

Risk Assessment Studies

Report No.20

VIBRIO SPECIES IN SEAFOOD

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Abstract

Vibrios are associated with live seafood as they form part of the indigenous microflora of the marine environment. Foodborne infections with *Vibrio* spp. are common in Asia. In Hong Kong, *V. parahaemolyticus* continued to be the top causative agent among all the reported food poisoning outbreaks in recent years. According to the figures provided by the Department of Health (DH), 552 confirmed *V. parahaemolyticus* food poisoning outbreaks affecting 2725 persons were reported during 1999 to 2003. Among these 552 outbreaks, 313 (56.7%) were due to consumption of seafood. Inadequate cooking (59.7%) and contamination by raw food (23.6%) were the main contribution factors for these cases. Cholera appears as sporadic diseases in Hong Kong. Information from the DH showed that there were totally 49 local cholera cases reported during 1999 to 2003. The suspected food item was identified in about half of the cases, of which, seafood accounted for about 80%. According to a Study on the Ecology of *V. cholerae* in Marine Water and Live Seafood, water samples taken from typhoon shelters and shoreline waters were found to have higher chance of detecting *V. cholerae* from open waters and fish culture zones. Water samples which were tested positive for *V. cholerae* also have higher *E. coli* counts. The results also implied that if *V. cholerae* is the concern for the abstraction of seawater for keeping live seafood, both the site where the water is abstracted and the *E. coli* count are important parameters to be considered. Good manufacturing practices should always be observed by the trade to minimise the risk of cholera and vibrio food poisoning associated with the consumption of seafood products. Hygienic quality of fish tank water in particular the source water for keeping live seafood is also important.

OBJECTIVE

The aims of this paper are to evaluate the local situation of *Vibrio* species (spp.) in seafood products and to make recommendations to reduce risk associated with the consumption of seafood.

INTRODUCTION

2. Seafood is a nutritious food that constitutes one of the desirable components of a healthy diet. Nevertheless, there are health risks associated with the consumption of seafood. One of the major risks involves the consumption of raw or undercooked seafood that may be naturally contaminated by foodborne pathogens present in the marine environment. Such risk is further increased if the food is mishandled during processing where pathogens could multiply exponentially under favourable conditions.

3. In contrast to most other foodborne pathogens, *Vibrio* spp. have the aquatic habitat as their natural niche. As a result, vibrios are

most commonly associated with seafood as natural contaminants. Foodborne infections with *Vibrio* spp. are common in Asia¹, including Hong Kong.

Vibrio Species

4. *Vibrio* spp. are Gram-negative, facultatively anaerobic motile curved rods with a single polar flagellum. Among the members of the genus, 12 species have so far been reported to be pathogenic to humans, where eight of these may be associated with foodborne infections of the gastrointestinal tract.² Most of these foodborne infections are caused by *V. parahaemolyticus* and *V. cholerae*, and to a lesser extent by *V. vulnificus*.³ The following paragraphs highlighted the characteristics of these three vibrios.

V. cholerae

5. Among the vibrios, *V. cholerae* is of most concern because of its ability to cause cholera. *V. cholerae* can be divided into serogroups on the basis of the O antigen. Of the more than 200 *V. cholerae* serogroups that exist, only O1 and O139 are associated with the epidemiological features and clinical syndrome of cholera. However, organisms of *V. cholerae* serogroups other than O1 and O139 (non-O1 non-O139 serogroups) have been associated with sporadic cases of foodborne outbreaks of gastroenteritis, but have not spread in epidemic form.⁴ The most important virulence factor associated with *V. cholerae* O1 and O139

serogroups is the cholera toxin. Non-O1 non-O139 serogroups are generally nontoxigenic.

6. Cholera remains a public health threat globally causing hundreds of thousand cases every year. However, this threat is much reduced in places with safe water supply and good standards of hygiene and sanitation. Cholera is an acute intestinal infection. Its incubation period ranges from a few hours to five days, usually two to three days. Although asymptomatic infection is more common, clinical illness may be exhibited. Symptoms include a sudden onset of profuse painless watery diarrhoea that can quickly lead to rapid dehydration, acidosis, circulatory collapse, hypoglycaemia in children, renal failure and death if treatment is not promptly given. Nausea and vomiting also occurs early in the course of illness. Cholera is transmitted through ingestion of food or water contaminated with the bacterium, especially via faeces or vomitus of infected persons, directly or indirectly. Human volunteer feeding studies utilising healthy individuals have demonstrated that the infective dose is approximately one million organisms. However, conditions which decrease acidity in the stomach such as antacid consumption markedly lowers the infective dose.⁵

