Case study of marine pollution in Teluk Bahang, Penang, Malaysia

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Abstract. Teluk Bahang is a small fishing village located in the north-western of Penang Island, Malaysia. It has several attractions which include forest reserved park, ecotourism sites, theme parks and famous for its aquaculture activities. On 18th April 2019, fish farmers in Teluk Bahang experienced mass mortality of cultured fishes, namely groupers, barramundi, golden and red snappers due to a sudden change in water quality. Hence, this study was conducted to discuss marine pollution that occurred in Teluk Bahang that had caused the death of tonnes cultured fishes. Water samples were collected at the fish cage to investigate the water quality (physical and chemical parameters), heavy metals content, cell density and phytoplankton composition for determination of algal bloom that might be the cause of this crisis. Water samples were collected three times on 19th April 2019, 8th May 2019 and 26th May 2019. The results for physical and chemical parameters (pH, salinity, surface temperature, nitrate and phosphate) were all within the permissible limit according to Malaysia Marine Water Quality Class 2 (for aquaculture and recreation). Almost no harmful dinoflagellate species were detected in the water samples which indicated that phytoplankton did not cause a direct effect on the fish mortality. The concentration of heavy metals namely Cu, Cd, Ni, Fe, As and Hg in water samples were measured by atomic absorption spectroscopy (AAS). Results showed no detection of As and Hg concentration. The concentration of Cd, Cu and Fe in water ranged from 0.058-0.065ppm, 0.057-0.077ppm and Fe 0.326-0.389ppm respectively. These levels exceeded 20-100 times from the permissible limit. Ni concentration detected at 0.472-0.513ppm which was 990 times exceeded the permissible levels. These results indicated that metal pollution occurred in the marine water of Teluk Bahang and the possibility that the area may no longer be suitable for aquaculture or recreational purposes.

Keywords: marine pollution; Teluk Bahang; massive death of cultured fishes; heavy metals.

1. Introduction

Environmental Teluk Bahang is a fishing village at the tail-end of the coastal road on the northern side of Penang Island. It has evolved into a tourist destination which include forest reserved park, ecotourism sites and theme park. Notably, it is also home to the Teluk Bahang Dam, the largest reservoir on Penang Island and famous for its aquaculture activities. Pantai Acheh and National Reserved Park, Teluk Bahang has currently more than 500 fish cages operating by six different owners or fish farmers. The highest number of cultured fish is groupers (5 tonnes), followed by red snappers
(4.5 tonnes), golden snappers (3 tonnes) and barramundi (3 tonnes). On 18th April 2019, fish farmers in Teluk Bahang experienced mass mortality of cultured fishes with an estimated loss of USD 175,000 due to unknown sources of marine pollution (personal communication with fish breeders).

Marine pollution occurs when unsustainable element gain entry to water masses, potentially causing spread of diseases, turn water quality to potentially toxic and also brings in invasive species [1]. Most sources of marine pollution are 1) land-based, such as from industrial/ domestic pollutant discharged, 2) wind blow debris 3) potential spill overs from freight ocean carries and 4) excessive nutrients inlet from the river. When toxins are concentrated within the ocean food chain, many elements combine in a manner of highly depletive oxygen, causing estuaries to become anoxic and create many ecological problems [1].

The objectives of this study were to identify the factors of marine pollution that might have cause the death of massive cultured fishes and to suggest possible measures to prevent massive fish kills to the fish farmers.

2. Materials and Methods

2.1. Seawater sample collection and location

Quantitative seawater samples were collected on 19th April 2019, 8th May 2019 and 26th May 2019 at the cultured fish cage, Teluk Bahang (5.4652 °N, 100.2058 °E) (Figure 1) using a Van Dorn water sampler. However, for phytoplankton composition, seawater samples were only taken on 19th April and 26th May 2019 only. Each time seawater samples were collected, the in-situ physical parameter reading such as dissolved oxygen (DO), pH, salinity and temperature were also taken using YSI Professional Plus. All water samples were wrapped with aluminum foil and placed inside an ice chest containing ice cubes to prevent any contamination. The samples were then taken back to toxicology laboratory at Centre for Marine and Coastal Studies (CEMACS), USM for further analysis.

