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Research Article

Analysis of the Environmental Quality of Seawater in the Bohai Sea, China

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Keywords: Seawater; Single factor analysis; Eutrophication index method (E value); Bohai Sea

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Abstract

According to the survey data on seawater quality in the Bohai Sea from 2020 to 2021, a single-factor data analysis was carried out on the seawater environmental quality of Liaoning, Hebei, Tianjin, Shandong and the offshore waters. The results show that the seawater quality of the Bohai Sea in 2021 Compared with the more serious pollution in 2020, the main pollutants are active phosphate and inorganic nitrogen. The spatiotemporal distribution characteristics of the eutrophication state index are high at the top of Bohai Bay and low on the outside, high in the southeast and low in the northwest. And through the comparison of water quality data for two years, the organic pollution and eutrophication near Panjin, Dalian, Yingkou and Weifang are getting worse day by day and the content of inorganic nitrogen and active phosphate in some waters in the Bohai Bay has increased. The total amount of materials discharged into the sea is controlled.

Introduction

The Bohai Sea is surrounded by land on three sides. It is between Liaoning, Hebei, Shandong and Tianjin. It is connected to the Yellow Sea through the Bohai Strait. Because the Liaohe, Luanhe, Haihe and Yellow Rivers bring a lot of sediment, the seabed is flat and the food is abundant. Large marine aquaculture base. In recent years, with the development and utilization of marine resources, terrestrial pollutants have been discharged into the ocean, resulting in eutrophication of seawater and the deterioration of the ecological environment in some waters of the Bohai Sea, which seriously affects the survival of benthic organisms. The results of the Bohai Sea water quality survey in 2020 showed that the sea area of the Bohai Sea that did not meet the first-class seawater quality standard was 13,490 square kilometers, an increase of 750 square kilometers year-on-year; the area of sea areas with inferior water quality was 1,000 square kilometers, a year-on-year decrease of 10 square kilometers, mainly distributed in the coastal waters of Liaodong Bay and the Yellow River Estuary [1]. There are 40 rivers along the coast of the Bohai Sea, including 19 along the coast of Lanzhou Bay, 16 along the coast of Bohai Bay and 15 along the coast of Liaodong Bay, forming three major water systems and three major bay ecosystems along the Bohai Sea. The shallow water area of the estuary along the Bohai Sea is rich in nutrients and is a natural aquaculture base. The central deep water area is both the migratory and distributing center of commercial fish and their overwintering ground. In the 21st century, water scarcity due to continuous population growth, limited natural resources and increased industrial activities is considered a serious social problem [2].

Background

With the advent of the "Ocean Age", the utilization of marine resources and the development of shipping have become more and more important to the development of human society and economy. Under the background of economic globalization, the ocean has become the focus of the world and the development and utilization of marine resources are an important part of it. However, frequent activities will also affect the relatively fragile ecological environment [2]. The coastal waters of China are typical and it has a near-closed shallow sea, the Bohai Sea, which

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penetrates deep into the Chinese mainland. There is a semi-closed shallow sea located on the continental shelf, the Yellow Sea, etc. Its wide range and widespread distribution. Because of their wide latitude span, variety, 26 types of landforms, high population density and increasing overexploitation and heavy pollution. Seriously, there were 68 red tides in 2017, 29 in China's coastal waters and the cumulative tidal area was 3,679 square kilometers. Inland pollutant input is a key factor affecting coastal water quality. In 2012, more than 56% of the Bohai Sea was unclean seawater. Since then, the water quality has gradually improved. In 2017, one-third of the Bohai Sea is still unclean sea water, inorganic nitrogen and petroleum hydrocarbons are the main pollutants in seawater, and about 840,000 tons of pollutants are transported to the ocean every year [3]. According to the research results, improving sewage discharge standards can reduce the eutrophication potential of the system by 4% and 14%, respectively, but increase the impact on fossil energy depletion, global warming potential, human toxicity, freshwater Ecotoxicity and acidification potential. 40% to more than 100 times. Further analysis showed that the moisture content of dewatered sludge needs to be reduced from 80% to 60% because of its significant impact on fossil energy depletion. Improving the reuse rate of sewage and replacing part of tap water are important measures to reduce environmental impact. In addition, physical methods should be preferred over chemical methods to reduce the environmental impact on water quality [4]. Therefore, it is very necessary to study the relationship between the coastal water environment and humans [5]. This year, the Dalian Municipal Government has taken a series of major measures to reduce the environmental pressure in the Bohai Sea to a certain extent. This paper analyzes the results of the water quality survey in 2020-2021 to provide a basis for controlling the discharge of pollutants and fishery development.