7. Gastroenteritis caused by *V. cholerae* non-O1 non-O139 serogroups is milder than cholera. The incubation period ranges from 12 to 24 hours in outbreaks⁴ and is characterised by diarrhoea and abdominal cramps. About 70% of infected individuals will have fever. Nausea and vomiting are reported in 21% and bloody diarrhoea in 25% of

cases.⁶ Cases of non-O1 non-O139 gastroenteritis are usually linked to consumption of raw or undercooked seafood, particularly shellfish. It is suspected that large numbers (more than one million) of the organism must be ingested to cause illness.⁷

8. *V. cholerae* is a mesophilic organism that grows in the temperature range of 10 to 43°C, with optimum growth at 37°C. The pH optimum for growth is 7.6 although it can grow in the pH range of 5.0 to 9.6. *V. cholerae* can grow in the salt range of 0.1 to 4.0% NaCl, while optimum is 0.5% NaCl.⁶

V. parahaemolyticus

9. *V. parahaemolyticus* was first identified as a foodborne pathogen in Japan in the 1950s. By the late 1960s and early 1970s, *V. parahaemolyticus* was recognised as a cause of diarrhoeal disease worldwide, although most common in Asia and the United States.³ In Hong Kong, *V. parahaemolyticus* continued to be the top causative agent among all the reported food poisoning outbreaks in recent years.^{8,9,10,11,12}

10. The illness caused by *V. parahaemolyticus* food poisoning is a gastroenteritis characterised by watery diarrhoea and abdominal cramps in most cases, with nausea, vomiting, fever and headache. The incubation period is usually between 12 and 24 hours⁴ and the disease usually resolves in three days.¹³ The infection is typically acquired through consumption of contaminated seafood. These could be raw or

inadequately cooked, or that have been cross-contaminated by improper handling. Poor temperature control of storage favours bacterial proliferation. The total dose of greater than one million may cause disease. This dose may be markedly lowered by coincident consumption of antacids or presumably by food with buffering capacity.¹⁴ One volunteer feeding study done in Japan estimated that 2×10^5 to 3×10^7 cells have to be ingested for disease.¹⁵

11. *V. parahaemolyticus* is a slightly halophilic bacterium. The optimum growth NaCl concentrations range from 2 to 4% and poor growth is exhibited in media below 0.5% NaCl. The bacterium is inactivated rapidly in distilled water and growth at levels of 10% NaCl is inhibited.¹⁶ The organism grows at a temperature range between 5 and 43°C, with optimum growth at 37°C. The optimum pH range for growth is 7.8 to 8.6, although it can grow in the pH range of 4.8 to 11.¹³

V. vulnificus

12. *V. vulnificus* is an opportunistic pathogen that can cause wound infections and primary septicemia. This bacterium has less often been described as a cause of gastroenteritis, and its role as a primary cause of gastrointestinal disease remains to be determined.¹⁷

13. Wound infections occur in connection with puncture wounds after handling of raw seafood or trauma and exposure to saline environments that harbour the organism.¹⁸

14. The primary septicaemic form is the major form of infection with *V. vulnificus* which involves a rapidly progressing septicemia with few gastrointestinal signs. The incubation period is from seven hours to several days. The most frequent symptoms are fever, chills, nausea and cardiovascular hypotension. This form of disease is predominantly associated with the consumption of raw bivalve shellfish containing the organism by individuals with underlying chronic disease, particularly liver disease.¹⁸ In these individuals, the microorganism enters the blood stream, resulting in septic shock, rapidly followed by death in many cases (about 50%). Over 70% of infected individuals have distinctive bulbous skin lesions. For predisposed persons, septicemia can presumably occur with doses of less than 100 total organisms.¹⁹

15. *V. vulnificus* is very similar to *V. parahaemolyticus* in cultural characteristics and sensitivity to processing procedures. It differs principally in salt requirement and tolerance, growing in media containing between 0.1 and 5% NaCl. Same as *V. parahaemolyticus*, the organism grows optimally at 37°C although it can grow at a temperature range between 8 and 43°C. The pH range for growth of *V. vulnificus* is 5 to 10, with an optimum at 7.8.²⁰

Vibrio spp. and seafood

16. Vibrios are abundant in the aquatic environment. Most of them require 2 to 3% NaCl or a seawater base for optimal growth.¹⁵ Vibrios are associated with live seafood as they form part of the indigenous

microflora of the environment at the time of seafood capture or harvest. Healthy live fish is protected by its immune system and therefore bacteria cannot grow in its flesh. When the fish dies, the immune system no longer functions and the bacteria present are able to proliferate freely.²¹ In addition, bacteria may be found on the skin, chitinous shell, gills as well as the intestinal tracts of fish or shellfish.²² If subsequent handling is improper and that there is no or inadequate pathogen reduction step (e.g. cooking) afterwards, the level of bacteria in the final product may increase to such an extent that may present a health risk to consumers.

