Water Quality Assessment for Deep-water Channel area of Guangzhou Port based on the Comprehensive Water Quality Identification Index Method

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Abstract. The comprehensive water quality identification index method is able to assess the general water quality situation comprehensively and represent the water quality classification; water environment functional zone achieves pollution level and standard objectively and systematically. This paper selects 3 representative zones along deep-water channel of Guangzhou port and applies comprehensive water quality identification index method to calculate sea water quality monitoring data for different selected zones from year 2006 to 2014, in order to investigate the temporal variation of water quality along deep-water channel of Guangzhou port. The comprehensive water quality level from north to south presents an increased trend, and the water quality of the three zones in 2014 is much better than in 2006. This paper puts forward environmental protection measurements and suggestions for Pearl River Estuary, provides data support and theoretical basis for studied sea area pollution prevention and control.

1. Introduction
The evaluation and analysis methods of water quality are mainly including index assessment method, fuzzy evaluation method, multi-variate statistics analysis method, artificial neural network and matter element analysis method[1-3]. The comprehensive water quality identification index method based on single factor evaluation method is an emerging method of the index assessment methods[4]. Wang Junbo[5] applied this method to Yongding River water quality assessment and obtained convincing result.

This paper applies the comprehensive water quality identification index method to evaluate and analyze the water quality in deep-water Channel area of Guangzhou Port. Environmental protection measurements and suggestions has been put forward for Pearl River Estuary, and data support and theoretical basis for pollution prevention and control of studied sea area has been provided as well.

2. General introduction of studied sea area
2.1. Deep-water Channel project in Guangzhou Port and Water quality situation
In order to adapt to the increasing demand of port transportation and the trend of large-scale ship development, deep-water Channel in Guangzhou port has experienced several large-scale renovation projects, including first-stage, second-stage and third-stage constructions and the widening construction.

The widening construction of deep-water Channel is under construction now and its design length from south to north is approximately 115km.
There are several environmental protection targets along deep-water channel of Guangzhou port, including Neilingding Island-Futian natural reserve, China white dolphin national nature reserve and Pearl River estuary economy fish breeding ground reserve. The general layout of environmental protection targets along deep-water channel is shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** General layout of environmental protection targets along deep-water channel in Guangzhou port

With the rapid development of the Pearl River estuary in recent years including the deep-water channel of Guangzhou port, the water pollution in the sea has become increasingly prominent. The environment bulletin of 2016 issued by Ministry of Environmental Protection showed that the water quality of the Bohai bay and the Pearl River estuary is the worst among 9 important bays and estuaries. Therefore it is really significant to analyze and study the water quality of deep-water channel area in Guangzhou Port, and the conclusion of this paper can be used as the theoretical basis for water quality control and repair.

2.2. **Assessment zones division and data collection**

According to water quality monitoring station layout and current situation of deep-water channel area, this paper selects Longxue Island, Inner Lingding Island and Guishan Island as three assessment zones, marking as Zone I, Zone II and Zone III. The water quality monitoring station layout is as below,
Figure 2. Monitoring station layout

Table 1. Monitoring station coordinates

| Assessment areas                  | Water quality target of water environment function zones | Year 2006                  | Year 2007                  | Year 2010                  | Year 2011/2012/2014          |
|----------------------------------|----------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|
| Zone I (Longxue Island)          | Class II                                                 | 22°37′50.00″ North 113°42′30.00″ East | 22°36′0.00″ North 113°42′24.00″ East | 22°35′30.60″ North 113°42′22.27″ East | 22°35′36.70″ North 113°41′24.76″ East |
| Zone II (Inner Lingding Island)   | Class II                                                 | 22°25′0.00″ North 113°45′30.00″ East | --                          | --                          | --                            |
| Zone III (Guishan Island)        | Class I                                                  | 22°8′10.00″ North 113°52′5.00″ East | --                          | --                          | 22°10′56.26″ North 113°47′14.87″ East |

“--” represents that there is no collected and usable data

3. Water quality analysis and evaluation method

3.1. Calculation method of the comprehensive water quality identification index method

This paper applies the comprehensive water quality identification index method in sea water quality assessment\(^6\), the composition of the comprehensive water quality identification index \(I_{wq}\) is as below,

\[I_{wq} = X_1 \cdot X_2 \cdot X_3 \cdot X_4\]
\( X_1 \text{ and } X_2 \) in the formula is calculated from,
\[
X_1 \cdot X_2 = \left( \frac{1}{m} \right) \sum (P_1' + P_2' + \cdots + P_m')
\]

In the formula 3-2, \( m \) is the number of single indexes of water quality; \( P_1' \), \( P_2' \) and \( P_m' \) are the first, the second and the "m-eth" index respectively.