Materials and methods

Data sources

The data comes from the field survey data in the Bohai Sea from November (October), August (July) and May (April) from 2020 to 2021 [6]. The survey sites include 713 in 2020 (Figure 1) and 715 in 2021 (Figure 2). The survey items include 6 indicators including PH, dissolved oxygen, COD, DIN, DIP and petroleum [6]. Sample collection and analysis were carried out in accordance with the "Ocean Monitoring Specification Part 4: Seawater Analysis" (GB 17378.4-2007). The prerequisite for studying the distribution of various indicators in the seawater environment is the collection and processing of uncontaminated samples, that is, the collection, storage, processing and analysis of samples to ensure their integrity.

Methods

Evaluation Criteria: The seawater sample analysis and evaluation standard are "People's Republic of China Seawater Quality Standard" (GB3097-1997). Among them, the first type of seawater is suitable for marine fishery waters, marine nature reserves and rare and endangered marine life reserves; the second type of seawater is suitable for aquaculture areas,

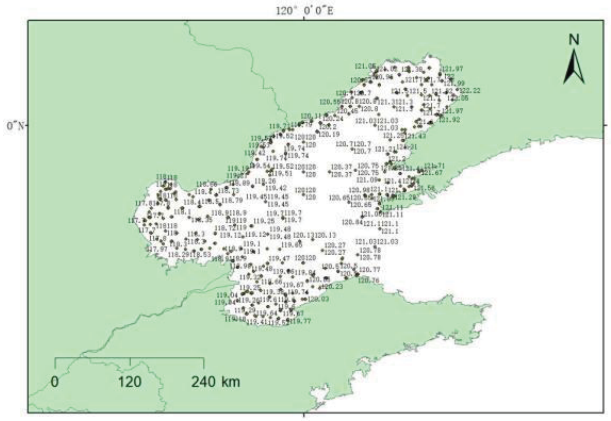

Figure 1: 2020 Seawater Survey Sites.

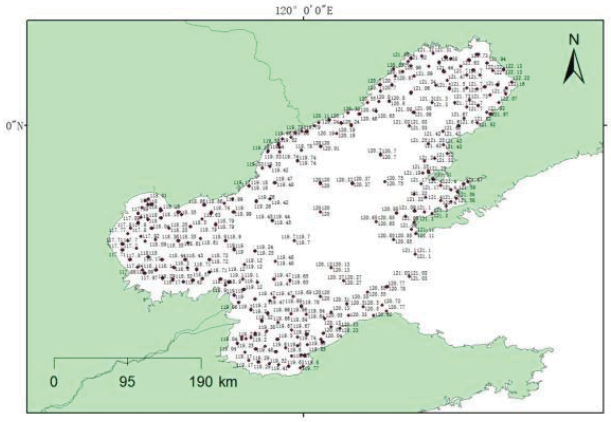

Figure 2: 2021 Seawater Survey Sites.

bathing beaches, marine sports, or entertainment areas where the human body is in direct contact with seawater and The industrial water area directly related to human consumption; the third type of seawater is suitable for general industrial water areas and coastal scenic tourist areas; the fourth type of seawater is suitable for marine port waters and marine development operation areas. This paper evaluates the water quality of a class of seawater.

