

Macao Beach Water Quality Monitoring Report 2021

Laboratory Division of Municipal Affairs Bureau PETER DAL

Table of Contents

I.		Introduction
	1.	Beach Water Quality Monitoring Programme
	2.	Assessment of Beach Water Quality4
	3.	Rainfall Effect on Beach Water Quality5
	4.	Summary of Annual Beach Water Quality5
II.		Monitoring Results of Bacteriological Parameters
	1.	Bacteriological Parameters6
	2.	Bacteriological Ranking of Water Quality7
III.		Monitoring Results of Physical and Chemical Parameters
	1.	Physical Parameters8
	2.	Organic Pollution Parameters8
	3.	Nutrient Pollution Parameters9
	4.	Heavy Metal Pollution Parameters10
	5.	Eutrophication Index12
	6.	Comprehensive Assessment of Water Quality12
IV.		Monitoring Results of Biological Parameters14
	1.	Algae14
	2.	Other Creatures15
v.		Summary

I. Introduction

To safeguard the health of swimmers and understand the long-term water quality of beaches, the Laboratory Division of the Municipal Affairs Bureau of Macao carries out regular monitoring of the water quality of the two public beaches in Macao, namely Hac Sá Beach and Cheoc Van Beach.



Hac Sá Beach has a vast sand surface and is an ideal place for aquatic activities.



Cheoc Van Beach is surrounded by mountains and a good place for spending the holidays.

1. Beach Water Quality Monitoring Programme

The three water quality monitoring points at Hac Sá Beach are located in the waters facing the three lifeguard stands respectively, while the two monitoring points at Cheoc Van Beach are located close to the two sides of the rope net in the swimming area.



Three monitoring points at Hac Sá Beach



Two monitoring points at Cheoc Van Beach



Upon arrival at the beaches, the sample collectors first observe and pay attention to the environmental conditions on site, such as weather changes and state of the sea, including the appearance of red tide and creatures like jellyfish. After carrying out on-site tests of pH value, dissolved oxygen and others, the sample collectors send the samples to the laboratory, which are subject to tests of multiple bacteriological, physical and chemical or biological parameters in accordance with the monitoring programme.

In view of the large number of visitors during the bathing seasons (from May to October each year), the monitoring of water quality must be strengthened during this period. Samples are collected once per week during the bathing seasons and once per month during nonbathing seasons. In 2021, regular sample collection was carried out 24 times at Hac Sá Beach and 25 times at Cheoc Van Beach. A total of 122 water samples were collected from both beaches and 3,628 tests were conducted for over 40 parameters.

2. Assessment of Beach Water Quality

The beach water quality is assessed on the basis of the geometric mean of *Escherichia coli* (*E. coli*) counts in the five most recent water samples. When the geometric mean count of *E. coli* in the five most recent samples exceeds 610 CFU/100 mL (>610 CFU/100mL), or the *E. coli* in the latest water sample collected exceeds 1600 CFU/100 mL (>1600 CFU/100mL), the beach water quality is graded as "fail".

In case of a fail in beach water quality, the relevant government authorities will be notified immediately to facilitate appropriate follow-up.

According to all results of geometric mean of E. coli, with reference to the annual ranking system of beach water quality of the Environmental Protection Department of Hong Kong which classifies beach water quality into four ranks, namely "Good", "Fair", "Poor" and "Very Poor", assessment on the annual conditions of water quality of beaches and provision of information about long-term trends of beach water quality can be made.

Annual Ranking System of Beach Water								
Quality								
Rank	<i>E. coli</i> count per 100mL							
Good	≤24							
Fair	25 - 180							
Poor	181 - 610							
Very poor	> 610							

3. Rainfall Effect on Beach Water Quality

The beach water quality can deteriorate rapidly during or after heavy rain, and it usually resumes normal in around three days. Therefore, it is advised to avoid swimming at beaches during or within three days after heavy rain.