\( X_3 \) is the number of the single indexes which are inferior to water environment function area target. \( X_4 \) is the comparative result between the comprehensive water quality level and water environment function area level. According to water pollution level, \( X_4 \) has one or two significant digits.

If the comprehensive water quality level is superior to or equal to the water environment function area level,
\[
X_4 = 0
\]

If the comprehensive water quality level is inferior to the water environment function area level, and \( X_2 \) is not equal to 0,
\[
X_4 = X_1 - f
\]

If the comprehensive water quality level is inferior to the water environment function area level, and \( X_2 \) is equal to 0,
\[
X_4 = X_1 - f - 1
\]

In the formula, “\( f \)” is the water environment function area level. According to water quality of the channel area, this paper selects inorganic nitrogen, phosphate, petroleum, COD and Zn as main pollution control indicators to carry out water quality assessment. The arithmetic mean value of single factor water quality index value for these five indicators (round to one decimal places) represents pollution level and the comprehensive water quality level,
\[
X_1 \cdot X_2 = \frac{1}{5} \sum (P_{\text{inorganic nitrogen}}' + P_{\text{phosphate}}' + P_{\text{petroleum}}' + P_{\text{COD}}' + P_{\text{Zn}}')
\]

After calculating \( X_1 \cdot X_2 \) from formulate 3-6 and adding the \( X_3 \) and \( X_4 \), the comprehensive water quality identification index \( I_{wq} \) can be obtained.

3.2. The significance of \( I_{wq} \)
The comprehensive water quality level can be determined through the integer and first decimal place of \( I_{wq} \).

| Criterion | Water quality level |
|-----------|---------------------|
| \( 1.0 \leq X_1 \cdot X_2 \leq 2.0 \) | Class I |
| \( 2.0 < X_1 \cdot X_2 \leq 3.0 \) | Class II |
| \( 3.0 < X_1 \cdot X_2 \leq 4.0 \) | Class III |
| \( 4.0 < X_1 \cdot X_2 \leq 5.0 \) | Class IV |
| \( 5.0 < X_1 \cdot X_2 \leq 6.0 \) | Class V |
| \( 6.0 < X_1 \cdot X_2 \leq 7.0 \) | Inferior to Class V but not malodorous black |
| \( X_1 \cdot X_2 > 7.0 \) | Inferior to Class V and malodorous black |

4. Results and discussion
4.1. Single factor water quality assessment and evaluation
The assessment results applied single factor evaluation method from 2006 to 2014 are shown in Table 3 to Table 5. It represents whether the selected water quality factors are reach standard or not and the variation trend, but cannot reflect the comprehensive water quality of studied sea area.

| Year | Inorganic Nitrogen | Phosphate | Petroleum | COD | Zn |
|------|--------------------|-----------|-----------|-----|----|
| 2006 | 0.73               | 5.02      | 0.84      | 0.20| 1.20|
| 2007 | 0.36               | 3.01      | 0.61      | 1.20| 5.00|
| 2010 | 6.29               | 1.18      | 1.30      | 0.66| 0.15|
| 2011 | 0.34               | 4.11      | 1.22      | 0.61| 0.65|
| 2012 | 0.53               | 5.16      | 1.03      | 1.71| 0.29|
| 2014 | 0.30               | 3.96      | 0.70      | 1.32| 0.47|

| Year | Inorganic Nitrogen | Phosphate | Petroleum | COD | Zn |
|------|--------------------|-----------|-----------|-----|----|
| 2006 | 6.12               | 1.62      | 0.20      | 0.62| 1.00|
| 2011 | 2.18               | 0.38      | 0.51      | 0.43| 0.68|
| 2012 | 1.66               | 0.50      | 0.81      | 0.20| 0.22|
| 2014 | 3.10               | 0.46      | 1.17      | 0.45| 0.56|

| Year | Inorganic Nitrogen | Phosphate | Petroleum | COD | Zn |
|------|--------------------|-----------|-----------|-----|----|
| 2006 | 0.52               | 2.73      | 1.11      | 0.20| 2.50|
| 2011 | 0.89               | 0.65      | 0.33      | 0.71| 0.71|
| 2012 | 1.93               | 0.82      | 0.12      | 0.19| 0.17|
| 2014 | 1.06               | 0.25      | 1.62      | 0.49| 0.86|

4.2. Water quality assessment and evaluation for deep-water channel area of Guangzhou port

Figure 3 shows the variation trend of water quality along deep-water channel area of Guangzhou port from 2006 to 2014.