Evaluation method:

1. Single factor index method

$Pi = Ci/Ssi$

In the formula: Pi-the seawater quality, sediment quality, or biomass quality index of the i-th pollutant;

Ci-the measured value of the i-th pollutant*;

Ssi-the evaluation standard value of the i-th pollutant.

2. Water quality eutrophication index

$E = COD \times Inorganic\ nitrogen \times Active\ Phosphate \times 10^6/4500$

In the formula, the unit of COD, inorganic nitrogen and active phosphate is mg·L-1.

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In the above formula, E is based on the monitoring law for many years. The structure of this judgment is revised as follows: when E ≥ 1, it means that the water body is eutrophic; when E < 1, the water body is nutrient-poor; when 1 ≤ E < 2, the water quality is light. Degree of eutrophication; when 2 ≤ E < 5, the water quality is moderately eutrophic; when 5 ≤ E < 15, the water quality is severely eutrophic.

3. Organic pollution evaluation index

$$A = COD\text{-}COD_o + DIN / DIN_o + DIP / DIP_o - DO / DO_o$$

In the formula: COD——the measured concentration of chemical oxygen demand in water, the unit is milligram per liter (mg/L);

DIN - the measured concentration of dissolved inorganic nitrogen, in milligrams per liter (mg/L);

DIP - the measured concentration of dissolved inorganic phosphorus, in milligrams per liter (mg/L);

DO - the measured concentration of dissolved oxygen, in milligrams per liter (mg/L); COD0, DIN0, DIP0, DO0——the evaluation criteria for the above indicators of water bodies, respectively, where: COD0 = 2.0 mg/L; DIN0 = 0.20 mg/L; DIP0 = 0.015 mg/L; DO0 = 6.0 mg/L; the pollution degree classification is shown in Table 1.

Results analysis

Distribution characteristics of each element

Element Analysis in 2020: PH: The content variation range is 7.80 - 8.48, the average value is 8.139, the highest value station is TJB02012 (2020.10), TJB02017 (2020.10), TJB02018 (2020.10), TJB02021 (2020.10), TJB02022 (2020.10), the lowest value station is LNB0 2020.08). Dissolved oxygen 5.46 mg/L-14.24 mg/L, the average value is 9.461 mg/L, the highest value station is SDB05028 (2020.10), the lowest value station is SDB05003 (2020.08), chemical oxygen demand 0.28 mg/L-5.49 mg/L, the average value is 1.261 mg/L, the highest value station is SDB06015 (2020.10), the lowest value station is TJB02018 (2020.10), the inorganic nitrogen is 0.007 mg/L-2.284 mg/L, the average value is 0.175 mg/L, the highest value The station is SDB05003 (2020.08), the lowest value station is LNB16018 (2020.05), the active phosphate is 0.001 mg/L-0.042 mg/L, the average value is 0.007 mg/L, the highest value station is LNB02050 (2020.05) and the petroleum is 0.001mg /L-0.124 mg/L, the average value is 0.014 mg/L, the highest value site is LNB12008 (2020.07) and the lowest value site is HBB (03006, 02006, 03008, 02009, 10004).

Table 1: Pollution degree classification.

Organic Pollution Index A	Pollution Degree Level	Water Quality Evaluation
< 0	0	good
0~1	I	better
1~2	II	began to be contaminated
2~3	III	light pollution
3~4	IV	moderate pollution
4~5	V	heavy pollution
>5	VI	Serious pollution

Factor analysis in 2021: PH-The content variation range is 7.80-8.48, the average value is 8.135, the highest value site is TJB (02002, 02005, 02008, 02016, 02017, 02021, 02008, 02022) and the lowest value site is SDB07001 (2021.07). Dissolved oxygen: the content change range is 6.58 mg/L-13.49 mg/L, the average value is 9.605 mg/L, the highest value station is LNB16008 (2021.04), the lowest value station is LNB02013 (2021.10), chemical oxygen demand: content change The range is 0.52 mg/L-4.90 mg/L, the average value is 1.339 mg/L, the highest value station is LNB12004 (2021.10), the lowest value station is SDB (06003, 06026, 06034), JHB00022, inorganic nitrogen: content variation range It is 0.004 mg/L-1.826 mg/L, the average value is 0.198 mg/L, the highest value site is SDB07001 (2021.10), the lowest value site is JHB00006 (2021.08), active phosphate: the content variation range is 0.001 mg/L-0.10 mg/L, the average value is 0.008 mg/L, the highest value site is SDB007002 (2021.10), petroleum: the content variation range is < 0.001 mg/L - 0.072 mg/L, the average value is 0.012 mg/L, the highest value The site is LNB12004 (2021.05).