4. Summary of Annual Beach Water Quality

This report makes a summary and comprehensive assessment of the water quality of the two beaches in Macao on the basis of the monitoring results of major parameters. The bases of assessment are as follows:

• Bacteriological parameters – With reference to the standards of beach water quality of the Environmental Protection Department of Hong Kong.

• Physical and chemical parameters – With reference to the "Sea Water Quality Standard" (GB3097-1997) Class II water: applicable to aquaculture zones, bathing beaches, water sports or recreational areas with direct human contact with sea water.

II. Monitoring Results of Bacteriological Parameters

1. Bacteriological Parameters

The bacteriological monitoring items include *Escherichia coli* (*E. coli*) and *Vibrio cholera* (serogroups O1 and O139).

(1) Escherichia coli (E. coli)

The monthly geometric mean of *E. coli* of Hac Sá Beach was the highest in March throughout the year, with a result of 721 CFU/100mL; the monthly geometric mean of *E. coli* of Cheoc Van Beach was the highest in June throughout the year, with a result of 355 CFU/100mL. The monthly geometric mean of *E. coli* of Hac Sá Beach was the lowest in September throughout the year, with a result of 10 CFU/100mL; the monthly geometric mean of *E. coli* of Cheoc Van Beach was the lowest in September throughout the year, with a result of 10 CFU/100mL; the monthly geometric mean of *E. coli* of Cheoc Van Beach was the lowest in April and December throughout the year, with a result of 3 CFU/100mL.



Monthly geometric mean of Escherichia coli in 2021

Samples were collected from Hac Sá Beach for a total of 24 times in the year with a pass rate of 100%. Samples were collected from Cheoc Van Beach for 25 times in total throughout the year and the water quality failed once, resulting in a pass rate of 96.0%. The annual geometric means of E. coli were lower than those of the previous two years.



(2) Vibrio cholera (serogroups O1 and O139)

Vibrio cholera (serogroups O1 and O139) was not detected at the two beaches.

2. Bacteriological Grading of Water Quality

On the basis of *E.coli* test results and with reference to the beach ranking system of the Environmental Protection Department of Hong Kong, the water quality of Hac Sá Beach reached the grade "Very Poor" rank in March. There were two months and three months respectively that the water quality of Hac Sá Beach and Cheoc Van Beach was graded as "Poor". The water quality of Hac Sá Beach and Cheoc Van Beach the grading "Good" for two months and three months respectively.

III. Monitoring Results of Physical and Chemical Parameters

The monitoring items of physical and chemical parameters include physical parameters, organic pollution parameters, nutrient pollution parameters and heavy metal pollution parameters, while the eutrophication index and the comprehensive water quality assessment index are also calculated.

1. Physical Parameters

Physical parameters (water temperature, conductivity, salinity, turbidity and pH value):

- The water temperature of the samples collected from the two beaches was between 17.0°C and 33.0°C.
- The electrical conductivity of the samples collected from the two beaches was between 8.6 mS/cm and 48.4 mS/cm, and the salinity was between 4.3 psu and 29.7 psu. The results of both parameters were relatively dispersed. The mean values of conductivity and salinity showed a continuous year-on-year rise which was estimated to be related to low rainfall.
- Turbidity is the most direct factor affecting the senses of beach users. The annual turbidity means of Hac Sá Beach and Cheoc Van Beach were 88 NTU and 77 NTU respectively, both higher than the annual turbidity means of 2020 (72 NTU and 61 NTU for Hac Sá Beach and Cheoc Van Beach respectively). It is estimated that the turbidity is mainly affected by the comparatively large suspended substances in beach water.
- All the pH value results of the year of Hac Sá Beach reached the "Sea Water Quality Standard" for Class II (7.8 – 8.5), whereas the pH values of Cheoc Van Beach were lower than 7.8 in January and May. The decrease of pH value of water was estimated to be related to organisms being brought to offshore areas.

