Preliminary water quality study in cockle farming area in Malaysia: a case study in Jeram, Selangor

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Abstract. Regular monitoring of the water quality in the cockle farming area is essential to sustain the production of adult cockles. The aim of this study is to collect the baseline data for water quality parameters consists of physical, organic, and inorganic parameters in the cockle farming area in Malaysia coastal water. Water quality sampling was conducted every two months, from July 2013 to June 2014. The sampling involved three sampling stations with different farming intensities, located in one lot of a 50 ha cockle farming area in Jeram, Kuala Selangor. For organic parameters, TOC ranged from 0.10 mg L^{-1} to 2.37 mg L^{-1}, COD ranged from 18.0 mg L^{-1} to 87.0 mg L^{-1}, and oil and grease ranged from 0.0016 mg L^{-1} to 1.6878 mg L^{-1}. For inorganic parameters, NO_{3-} ranged from 0.10 mg L^{-1} to 3.70 mg L^{-1}, PO_4^{3-} ranged from 0.01 mg L^{-1} to 0.63 mg L^{-1}, and SO_4^{2-} ranged from 19 mg L^{-1} to 180 mg L^{-1}. Results showed that the level of nitrate and oil and grease have exceeded the Malaysian Marine Water Quality Criteria and Standard permissible limit. Two-factor ANOVA test showed that all parameters were significantly different ($p < 0.05$) among sampling stations and sampling dates. Monitoring of water quality parameters should regularly be conducted in a wider cockle farming area towards a better cockle farm management.

Key Words: water quality, physical parameters, organic parameters, inorganic parameters, cockles.

Introduction. Cockle is the main shellfish species produced in Malaysia and dominates 93% of the total shellfish species production (DOFM 2013). Malaysia is one of the major producers of adult cockles in Asia region with the biggest market to Thailand and Singapore (FAO 2012). The species that is rear in Malaysia is *Anadara granosa* (Pathansali & Soong 1958; Tookwinas 1985). Cockle farming, which was once practiced only by traditional farmers, is becoming one of the highly marketed components of the shellfish industry. Nowadays, cockle farming area in Peninsular Malaysia covers 10,000 acres along the west coast of Peninsular Malaysia, which involves approximately 1,000 farmers (DOFM 2013). The states of Selangor, Perak, and Pulau Pinang play a significant role in producing adult cockle and in conserving the natural habitat of cockle spat. As a result of the gazettement of the cockle farming areas along its west coast, Selangor has been a major producer of adult cockle since 2007.

Cockle farming areas are normally situated in open areas such as estuaries and coastal zones, which are major recipients of pollutants that come from a variety of point and non-point sources (Buck et al 2004; Jarernpornnipat et al 2003; Shamsuddin 1992). Cockles, being filter feeders, are in the bottom of the food chain and able to improve water quality by absorbing particulates, such as organic materials, nutrients, clay, bacteria, and viruses, and prevent the occurrence of eutrophication processes (Wan et al 2011). Cockles survive in a polluted environment by accumulating pollutants into their tissue (Abbas Alkarkhi et al 2008; Agusa et al 2005; Hassan & Kanakaraju 2013; Koh et al 2011). Thus, cockles are also used as a bio-indicator for detecting the level of toxicity in aquatic communities (Ong & Din 2001; Tu et al 2011). Many studies have been conducted on the toxicity of heavy metals in the tissue of cockles to ensure that cockles are safe for human consumption (Agusa et al 2005; Fisal et al 2007; Yap et al 2003).

However, water quality monitoring in cockle farming area is important to ensure several critical factors such as the appropriate range of temperature and dissolved oxygen, identifying risks of any sharp decline in salinity, and effects of red tide and other contaminants (Seikai 2000; Yurimoto et al 2014). Water quality monitoring concerning organic and inorganic parameters are also crucial to evaluate the effect of anthropogenic factors and to examine the effect of aquaculture farming intensity towards the environment (Dahlbäck & Gunnarsson 1981; Seppälä et al 2004). Nutrients such as nitrate, phosphate, and sulfate levels in seawater depicted the suitable physicochemical conditions for the production of natural food for shellfish (Treece 2000). The dry season could affect the mineralisation process in an ecosystem, causing soil organic matter to release extra nitrogen, phosphate, and carbon (Delpla et al 2009). In another study, Varanka & Luoto (2012) chose total phosphorus and nitrogen among other physical water quality parameters in defining the relationship of water quality and environmental condition.