The content of the above six elements is mostly DO, COD, DIN and DIP, which are mostly concentrated in Panjin, Dalian, Liaoning and Weifang, Dongying, Shandong, showing a gradually increasing trend. The first reason is that the main pollution factor is inorganic nitrogen and the second reason is that the 118km coastline of Panjin is in the middle of the Liaohe Estuary and on both sides are the Daliaohe Estuary and the Daling River Estuary. The total pollutants of the three rivers all enter the sea from Panjin [3]. It is of practical significance for the analysis of the environmental conditions in the Bohai Sea.

Evaluation of water quality and environmental quality

Single factor index method: When Pi ≤ 1.0, the seawater quality, sediment quality, or biomass quality meets the standard; when Pi ≥ 1.0, the seawater quality, sediment quality, or biomass quality exceeds the standard.

The pollution category is determined by comparing the measured content of a pollutant in the paddling water with the evaluation standard of the pollutant. The results are shown in Tables 2,3.

According to the data in the table, the DPS data processing system is used to reflect the distribution characteristics of the original data in the form of box plots. The box plots were invented by the famous American statistician John Tukey in 1977. It counts the dispersion of a set of data, respectively the upper edge, the lower edge, the median and two quartiles, namely the 25% quantile (Q1) and the 75% quantile (Q3), connecting the two quartiles the upper and lower edges are connected to the box, and the median is in the middle of the box. IQR: Q3-Q1, lower edge (minimum observation) = Q1-1.5IQR, upper edge (maximum observation) = Q3+1.5IQR. At the same time, the data of 6 groups of PH, DO, COD, DIN, DIP and oil were compared, respectively, indicating that the

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indicators of Bohai Bay tend to be stable in 2020-2021, and the main pollutants in the two-year data are inorganic nitrogen and active phosphoric acid. Salt, of which the pollution level of inorganic nitrogen has decreased and the active phosphate has increased and the data are not abnormal.

Evaluation index of organic pollution: The following table shows the analysis of the organic pollution index results of 713 sites in the Bohai Sea in 2020 and 715 sites in the Bohai Sea in 2021. If A < 0, the pollution level is 0 and the water quality is evaluated as good; if 0 < A < 1, the pollution level is 1, the water quality evaluation is good; if 1 < A < 2, the pollution level is 2, the water quality evaluation is beginning to be polluted; if 2 < A < 3, the pollution level is 3, the water quality evaluation is light pollution; if 3 < A < 4 If the pollution level is 4, the water quality is rated as moderately polluted; if 4 < A < 5, the pollution level is 5 and the water quality is rated as heavy pollution; if A>5, the pollution level is 6 and the water quality is rated as severely polluted (Table 4).

It can be concluded from the table that when the water quality is < 3, the overall water quality is in an increasing state and the water quality evaluation is good or slightly polluted, but in the table below, from 2020-2021, the index of organic pollution >3 in the Bohai Sea is also In an increasing state, the number of seriously polluted cities within this range has also changed from 14 cities to 22 cities. It can be seen from (Figure 3) that the heavily polluted cities in 2021 are mainly Panjin, Dalian and Weifang.