17. Molluscan bivalves are filter feeders and they tend to accumulate microorganisms in the surrounding waters which may also contain vibrios. They are usually grown and harvested in shallow, near-shore estuarine waters and are therefore likely to harbour high concentrations of pathogenic organisms including pathogenic vibrios. As they often are eaten raw or after a very mild heat treatment, they constitute a significant health risk to the consumers.²¹

18. Among the potentially pathogenic vibrios occurring naturally on fish and shellfish, *V. parahaemolyticus* is the most widespread. Endogenous marine species of *V. cholerae* can also be isolated from fish during cholera outbreaks. It has been suggested that vibrios are the most common bacterial causative agents in food poisoning resulting from the consumption of shellfish.²²

19. Water temperature can greatly affect the vibrio levels in seafood. Vibrios can multiply rapidly between 20 and 40°C. Growth at the optimum temperature (37°C) can be very rapid and generation times of 9 to 10 minutes have been reported.⁶ *V. parahaemolyticus* is primarily associated with coastal inshore waters rather than the open sea. It is rarely isolated from water with temperatures below 15°C.^{23,13}

Factors affecting growth and survival of vibrios in seafood

i. Effect of temperature

20. Growth of pathogenic vibrios occurs optimally at around 37°C although the maximum and minimum growth temperatures are 43°C and 5°C respectively.²³ All vibrios are sensitive to heat. In shellfish, heating to produce an internal temperature of at least 60°C for several minutes appears sufficient to eliminate the pathogenic vibrios.¹⁷ Chilling and refrigeration are critical control measures to prevent growth of these microorganisms.

ii. Effect of pH and other factors

21. Vibrios are acid sensitive and grow best at pH values slightly above neutrality, i.e. 7.5 to 8.5.²³ They are also sensitive to drying. While *V. parahaemolyticus* has an absolute Na⁺ ion requirement and shows optimal growth at about 2 to 4% NaCl, freshwater inactivates this organism.

LOCAL FOODBORNE DISEASE FIGURES

22. Food poisoning and cholera are notifiable infectious diseases under the Quarantine and Prevention of Diseases Ordinance, Cap.141, Laws of Hong Kong. The following paragraphs summarised the figures concerning local food poisoning outbreaks due to *V. parahaemolyticus* and local cholera cases.

V. parahaemolyticus food poisoning

23. *V. parahaemolyticus* ranked first as the most common causative agent of food poisoning outbreaks in Hong Kong in recent years. According to the figures provided by the Department of Health (DH), 552 confirmed *V. parahaemolyticus* food poisoning outbreaks affecting 2725 persons were reported during 1999 to 2003. **Table 1** showed the breakdown of these cases by food group.

Table 1: *V. parahaemolyticus* Food Poisoning by Food Group (1999 to 2003)

Food Group	Number of confirmed case (%)*	Number of persons affected (%)*
<i>Seafood</i>	313 (56.7%)	1465 (53.8%)
Mixed Dishes	68 (12.3%)	449 (16.5%)
Meat, Meat Products and Offals	54 (9.8%)	314 (11.5%)
Cereals and Cereal Products	39 (7.1%)	89 (3.3%)
Poultry and Poultry Products	29 (5.3%)	187 (6.9%)

Fruits, Vegetables and their Products	25 (4.5%)	98 (3.6%)
Others	15 (2.7%)	75 (2.8%)
Unknown	9 (1.6%)	48 (1.8%)
Total	552 (100%)	2725 (100%)

* Percentages may not add up to 100% due to rounding of figures.

24. Among all the food groups, seafood is the most frequently incriminated food which caused *V. parahaemolyticus* food poisoning outbreak. It accounted for 56.7% of the total number of confirmed cases. **Table 2** summarised the various seafood items which caused *V. parahaemolyticus* food poisoning.