Adult cockle production in Selangor has declined in the past five years (DOFM 2013). Various natural factors caused the mortality event of adult cockles in Selangor. Flooding event drastically decrease the salinity level in cockle culture area (Yurimoto et al 2014). Cockles have a higher sensitivity during the spawning season and sudden changes in the ecosystem caused the massive mortality event of adult cockles (Yurimoto et al 2014). This situation suggests that a water quality study in the cockle farming area should be carried out thoroughly. Regular monitoring of the water quality in cockle farming areas is essential not only to ensure that cockles are safe for human consumption but also to sustain the production of adult cockle.

This article reports on findings regarding the measurement of physical (temperature, pH, salinity, dissolved oxygen, total dissolved solid, total suspended solid), organic (total organic carbon, chemical oxygen demand, oil and grease), and inorganic parameters (nitrate, phosphate, sulfate) in a cockle farming area in Jeram, Kuala Selangor. The aim of this paper is to collect a baseline data on the water quality in the cockle farming area in Malaysia. The concentration levels of related parameters are compared with those under the Malaysian Marine Water Quality Criteria and Standard (MWQCS).

Material and Method

Study area. This case study involved one lot in a 50 ha cockle farming area in Jeram, Kuala Selangor, Malaysia. The study site was selected based on two criteria that were i) among the higher yearly production in cockle production compared to other cockle farming lots, and ii) anecdotal factors on water quality issues that might affect the current cockle production. The sampling stations are shown in Figure 1. Three sampling stations were chosen by the following criteria: i) Station 1 (Stn 1): sampling station outside a cockle farming area, situated in between of the Buloh River estuary and cockle farming area (N 03.25172, E 101.29520); ii) Station 2 (Stn 2): sampling station in a cockle farming area that is an active production area for adult cockle (N 03.24687, E 101.28811); iii) Station 3 (Stn 3): sampling station in a cockle farming area near the sea, one that is an inactive production area for adult cockle (N 03.24907, E 101.28445).

Sampling procedures. Field work was conducted every two months between July 2013 and June 2014, which cover the life cycle of cockles from seeding to harvesting phase. Soil and water samples were collected using a sediment grab sampler and water sampler, respectively. In situ parameters namely temperature, conductivity, dissolved oxygen (DO), total dissolved solids (TDS), salinity, and pH were collected using YSI Professional Plus handheld multiparameter meter. Water samples were stored in acid-washed plastic bottles. However, water samples for the oil and grease (O & G) test were stored in HACH glass bottles. Each samples was then stored at 4°C in the laboratory. All parameters were tested immediately within three days from the sampling date.