Figure 3. Variation trend of water quality along deep-water channel area

The comprehensive water quality classification is shown in Table 6.
Table 6. The comprehensive water quality index values and water quality classification

| Year | Zone I   | Zone II  | Zone III |
|------|----------|----------|----------|
| 2006 | 3.622    | Class III| 3.922    | Class III| 2.431    | Class II |
| 2007 | 4.022    | Class III| -        | -        | -        |          |
| 2010 | 3.932    | Class III| -        | -        | -        |          |
| 2011 | 3.422    | Class III| 2.810    | Class II | 1.700    | Class I  |
| 2012 | 3.732    | Class III| 2.710    | Class II | 1.610    | Class I  |
| 2014 | 3.422    | Class III| 3.222    | Class III| 1.910    | Class I  |

According to the identified comprehensive water quality level in Table 6, the water quality in area I from year 2006 to 2014 is inferior to the water quality target. The water quality in area II and area III can basically satisfy water quality target of water environment function zones during 2011 to 2014, and water quality from year 2011 to 2014 is better than year 2006.

Table 6 reflects the comprehensive water quality level, water quality situation and compared result between water quality and water environment function level respectively. According to the $X_i$ values in Table 6, over-limit ratio of sea water quality factors is high in area I, the data changes slightly annually. The over-limit ratio of sea water quality factors in area II and III is lower than the ratio in area I, and the water quality from 2011 to 2014 is better than in 2006.

The water quality situation along the channel represents water quality variety in the Pearl River estuary basically. The water quality of Zone I is the worst among those three zones, and there is no better indicator in current years. The water quality in Zone II and Zone III is much better than in Zone I and there is an improvement due to environmental governance these years. The comprehensive water quality level has an improved trend from north to south.

The main over-limit reasons of petroleum are shipping and platform construction activities along the deep-water channel and the discharge of oil spill during operation, the main over-limit reasons of inorganic nitrogen and COD are terrestrial runoff and artificial breeding, the possible over-limit reasons of phosphate include extensive aquaculture in north of the Pearl River estuary.

4.3. **The comparison between single factor evaluation method and comprehensive water quality identification index method**

The single factor evaluation method is easy to calculate and understand, but its results cannot represent the comprehensive water quality situation of studied sea area. In comparison, the comprehensive water quality identification index method is able to assess water quality qualitatively and quantitatively, reflect comprehensive water quality situation and area water quality level objectively and accurately.

Compared with single factor evaluation method, the comprehensive water quality identification index method is able to conduct a longitudinal comparison of water quality in the same zone and a horizontal comparison of water quality in different zones, the results are credibly and intuitively[7]. This paper is aim to obtain the comprehensive water quality situation for selected zones along deep-water channel of Guangzhou port, the assessment results above show that the comprehensive water quality identification index method is much more appropriate.

4.4. **Conservation strategies and suggestions**

According to evaluation results above, the water conservation and comprehensive management along deep-water channel of Guangzhou port is urgent. In order to improve the water quality, recommendations are shown as below.

1. To enhance the management of ship and oil platform in order to avoid the occurrence of sudden oil spill and regulate the discharge behavior of ships and oil platforms,

2. To improve the treatment rate and target rate of the land-based sewage and to regulate the discharge of land-based pollution,
(3) To strengthen the comprehensive remediation of channel water areas, formulate regional total control amount indicators and control total regional pollutant emission.

5. Conclusion

This paper applies the comprehensive water quality identification index method to sea water quality assessment, this method is superior to the single factor index method which usually applied in environmental impact assessment report. The comprehensive water quality level from north to south presents an increased trend, and the water quality of the three zones in 2014 is much better than in 2006.

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