Table 2: *V. parahaemolyticus* Food Poisoning Outbreaks Due to Consumption of Seafood (1999 to 2003)

Food group	Food type	Number of confirmed case (%)*	Number of persons affected (%)*
Crustaceans	Crab	46 (14.7%)	180 (12.3%)
	Shrimp / Prawns	43 (13.7%)	299 (20.4%)
	Lobster	1 (0.3%)	2 (0.1%)
	Subtotal	90 (28.7%)	481 (32.8%)
Gastropods	Squid / Octopus	55 (17.6%)	167 (11.4%)
	Jellyfish	27 (8.6%)	204 (13.9%)
	Subtotal	82 (26.2%)	371 (25.3%)
Bivalve Shellfish	Mussels	15 (4.8%)	49 (3.3%)
	Oyster	12 (3.8%)	41 (2.8%)
	Clams	12 (3.8%)	45 (3.1%)
	Scallops	6 (1.9%)	24 (1.6%)
	Other Bivalve Shellfish	4 (1.3%)	29 (2.0%)
	Subtotal	49 (15.7%)	188 (12.8%)
Others /	Sashimi	30 (9.6%)	113 (7.7%)

Unspecified	Marine Product Other	18 (5.8%)	138 (9.4%)
	Marine Product Unspecified	1 (0.3%)	4 (0.3%)
	Subtotal	49 (15.7%)	255 (17.4%)
Fish	Marine Fish	41 (13.1%)	166 (11.3%)
	Freshwater Fish	2 (0.6%)	4 (0.3%)
	Subtotal	43 (13.7%)	170 (11.6%)
Total		313 (100%)	1465 (100%)

* Percentages may not add up to 100% due to rounding of figures

25. Of the 313 confirmed *V. parahaemolyticus* food poisoning outbreaks due to consumption of seafood during 1999 to 2003 (**Table 1**), inadequate cooking was the main contribution factor which accounts for 59.7% of the cases, and this was followed by contamination by raw food which accounts for 23.6% of the cases. These two factors contributed to more than 80% of all the cases. Other factors included other reasons for cross contamination, improper storage, inadequate reheating and food prepared too far in advance. (**Table 3**)

Table 3: Primary Contributing Factors* of *V. parahaemolyticus* Food Poisoning Outbreaks Due to Consumption of Seafood (1999 to 2003)

Contributing factor	No. of confirmed case (% of total) †
Inadequate cooking	187 (59.7%)
Contamination by raw food	74 (23.6%)
Contaminated raw food	14 (4.5%)
Improper storage of cooked food	8 (2.6%)
Contamination by utensil	7 (2.2%)
Improper holding temperature	6 (1.9%)
Contaminated processed food	5 (1.6%)
Inadequate reheating	5 (1.6%)
Others / Unknown	4 (1.3%)

Food prepared too far in advance	3 (1.0%)
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* More than one factor may be involved in an outbreak.

† Percentages may not add up to 100% due to rounding of figures.

Cholera cases

26. Information from the DH showed that there were totally 49 local cholera cases reported during 1999 to 2003. The suspected food item was identified in about half of the cases, of which, seafood accounted for about 80% (**Table 4**)

Table 4: Local Cholera Cases by Food Group (1999 to 2003)

Food Group	Number of cases (%)
Unknown / unspecified	25 (51.0%)
<i>Seafood</i>	19 (38.8%)
Others	5 (10.2%)
Total	49 (100%)

STUDY ON THE ECOLOGY OF *V. CHOLERAE* IN MARINE WATER AND LIVE SEAFOOD

27. Following the isolation of *V. cholerae* in fish tank water of two retail outlets selling live seafood in 2003, there were calls to further strengthen the control the microbiological quality of fish tank water and abstraction of seawater for keeping live seafood. The limited number of local study on ecology of *V. cholerae* suggested that the non-O1 non-O139 serogroup were isolated in both local seawater and seafood samples.^{24,25} However, these studies were limited by small sample

numbers and limited coverage of sampling locations.

28. In light of the above, a one-year study was conducted in 2004 by an interdepartmental task force (TF) which comprised representatives from the Food and Environmental Hygiene Department (FEHD), Agriculture, Fisheries and Conservation Department (AFCD), Environmental Protection Department (EPD) and Department of Health (DH) in 2004 to fill in the existing data gaps. The objectives of this study are to determine: (i) the occurrence and distribution of *V. cholerae* in local waters and its association with environmental factors including the *E. coli* count; (ii) the occurrence of *V. cholerae* in live fish kept in fish culture zones and its association with other parameters.