2. Organic Pollution Parameters

The organic pollution parameters include dissolved oxygen, permanganate index (chemical oxygen demand) and five-day biochemical oxygen demand. They are all important indicators of the severity of organic pollution of the water and its ability to achieve self-cleaning effect through self-oxidation process.

- The dissolved oxygen of Cheoc Van Beach maintained at relatively high level and all the results reached the "Sea Water Quality Standard" for Class II (>5 mg/L). The results of Hac Sá Beach were below 5.0 mg/L in July and September as the dissolved oxygen was reduced due to relatively high water temperature, turbid water and other factors.
- The permanganate index (chemical oxygen demand) basically reached the "Sea Water Quality Standard" for Class II (≤ 3 mg/L). Throughout the year, the permanganate index of the two beaches exceeded 3 mg/L for three times, fewer times compared to the results in 2020. Among them, the permanganate index of Hac Sá Beach was 4.31 mg/L and 3.50 mg/L for March and May respectively, while the permanganate index of Cheoc Van Beach was 3.65 mg/L in July. The mean values of the results of the two beaches were 2.13 mg/L (Hac Sá Beach) and 1.90 mg/L (Cheoc Van Beach) respectively, closely comparable with the results of 2.05 mg/L (Hac Sá Beach) and 2.02 mg/L (Cheoc Van Beach) in 2020.
- Five-day biochemical oxygen demand: The test results of Hac Sá Beach and Cheoc Van Beach exceeded the "Sea Water Quality Standard" for Class II (≤ 3 mg/L) in February. The test results of the two beaches in the remaining months complied with the "Sea Water Quality Standard". Among them, the test results of Hac Sá Beach in April, June and July, and those of Cheoc Van Beach in July were higher than the limit of detection (2 mg/L) of the analysis method. The results indicated that the level of organic pollution in water was lower at Cheoc Van Beach than Hac Sá Beach.

3. Nutrient Pollution Parameters

The nutrient pollution parameters include non-ionic ammonia, inorganic nitrogen and reactive phosphate.

 The test results of non-ionic ammonia of the two beaches complied with the "Sea Water Quality Standard" for Class II (≤ 0.020 mg/L). The mean values for Hac Sá Beach and Cheoc Van Beach were 0.008 mg/L and 0.006 mg/L respectively in 2020, whereas those of the two beaches in 2021 were both 0.007 mg/L. On the whole, there was no significant difference between the test results of the two beaches and those of 2020 and 2021.

- The components of inorganic nitrogen include ammonium nitrogen and total oxidised nitrogen. Due to the high dissolved oxygen content in the water of the two beaches, the nitrification process of nitrogen pollutants in water was favoured, making total oxidised nitrogen the major component of inorganic nitrogen. The mean values of the results of the two beaches were 0.83 mg/L (Hac Sá Beach) and 0.87 mg/L (Cheoc Van Beach), a slight decrease compared to the results of 1.12 mg/L (Hac Sá Beach) and 1.15 mg/L (Cheoc Van Beach) in 2020. However, the results of inorganic nitrogen of the year kept exceeding the "Sea Water Quality Standard" for Class II (≤ 0.30 mg/L).
- Throughout the year, 39% of the results of reactive phosphate of the two beaches exceeded the "Sea Water Quality Standard" for Class II (≤ 0.030 mg/L), representing a slight decrease compared to the results of 2020 (62%). The test results ranged between the limit of detection (0.009 mg/L) of the analysis method and 0.053 mg/L. The phosphorus pollution of the year was mainly concentrated in the second half of the year. The monitoring results in the recent years indicated that there was continuous improvement in the reactive phosphate situation.
- Extra water quality monitoring was carried out on the two beaches due to red tides. The inorganic nitrogen and reactive phosphate contents were relatively high on 15 February (6.7 mg/L inorganic nitrogen and 0.38 mg/L reactive phosphate) at Hac Sá Beach, as well as on 27 January (56 mg/L inorganic nitrogen and 5.2 mg/L reactive phosphate) and 15 February (22 mg/L inorganic nitrogen and 1.7 mg/L reactive phosphate) at Cheoc Van Beach. This resulted in the occurrence of eutrophication in the water, thus prone to cause red tides in the seawater.