Water quality eutrophication index: Nutrients in seawater are the material basis of marine biological resources, but excessive nutrient content will lead to the eutrophication of seawater. This year, the economy of the Bohai Rim region has been developing rapidly and at the same time, the environment of the Bohai Sea has been severely damaged, and land sources The increase of pollutants, the discharge of factories, man-made damage and the gradual increase in the degree of eutrophication of seawater, which leads to red tides and leads to poor water environment [6-9], the marine environment is increasingly polluted by microorganisms, people's recreational activities and pollution discharges. It will affect the drainage ditches and point or non-point pollution source waters in coastal cities [10]. The Bohai Sea is a large-scale breeding place for yellow croaker and shrimp, which will inevitably affect its output and the living environment of benthic organisms, causing serious damage and huge losses to the marine ecological environment Tables 5-7.

Table 2: The environmental factor pollution index in 2021.

Item	PH (dimensionless)	DO (mg/L)	COD (mg/L)	DIN (mg/L)	DIP (mg/L)	Oil (mg/L)
Pollution index range	0.975-1.060	1.092-2.848	0.093-1.830	0.035-11.420	0.033-1.400	0.010-1.24
Average pollution index	0.992	1.519	0.409	0.852	0.213	0.108

Table 3: The environmental factor pollution index in 2020.

Item	PH (dimenionless)	DO (mg/L)	COD (mg/L)	DIN (mg/L)	DIP (mg/L)	Oil (mg/L)
Pollution index range	0.975-1.060	1.316-2.698	0.173-1.633	0.020-9.130	0.033-3.333	0.010-0.720
Average pollution index	0.995	1.543	0.436	0.967	0.217	0.093

Table 4: Calculation results of an organic pollution index.

A	Site(s)	Proportion (%)	Site(s)	Proportion (%)
< 0	405	57%	358	50%
0-1	186	26%	215	30%
1-2	97	0.14%	98	0.14%
2-3	11	0.02%	22	0.03%
3-4	8	0.01%	13	0.02%
4-5	3	0.004%	4	0.006%
>5	3	0.004%	5	0.007%
A	2020(-2.170-------11.908)		2021(-2.046----9.925)	

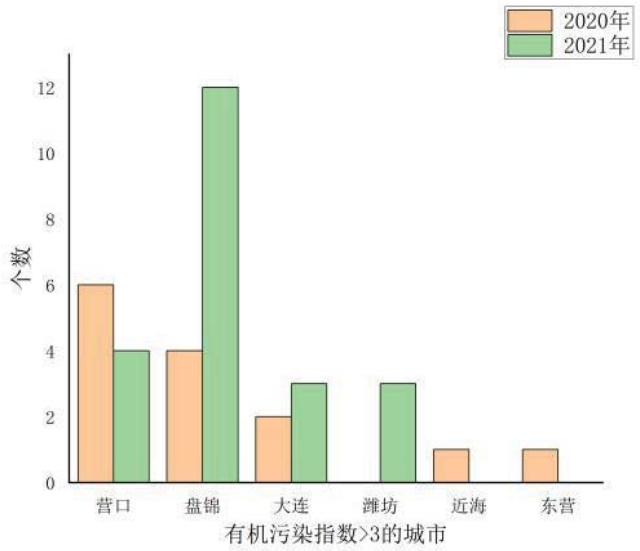

Figure 3: Cities with Organic Pollution Index > 3 in 2020-2021.

It can be seen from the above table that from 2020 to 2021, seawater eutrophication is increasing day by day. Among the 713 2020 stations and 715 2021 stations eutrophication calculation results, the most serious eutrophication in 2020 is Panjin, Liaoning Province at 30.131 mg/L. , when E < 1, there are 641 sites with nutrient-poor water, accounting for 70%; when 1 ≤ E < 2, there are 44 sites, accounting for 0.06%, the water body is slightly eutrophic; when 2 ≤ E < 2 5, there were 15 sites, accounting for 0.02% and the water body was in a moderately eutrophic state; when 5 ≤ E < 15, there were 14 sites, accounting for 0.020%, which belonged to a severe eutrophic state. In 2021, the most serious seawater eutrophication is in Weifang, Shandong, at 51.996 mg/L. When E < 1, there are 599 sites, accounting for 84% and the water body is nutrient-poor; when 1 ≤ E < 2, there are 61 sites, When 2 ≤ E < 5, there are 31 stations, accounting for 0.04% and the water quality is moderately eutrophic; when 5 ≤ E < 15, there are 24 stations, accounting for 0.03%, the water quality is severely eutrophic.