29. A total of 90 water samples were taken from 15 selected sampling sites of four categories (**Annex I**). The *V. cholerae* count, *E. coli* count, salinity and water temperature were determined. Twenty-four live fish samples that were mature live fish ready for market were collected at the four selected fish culture zones.

30. Results showed that no *V. cholerae* O1 or O139 serogroups were detected in any of the samples. During the 12-month study period, 14 (16%) out of all the 90 water samples were tested positive for *V. cholerae* non-O1 non-O139 serogroups. Among these 14 samples, eight (57%) were from typhoon shelters, five (36%) were from shorelines close to the wholesale fish markets and one (7%) was from a fish culture zone. There was significant difference among the four sampling site categories

in terms of isolation of *V. cholerae* in water samples (χ^2 test, $p < 0.001$). The isolation rate of *V. cholerae* in water samples from typhoon shelters and shoreline (13 out of 42 water samples, or 31%) is significantly higher than that from fish culture zone (1 out of 24, or 4%) (χ^2 test, $p = 0.01$) and that in open waters (0 out of 24, or 0%) (χ^2 test, $p = 0.002$).

31. Water samples which were tested positive for *V. cholerae* were found to contain significantly higher *E. coli* count (Mann-Whitney U Test, $p < 0.001$). When analyses were conducted within the samples collected at typhoon shelters and shoreline waters, those water samples which were tested positive for *V. cholerae* were found to contain significantly higher *E. coli* (Mann-Whitney U Test, $p = 0.049$).

32. No correlation between *V. cholerae* counts and water temperature ($p = 0.96$) and salinity of seawater ($p = 0.89$) was found in the study.

33. Twenty-four water samples were taken from the sampling sites within the open waters category and none of them were found positive with *V. cholerae*.

34. As for the 24 live fish samples taken from fish culture zones, none of the fish samples were tested positive for *V. cholerae* even though one water sample taken from a fish culture zone was found positive with the non-O1 non-O139 *V. cholerae*.

DISCUSSION

35. While vibrios are natural habitants of seawater, it is not surprising that the majority (56.7%) of *V. parahaemolyticus* food poisoning outbreaks are caused by the consumption of seafood (**Table 1**). Among all the seafood items, crustaceans, including crab, shrimp/prawns and lobster, represented the highest percentage (28.7%) of incriminated seafood involved in *V. parahaemolyticus* outbreaks (**Table 2**). Nearly 60% of all the *V. parahaemolyticus* food poisoning cases by seafood occurred in 1999 to 2003 were due to the consumption of inadequately cooked food (**Table 3**). The second and third major contributing factors for *V. parahaemolyticus* food poisoning was due to the consumption of food contaminated by raw food and the consumption of contaminated raw food respectively. Thorough cooking and avoidance of cross contamination hold the key to successful prevention of *V. parahaemolyticus* food poisoning.

36. Because of the availability of safe water supply to the population and a reasonably high standard of sanitation locally, cholera no longer appears in an epidemic form in Hong Kong. However, since *V. cholerae* are widely distributed in temperate and tropical aquatic environment, in particular estuarine waters and that cholera is endemic in this part of the world, cholera still appears in Hong Kong as sporadic diseases. For the local cholera cases in which a suspected food item was identified, most of them were related to the consumption of seafood (**Table 4**).

37. In the Study on the Ecology of *V. cholerae* in Marine Water and Live Seafood, water samples taken from typhoon shelters and shoreline waters were found to have higher chance of detecting *V. cholerae* than that from open waters and fish culture zones. Typhoon shelters and shoreline waters (especially the shorelines in urban areas) are sites which are considered more polluted. Water samples which were tested positive for *V. cholerae* also have higher *E. coli* counts. The results implied that if *V. cholerae* is the concern when considering abstracting seawater for keeping live seafood, both the site where the water is abstracted and the *E. coli* count are important parameters to be considered. Abstraction of seawater from typhoon shelters and shoreline in urbanised areas for this purpose is therefore not recommended.

CONCLUSION AND RECOMMENDATIONS

38. To minimise the potential risk of cholera and vibrio food poisoning due to the consumption of seafood products, good manufacturing and handling practices should always be observed. Attention should also be paid to the hygienic quality of fish tank water for keeping live seafood. Source of the seawater is of particular importance. The followings are some recommendations:

Advice to Trade

(A) Handling of raw materials:

1. Purchase raw materials from reputable and reliable suppliers.

2. Buy only those shellfish which are fresh, with intact shell and free from abnormal odour.
3. Do not abstract seawater from shoreline in urbanised areas and typhoon shelters for keeping live seafood. Use of synthetic seawater is more desirable than the use of natural seawater.
4. Keep live fish and shellfish separately in different fish tanks equipped with proper filtration and disinfection systems. These systems should be regularly maintained. References can be made to FEHD's Guidelines on the Filtration and Disinfection Facilities for Fish Tank Water.²⁶
5. Scrub and rinse shellfish in clean water. Remove internal organs of shellfish.

