangtze River Delta region was completed one year ahead of schedule.

In view of the water bloom situation in the Yangtze River Delta, we found that the traditional water source pollution control effect is not great, and its main problems are: 1) The traditional method for the treatment of point source pollution, such as industrial wastewater and residential water, is to force the wastewater discharged by enterprises and residents to meet the corresponding standards to reduce water pollution. However, the control of up-to-standard emissions and total control is in the long-term development It is difficult to formulate a medium, and the difficulty of sewage treatment is increasing, and the standard setting cannot keep up with the pace of sewage discharge, making it difficult for this method to be effective in the later stage. 2) Non-point source pollution control mainly includes farmland runoff, animal husbandry, aquaculture, etc. The pollution scope is wider and management and governance are more difficult. Although this water area has achieved certain results in point source control, it is difficult to control non-point source pollution. Therefore, the deterioration of the water body has a tendency to increase.

The current policy puts the focus on governance. First, the former divisional governance is transformed into overall governance, rather than divided into rivers, lakes, and sea areas for separate governance, and each region coordinates with each other and manages together. Secondly, the individual treatment is transformed into a comprehensive treatment, that is, regardless of whether the pollution source comes from a point source, a non-point source or an internal source, it is all based on the control of the pollution source. For example, sediment dredging is performed on the bottom of a wide shallow lake. Although this method is effective in a short time, it is costly and cannot fundamentally solve the problem. Therefore, controlling external pollution is the key [27]. The third point is to adjust the industrial structure and promote cleaner production. This will not only increase the utilization rate of water resources, but also point out clear aspects for the comprehensive treatment of water pollution [28]. 5. Conclusion and Recommendation

5. Conclusion and Recommendation

With the analysis using DPSIR, we could conclude that: as the most developed area in China with the most populated density, the freshwater resource in Yangtze River Delta is facing serious challenge Eutrophication. Anthropogenic activities combined with the explosive urbanized population growth, are the root causes. Original topology and hydrology of the Yangtze Delta have been altered to a large extent and the natural environment of wild species in this region have been damaged. With the lack of insufficient sewage treatment facilities, the total input of nitrogen and phosphorus into the Yangtze Delta have been hugely increased. As a result, rapid and large-scale eutrophication of waterbody is inevitable. Triggered by the climate characters (high temperature, more arid and less rainfall) in Yangtze Delta, HABs occurred frequently since 2000. Water quality is intensively deteriorated, both natural system and socio-economy are severely influenced.

Comprehensive water pollution control measures have been enacted around 2010. Ecological restoration measures have been taken in serious eutrophication tributaries such as Tai lake. The sewage collection and treatment capabilities have been intensively developed. Till 2019, in Yangtze River Delta, the sewage collection and treatment capabilities reach about 90%, the utilization rate of chemical fertilizers increases to over 40%. However, the traditional water source pollution control effect is not effective in terms of the HAB. Although the point-source control such as industrial and household swage has achieved certain results, the deterioration of the waterbody has not been stopped. This is due to the difficulty of controlling the non-point source pollution such as farmland runoff and aquaculture.

Based on the current circumstance, it is reasonable to say there is still a long way to go to tackle the challenge of Eutrophication. The whole countermeasures are mainly focusing on the pollution control instead of pollution prevention. The treatment measures are also limited to point-sources.

For the pollution prevention, policies related to the long-term sewage disposal target should be established. Based on this target, the rapid expansion of urbanization should be properly controlled. The stricter market access of industry, agriculture, and tourism should also be established. Only activities meet the requirement of sewage disposal target can be approved. For the treatment measures related to non-point sources, the full-scale monitoring system of water, soil and air should be build-up at first, as nutrients (mainly nitrogen and phosphorus) in air, soil can be the input source

of waterbody. With this monitoring system, government and scientific researchers can have a full understanding of the distribution of non-point sources, and can formulate strategic action plans. In the process of formulating plans, different stakeholders including local residence, economic entities should all be involved to ensure the good implementation.

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