Figure 1. Location of Teluk Bahang, Penang.
2.2. Nutrients analysis
To determine nutrient conditions of the seawater samples, nutrient analysis of nitrite, ortho-phosphate and ammonia were carried out using standard titration method modified from Strickland and Parson [2] and Hing et al. [3]. A spectrophotometer (UV-1800, Shimadzu, Japan) was used to measure the absorbance of the solution using a 1 cm quartz cuvette and distilled water as blank for all nutrient analyses.

2.3. Heavy metals analysis
To ensure the removal of organic impurities from samples and prevent interference in analysis, the samples were digested with concentrated methyl methyl-butyl-ketone (MLBK). A total 10mL MLBK was added to 50mL of seawater in a 250mL conical flask. The mixture was evaporated to half of its volume on a plate after which it was allowed to cool and then filtered. The digested seawater samples were analysed for the presence of copper, cadmium, nickel, iron, arsenic and mercury using the Atomic Absorption Spectrophotometer (AAS). The calibration plot method was used for the analysis.

2.4. Determination of phytoplankton composition
Aliquot of 1L seawater samples were concentrated by 15-µm mesh sieve and preserved with Lugol’s solution for phytoplankton density and composition analyses. Cell counts were performed using a Sedgewick-rafter chamber under a trinocular inverted light microscope (Motic AE2000). Species identification was carried out following Round et al. [4] and Tomas [5].

3. Results and discussion
3.1. Nutrient and heavy metals analysis results
The results for physical and chemical parameters (pH, salinity, surface temperature, nitrate and phosphate) (Table 1) were all within the permissible limit according to Malaysia Marine Water Quality Class 2 (for aquaculture and recreation) [6]. However, ammonia concentration detected ranged from 0.05-0.137 mg/L and 1.9 times higher from the permissible levels. Ammonia can be produced naturally from the breakdown of organic matter and is excreted by fish as nitrogenous product. In fish, ammonia is the by-product of protein metabolism and is primarily excreted across the gill membrane, with a small amount excreted in the urine [7]. Nitrate can be used by plant and algae and is generally considered harmless to fish in natural seawater. Ammonia’s aquatic toxicity is principally due to the unionised form (NH₃) [8]. As pH increases, the toxicity of ammonia increases because the relative proportion of unionised ammonia increases. The toxic level of ammonia to fish is both pH and temperature dependent [7]. Toxicity increases as pH increases and as temperature increases. Ammonia levels in excess of the recommended limits may harm aquatic life. Although the ammonia molecule is a nutrient required in life, excess ammonia may accumulate in the organism and cause alteration of metabolism or increase in body pH [9].

Results for heavy metals showed no detection of As and Hg concentration. The concentration of Cd, Cu and Fe in water ranged from 0.058-0.065ppm, 0.057-0.077ppm and Fe 0.326-0.389ppm, respectively. These levels exceeded 20-100 times from the permissible limit. Ni concentration detected was 0.472-0.513ppm and 990 times higher which exceed from the permissible levels. Heavy metals in marine water have natural and anthropogenic origin. Heavy metals are one of the main groups of those pollutants which could enter via wastewater or atmospheric deposition. They are ubiquitous, highly persistent and non-biodegradable with long biological half-lives, and they can accumulate in water at environmentally hazardous levels. The toxicity of metals is highly influenced by geochemical factors that influence metals bioavailability [10]. In this case, the sources of metals pollution found in the ocean are still unknown. A further observation from the surrounding of the area affected and analysis of sources of metal pollution is indeed needed to find the origin of the problems.
Table 1. Results of seawater for physical, chemical and heavy metals analysis.