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Table 5: Calculation results of eutrophication.

Calculation results of eutrophication in the Bohai Sea in 2020		Calculation results of eutrophication in the Bohai Sea in 2021	
E value range (mg/L)	0.002-30.131	E value range (mg/L)	0.001-51.996
The average value of E value (mg/L)	0.530	The average value of E value (mg/L)	0.889

Table 6: Cities with severe eutrophication in water quality in 2020 (E ≥ 5).

Point code	E value (mg/L)
LNB08009	5.501
LNB12002	5.605
LNB12008 (2020-05)	5.627
LNB12008 (2020-07)	6.816
LNB08001	7.846
LNB08009	7.961
LNB02050	9.240
LNB12001 (2020-07)	9.360
LNB12001 (2020-05)	11.020
LNB08001 (2020-07)	12.166
LNB08001 (2020-10)	19.651
SDB05003	26.494
LNB12001	30.131

Table 7: Cities with severe eutrophication in water quality in 2021 (E ≥ 5).

Point code	E value (mg/L)
LNB08009	5.533
TJB02013	5.713
LNB02050	5.713
LNB12004	5.715
LNB12005	6.156
SDB13004	6.753
TJB02016	7.490
LNB08001	7.734
SDB07004	8.523
LNB12004	8.678
LNB12008	9.497
LNB12007	9.729
LNB12002	10.073
LNB12001	10.443
LNB02005	12.167
LNB12004	13.306
LNB12008	14.222
LNB12003	14.412
SDB07002	17.455
LNB12001 (2021-10)	19.621
LNB08001	25.636
LNB12003	29.762
LNB12001 (2021-05)	50.956
SDB07001	51.996

Discussion and conclusion

Discussion

The deterioration of the marine ecological environment will cause the turbidity of the seawater, seriously affect the photosynthesis of phytoplankton and seaweeds and affect the productivity of the sea area. The content of heavy metals in sediments and marine organisms will also increase and accumulate in the ocean. , endanger other animals. At the mouths of rivers entering the sea in major cities in Bohai Bay, industrial and agricultural development is developed and industrial waste water and domestic sewage are discharged into the sea, which has adverse effects on the production and life of coastal residents and social and economic development. United Nations Environment Programme (UNEP, 2013) Highlights "global chemical intensification": in many parts of the world, the metal input to the ocean is estimated to be much larger than non-anthropogenic input and the way it affects, global biogeochemical cycles and ecosystem diversity are not fully understood and, domestic sewage treatment operations discharge inorganic pollutants into waters in receivers and the development of aquaculture in coastal areas is associated with an increase in pollution from inorganic compounds [11]. Therefore, in order to effectively deal with seawater pollution and improve social and economic development, the following countermeasures and suggestions are put forward.

1. **Strengthen the ecological protection and restoration of coastal zones:** Apply the plants in the garden with "trees, shrubs, and grasses" to the coastal zone, enrich coastal vegetation, increase the green area and practice the concept of sustainable development. Coastal zones also provide important buffer and filtering systems for coastal ecosystems [12]. For the ecological transformation of the revetment, based on the evaluation results, select the best measures to protect and restore the coastal zone, strictly control the discharge of land-based pollutants, use greening and ecological concepts to protect the coast, and restore the coast destroyed by coastal erosion. Protect and restore typical coastal ecosystems such as bays, coral reefs and seagrass beds and restore ecosystem services between oceans, coasts, and land.

2. **Strictly control the reclamation:** Strengthen the supervision of suspected illegal reclamation, comprehensively use a variety of supervision methods to carry out supervision, strictly review new reclamation projects, focus on protecting the ecological environment, control the area of reclamation to the maximum extent and conduct illegal and illegal reclamation projects. In order to maintain the marine ecological environment, ecosystem-based marine spatial planning should be formulated as the basis for marine environmental management [13].