4. Heavy Metal Pollution Parameters

The heavy metal pollution parameters include arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium and zinc, a total of nine items. The test results

showed that the influence of lead pollution on the two beaches was not improved but there was even a deteriorating trend. In 2020, there was one occasion in the results of both Hac Sá Beach and Cheoc Van Beach that the lead test result exceeded the "Sea Water Quality Standard" for Class II, whereas there were 4 occasions and 1 occasion respectively at the two beaches in 2021. With respect to copper tests, 75% of the copper test results of Cheoc Van Beach of the year were higher than the limit of detection (0.0020 mg/L) of the analysis method, with 58% for Hac Sá Beach. Both figures were an increase compared to those in 2020. In regard to mercury test results, there was once in March that the result of Cheoc Van Beach exceeded the "Sea Water Quality Standard" for Class II. Moreover, the water samples of the two beaches were tested to contain a small amount of arsenic. The following table shows the mean values of results of various heavy metals in the recent two years for comparison.

Mean	Cheoc Van Beach		Hac Sá Beach	
Parameter (limit) (GB 3097-97 Class II)	2020	2021	2020	2021
Arsenic (≤0.030 mg/L)	<0.0020	0.0024	<0.0020	0.0024
Cadmium (≤0.005 mg/L)	<0.00010	<0.00010	<0.00010	<0.00010
Chromium (≤0.10 mg/L)	<0.0020	<0.0020	<0.0020	<0.0020
Copper (≤0.010 mg/L)	0.0021	0.0068	<0.0020	0.0037
Mercury (≤0.0002 mg/L)	<0.00010	0.00019	<0.00010	<0.00010
Nickel (≤0.010 mg/L)	<0.0020	<0.0020	<0.0020	<0.0020
Lead (≤0.005 mg/L)	<0.0020	<0.0020	<0.0020	0.003
Selenium (≤0.020 mg/L)	<0.010	<0.010	<0.010	<0.010
Zinc (≤0.050 mg/L)	<0.020	<0.020	<0.020	<0.020

Table of Comparison of Mean Values of Heavy Metal Pollution Parameters

0

5. Eutrophication Index

The eutrophication index is used for evaluation of the degree of eutrophication of the sea. As a reference indicator of organic and nutrient pollution of sea water, it is calculated by permanganate index (chemical oxygen demand), inorganic nitrogen concentration and reactive phosphate concentration. The larger the index, the more severe is the eutrophication of the water.

As the test results of inorganic nitrogen and reactive phosphate slightly decreased, the eutrophication index slightly reduced compared to that of 2020. It can be seen from the test results that the eutrophication index of Hac Sá Beach and Cheoc Van Beach ranged from 4 to 36 with both of the annual mean values at 10, a slight decrease compared to the annual mean values (16 and 18 respectively) of 2020. The test results indicated that the coastal water was still subject to pollution caused by excessive nitrogen, phosphorus and other nutrients. The statistics showed that eutrophication was still severe in the water of the two beaches.

6. Comprehensive Assessment of Water Quality

The comprehensive assessment of water quality is made by statistical analysis of the 16 items of the "Sea Water Quality Standard", and it is a comprehensive embodiment of the annual water quality of the two beaches. In order to differentiate the impacts of non-metal and metal pollutants on the beach water quality, the comprehensive assessment is divided into non-metal assessment (7 non-metals: pH value, dissolved oxygen, permanganate index, biochemical oxygen demand, non-ionic ammonia, inorganic nitrogen and reactive phosphate) and metal assessment (9 metals: arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium and zinc), along with the assessment given by the statistical analysis of the physical and chemical assessment of the mentioned 16 items and their impact on the beach water quality. The larger the assessment index, the more severe is the pollution.