(B) Manufacturing and storage

1. Adopt a first-in-first-out principle to store raw materials and keep them at appropriate temperatures.
2. Avoid holding chilled ingredients and finished products at above 4°C for more than 2 hours.
3. Reserve a specific portion of a refrigerator or a designated refrigerator for storage of seafood to be eaten raw, such as sashimi and oysters. Seafood shall be properly wrapped or covered before storage.
4. Remove the shells of shellfish, as far as possible, before cooking as it impedes heat penetration.
5. Cook food thoroughly before consumption. High-risk food such as oysters shall be cooked in boiling water for not less than five

minutes.

6. Avoid preparing ready-to-eat dishes and raw foods at the same time.
7. Avoid preparing dishes in large quantities at one time and too far in advance.
8. Display seafood at 4°C or below or 60°C or above in buffet settings.

(C) Equipment, utensil and personal hygiene

1. Establish a clean-up and disinfection programme to clean and sterilise equipment and utensils including fish tanks, refrigerators, chopping boards, choppers, containers and mixers.
2. Observe good personal hygiene. Food handlers should wash their hands with soap and potable water thoroughly before preparing food and after every interruption in food preparation, particularly after having used the toilet.
3. Prevent cross-contamination between fish tank water, raw seafood and other food.

Advice to Public

(A) Purchase

1. Buy food from reputable and reliable suppliers.
2. Do not patronise illegal hawkers as their source of supply may not be safe.
3. Buy only those shellfish which are fresh, with intact shell and free

from abnormal odour.

(B) Preparation

1. Wash seafood thoroughly before cooking.
2. Scrub and rinse shellfish in clean water. Remove internal organs of shellfish.
3. Remove the shells of shellfish, as far as possible, before cooking as it impedes heat penetration.
4. Cook food thoroughly before consumption. High-risk food such as oysters shall be cooked in boiling water for not less than five minutes.
5. Discard leftovers or otherwise store them properly in the refrigerator at 4°C or below. Reheat leftovers thoroughly before consumption.
6. Observe good personal hygiene and prevent cross-contamination.

(C) Consumption

1. Consume seafood as soon as possible.
2. If seafood is not consumed immediately, they should be:
 - packed and stored at 4°C or below.
 - separated from raw food.
 - consumed within 1 to 2 days.
3. Avoid consuming the internal organs of shellfish.
4. The elderly, children, pregnant women and persons with lowered immunity should be careful when choosing food especially high risk food, such as sashimi and oysters to be eaten raw.

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Selected Sites for Water Sampling

Category	Sampling Site (Code)
Fish Culture Zones	Tap Mun, Sai Kung (FCZ7) * Kau Sai, Sai Kung (FCZ16) * Cheung Sha Wan, Lantau Island (FCZ26) * Tung Lung Chau, Sai Kung (FCZ29) *
Open Waters	Deep Bay (DM3) † Mirs Bay (MM15) † Port Shelter (PM7) † Southern, between Cheung Chau & Lamma Island (SM6) †
Shoreline Waters	Aberdeen Wholesale Fish Market (ABR) ‡ Cheung Sha Wan Wholesale Fish Market (CSW) ‡ Kwun Tong Wholesale Fish Market (KT) ‡ Tso Wo Hang, Sai Kung (TWH) §
Typhoon Shelters	Tuen Mun (NT1) † Sam Ka Tsuen, Lei Yue Mun (VT3) † Aberdeen, West (WT3) †

* Designated fish culture zones governed by AFCD. Sampled by AFCD during even months.

† Designated water quality monitoring stations under the Marine Water Quality Monitoring Programme of EPD. Sampled by EPD during odd months (Typhoon Shelters) and even months (Open Waters).

‡ Designated wholesale fish markets governed by the Fish Marketing Organization, a statutory body established under the Marine Fish (Marketing) Ordinance, Cap 291 which was administered by AFCD. Sampled by AFCD during odd months.

§ A popular seawater abstraction point where seawater was less likely to be polluted as suggested by EPD. Sampled by FEHD during odd months.