| Parameter          | Class 2 (Aquaculture) | 19.4.2019   | 8.5.2019   | 26.5.2019   |
|--------------------|-----------------------|-------------|-------------|-------------|
| Sampling time      | 0900 - 1030           | 0900 - 1030 | 0900 - 1030 |             |
| DO (mg/L)          | 5-10                  | 8.24 ± 0.06 | 5.88 ± 0.00 | 6.66 ± 0.02 |
| Salinity (ppt)     | 30.28 ± 0.001         | 29.92 ± 0.00 | 29.92 ± 0.01 |             |
| Temperature (°C)   | 31.2 ± 0.00           | 30.3 ± 0.00 | 30.4 ± 0.00 |             |
| pH                 | 7.98 ± 0.02           | 7.73 ± 0.01 | 8.01 ± 0.01 |             |
| Nitrite (mg/L)     | 0.055                 | 0.027 ± 0.004 | 0.031 ± 0.00 | 0.029 ± 0.01 |
| Ammonia (mg/L)     | 0.07                  | 0.083 ± 0.001 | 0.05 ± 0.00 | 0.137 ± 0.01 |
| Phosphate (mg/L)   | 0.075                 | 0.040 ± 0.010 | 0.071 ± 0.02 | 0.072 ± 0.03 |
| Cd (mg/L)          | 0.002                 | None detected | 0.065 | 0.052 |
| Pb (mg/L)          | 0.0085                | None detected | 0.804 | 1.028 |
| Cu (mg/L)          | 0.0029                | None detected | 0.077 | 0.0013 |
| Ni (mg/L)          | 0.0005                | None detected | 0.472 | 0.323 |
| Hg (µg/L)          | 0.16                  | None detected | 0.06 | None detected |
| As (µg/L)          | 3                     | None detected | 2.979 | None detected |

Table 2. Results for phytoplankton composition

| Date       | Species name | Species composition (%) | Cell density (cells/L) |
|------------|--------------|-------------------------|-----------------------|
| 19.4.2019  | Belleroca sp. 1 | 1.00                    | 7,771                 |
|            | Ceratium sp. 1 | 0.21                    | 432                   |
|            | Coscinodiscus sp. 1 | 27.44                 | 56,991                |
|            | Dinophysis caudata | 0.21                    | 432                   |
|            | Protoperiinium sp. 1 | 0.42                    | 863                   |
|            | Skeletonema sp. 1* | 3.11                    | 10,838                |
|            | Skeletonema sp. 2* | 3.36                    | 11,429                |
|            | Thalassionema sp. 1 | 13.10                   | 27,200                |
|            | Others         | 37.42                   | 77,715                |
|            | Total          | 100.00                  | 207,671               |
| 26.5.2019  | Actinocylus sp. | 41.03                   | 28,126                |
|            | Ceratium sp. 1 | 0.14                    | 93                    |
|            | Gyrodinium sp. 1* | 0.07                    | 47                    |
|            | Karenia sp. 1* | 0.07                    | 47                    |
|            | Prorocentrum sp. 1* | 0.07                  | 47                    |
|            | Protoperiinium sp. 1* | 0.14                  | 93                    |
|            | Protoperiinium sp. 2* | 0.07                  | 47                    |
|            | Protoperiinium sp. 3* | 0.07                  | 47                    |
|            | Others         | 58.36                   | 40,000                |
|            | Total          | 100.00                  | 68,545                |

3.2. Phytoplankton composition results

The blue green algae or dinoflagellate found in seawater were Skeletonema sp. 1, Skelotonema sp. 2, Gyrodinium sp. 1, Prorocentrum sp. 1, Protoperiinium sp. 1, Protoperiinium sp. 2 and Karenia sp. Based from microscopic observation, the majority of the phytoplankton found in the samples were not harmful species and did not have an association to fish mortality. Phytoplankton has the role and importance in ecological function as a primary producer that directly and indirectly fuels the food chain [11]. They have important impacts on water quality by affecting turbidity and concentration of dissolved oxygen and play other major roles in many ecosystem processes [11]. Different
phytoplankton attributes that are essential to assess the ecological status, specifically phytoplankton composition, abundance and biomass as well as frequency and intensity of phytoplankton blooms are required to be evaluated [11-12].

4. Conclusions
The study examined the possible marine pollution factors that had caused the death of cultured fish in Teluk Bahang. The areas of cultured fish cages were affected by heavy metals pollution. However, it is uncertain that heavy metals were the main cause of the death of tonnes of cultured fishes as heavy metals usually not give an immediate effect to organism affected. Since the depth of seawater around the cages are very shallow (about 4 m), the water current and circulation are quite poor and stagnant. This could contribute to hypoxic condition and result in death of fishes. Further investigation needs to be done to come out with the proper solution for this case. What can be suggested now is the location is no longer suitable for aquaculture and recreational activities. Besides, as the source of heavy metal pollution is still unknown, the authority must ensure safe disposal of agricultural, domestic sewage and industrial effluent and recycles the possible to avoid these metals and other contaminants from going into the sea.

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