• Non-metal assessment: Both beaches showed a slight decrease in the test results of inorganic nitrogen and reactive phosphate, resulting in a lower non-metal

assessment index than that of 2020. The non-metal assessment indexes of Hac Sá Beach and Cheoc Van Beach were 0.83 and 0.87 respectively, showing the unfavourable conditions of the non-metal assessment of the two beaches.

- Metal assessment: The metal assessment indexes of Hac Sá Beach and Cheoc Van Beach were 0.18 and 0.24 respectively, both higher than those of 2020. 58% of the copper test results of Hac Sá Beach and 75% of those of Cheoc Van Beach were higher than the limit of detection (0.0020 mg/L) of the analysis method. Moreover, some individual results of lead tests of the two beaches exceeded the "Sea Water Quality Standard" for Class II, resulting in a higher metal assessment index than that of 2020. Furthermore, trace metals, such as arsenic, nickel, iron and manganese, were detected at both beaches, but the contents were at relatively low levels. The overall metal pollution was relatively minor.
- Overall physical and chemical assessment: The non-metal assessment indexes of the two beaches were lower than those of 2020, but the metal assessment indexes were higher than those of last year, thus causing an increase in the overall assessment index. The overall assessment indexes of the two beaches maintained at medium level for years.

IV. Monitoring Results of Biological Parameters

1. Algae

- Qualitative analysis: The most common dominant algae of the two beaches was similar to that of last year, with *Skeletonema costatum* and *Chaetoceros* as the major types. Among the 26 tests (2 red tides) at Hac Sá Beach throughout the year, *Skeletonema costatum* and *Chaetoceros* were detected for 11 times respectively, being the most frequently occurring algae. The next frequently occurring algae was *Coscinodiscus*, being detected for 9 times in total. Among the 28 tests (4 red tides) at Cheoc Van Beach throughout the year, *Chaetoceros* was the most frequently detected algae for a total of 16 times. It was followed by *Skeletonema costatum* which was detected for 11 times in total.
- Quantitative analysis: The annual geometric mean of algae at Hac Sá Beach and Cheoc Van Beach were 550 Natural units/mL and 530 Natural units/mL respectively, both representing a relatively large increase compared to the mean of 180 Natural units/mL and 190 Natural units/mL in 2020.
- Red tide: A total of two red tides occurred at Hac Sá Beach in February and December, which were mainly formed by *Noctiluca scintillans* (February) and *Phaeocystis* (December). There were a total of four red tides that occurred at Cheoc Van Beach, namely in January, February, August and December. The major red tide algae was *Noctiluca scintillans* (January and February), *Polykrikos geminatum* (August) and *Phaeocystis* (December).



Noctiluca scintillans



Phaeocystis



Polykrikos geminatum

2. Other Creatures

• No other creature was observed.

V. Summary

- 1. Classification was made according to the annual geometric mean values of *E. coli* with reference to the Environmental Protection Department of Hong Kong. The water quality of the two beaches was ranked as "Fair" this year, showing an improvement compared to the ranking of last year.
- 2. The test results of both inorganic nitrogen and reactive phosphate slightly decreased, resulting in a slight decrease in eutrophication index compared to that of 2020.
- 3. The metal assessment indexes of the two beaches rose for two consecutive years, leading to an increase in overall assessment index. However, the overall physical and chemical assessment index of the two beaches maintained at medium level.
- 4. A number of red tides occurred at the two beaches, causing the increase in annual geometric mean of number of algae compared to that of 2020. When red tide occurred at both beaches, the types of red tide algae are relatively consistent, with *Noctiluca scintillans* being the red tide algae appearing more frequently. The most common dominant algae of the year for both beaches was *Skeletonema costatum* and *Chaetoceros*.