3. **Strengthen the supervision of marine dumping:** Marine debris will cause the deterioration of seawater quality. The pollution of the ocean mainly occurs in the bays

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close to the mainland. Due to the dense population and industrial factories, a large amount of wastewater and solid waste are dumped into the seawater. The self-purification ability is blocked, so the pH, temperature, inorganic salt, transparency, biological species and quantity in seawater are changing, affecting the entire marine ecological balance. Marine pollution is mainly manifested in oil pollution, red tide, accumulation of toxic substances, plastic pollution and nuclear pollution. Oil and COD have exceeded the standard in various sea areas, and the most serious pollution is the Bohai Sea, which has caused the relocation of fisheries, the death of fish, the flooding of red tides and the abandonment of some tidal flat farms. However, under the supervision and management of the government, the marine environment in the Bohai Bay area is constantly improving. In this paper, some economic fish farming in the Bohai Sea has been recovering in recent years, which is inseparable from the measures to improve the ecological environment. It is necessary to strengthen supervision and maintain the ecological balance of the sea area [14-22].

4. **Strictly control overfishing:** Overfishing will destroy the stability and biodiversity of the original marine ecosystem and directly affect the natural resilience of fisheries. The ratio of the ocean to land in the world is 71:29. The vast ocean provides a broad space for the growth of organisms. It also provides economic sources for human beings. Until now, industrialized fishery production has become very common and marine economic fish is also being fished on a large scale. When human demand exceeds the limit of ocean load, fishery resources will also shrink. Coupled with the growth of population, we must protect the growing environment of marine life and prohibit overfishing while continuing to march into the ocean. Therefore, we must maintain the marine ecological environment and achieve a marine-coast-land ecological balance and we must strengthen marine governance and protection when developing and utilizing the ocean.

Conclusion

1. The overall situation of my country's marine ecological environment is stable. The water quality of rivers entering the sea in 2021 is higher than that of rivers entering the sea in 2022, which is concentrated in Panjin, Yingkou, and Weifang. According to the water quality survey results in spring, summer and autumn of 2020-2021, the main pollutants are inorganic nitrogen and active phosphate. Liaoning is mainly in the Panjin aquaculture area with serious water eutrophication, Shandong is mainly in Weifang and Tianjin is the most serious. The water quality of some sea areas is eutrophic and it is necessary to strengthen the management of sewage discharge from the estuary of each sea area and control the content of nutrient salts discharged into the sea. In general, the proportion of coastal seawater is consistent with the proportion of immediately estuarine waters, and pollution is mainly due to public and private discharge of untreated sewage pipes in the river course. During this period, seawater pollution can lead to loss of habitat and have harmful effects on the land environment [23,24]. To protect the ecological environment of the Bohai Sea, through the comprehensive analysis of the results of the A value and E value, whether in 2020 or 2021, the water quality of the Bohai Sea water is slightly eutrophic and the water quality between $0 < A < 1$ is the main part, but in 2021 The proportion of high indicators of organic pollution index is increasing, the average value of eutrophication and the maximum range value are also increasing. Therefore, it is necessary to strengthen ecological protection measures, realize the overall control of land-based pollutants, reduce the occurrence of red tides and maintain the marine ecological environment according to the pollution-absorbing capacity of the sea area.

2. In 2021, the number of cities with pollution of water quality and environmental elements and water quality eutrophication in the Bohai Bay of my country will be more than in 2020 and the main indicators exceeding the standard of spawning grounds, feeding grounds, migratory channels and aquatic nature reserves of important marine fishery resources will be for inorganic nitrogen and active phosphate. A large amount of domestic sewage and industrial wastewater are directly or indirectly discharged into the offshore waters, causing water pollution, ecological damage and huge economic losses. The seawater environment is affected by many factors, namely PH, DO, COD, DIN, DIP, OIL and these Pollution factors are characterized by uncertainty and ambiguity [25-31].

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