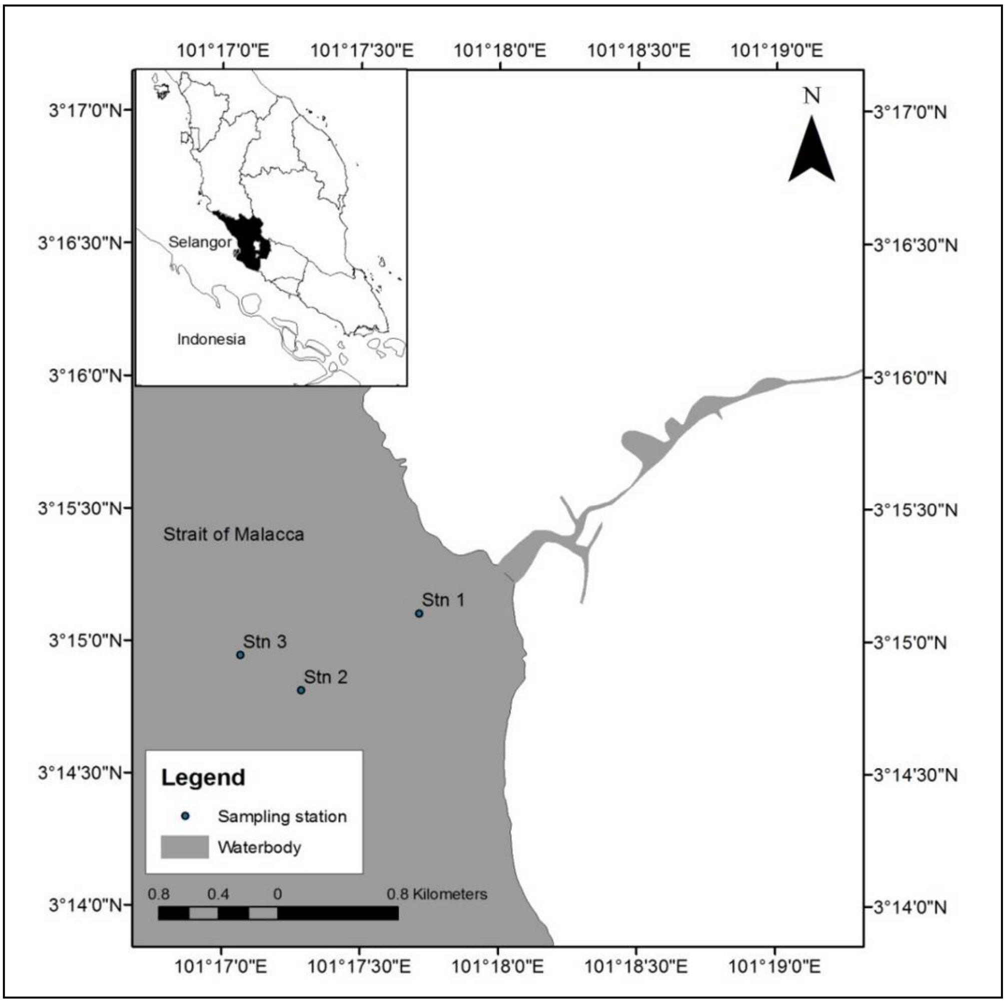

Figure 1. Location of water quality sampling stations in Jeram, Kuala Selangor, Malaysia.

Laboratory analysis. The 2540 (D) method (APHA 1995) was used to determine the total suspended solid (TSS) in the water samples. A total of 200 mL of water samples were filtered by using filter paper with 0.45 µm size. The filter paper was first dried and weighed. The rest of the filtrate on the filter paper was dried to constant weight at a temperature of 103^{o}C to 105^{o}C. The increase in weight of the filter paper represents the TSS.

The total organic carbon (TOC) in the sediment samples was determined according to the method of Walkley and Black (Lim 2001). A total of 0.2 g of sediment was dried and sieved to a size of 63 µm. About 10 mL of 1 N $K_2Cr_2O_7$ and 20 mL of concentrated H_2SO_4 were added to the sample. The sample was then shaken in a 500 mL conical flask. After 30 min, 200 mL of distilled water and 10 mL of phosphoric acid were added to the mixture, followed by a 10-drop diphenylamine indicator solution. The mixture was then titrated with a solution of 0.5 N ferrous ammonium sulfate. The titration process led to a change in the mixture color, from orange to dark green, to turquoise, and then to red wine.

The 5220C HACH method (APHA 1995) was used to measure chemical oxygen demand (COD) levels. Water samples were diluted to a ratio of 1:10 mL. About 2 mL of the diluted water sample was placed into the HACH digestion tube. The sample and blank were refluxed using a COD meter at 150°C, at the high range, and for 120 min. The sample and blank were allowed to cool for 40 min before COD reading was taken. The COD reading was analyzed by using a DR/2010 spectrophotometer at 620 nm wavelength.

The 5520B partition-gravimetric method (APHA 1995) was used to determine the concentrations of O & G in the water samples. A total of 500 mL of sample, 30 mL of petroleum spirit, and 5 mL of HCl was placed in a 1000 mL separatory funnel and shaken vigorously for 2 min. The mixture in the separatory funnel appeared to have two layers. The top layer was a concoction of petroleum and grease, whereas the bottom layer was of the water sample. The bottom layer was filtered out slowly into a separate beaker. The oil components remaining in the separatory funnel were then filtered into the beaker weight. The filtration process was conducted with 10 g of sodium sulfate by using a filter paper size of 125 mm. The procedure was repeated for the same water sample but without HCl to dissolve the O & G that adhered to the wall of the bottle. The samples were then dried in an oven at 100^{o}C, cooled, and weighed.

NitraVer® 5 Cadmium Reduction Method was used to determine the concentrations of nitrate in the water samples (Lim 2001). A total of 10 g of Nitra Ver 5 powder was added to the 10 mL samples for examining the nitrate level. Samples and blank were measured by using a DR/2010 spectrophotometer at 400 nm wavelength. PhosVer® 3 Ascorbic Acid Method was used to determine the concentrations of phosphate in the water samples (Lim 2001). Ten (10) g of Phos Ver 3 powder was added to the 10 mL samples and then measured by DR/2010 spectrophotometer at 890 nm wavelength. Meanwhile, SulfaVer® 4 Turbidimetric Method was used for testing sulfate in the water samples (Lim 2001). Samples were diluted to a ratio of 1:50 mL and 10 g of Sulfa Ver 4 powder was added to the samples. The level of sulfate was determined by DR/2010 spectrophotometer at 450 nm wavelength.

Results and Discussion. Table 1 presents the descriptive analysis of the physical parameters from the three sampling stations. The level of DO compared to Class II Malaysian Marine Water Quality Criteria and Standards (MWQCS), where DO must be at 5 mg L^{-1} to be suitable for marine life, fisheries, coral reefs, marine recreational activities, and mariculture. The DO level in Station 1 ranged between 2 mg L^{-1} to 5 mg L^{-1}. Based on the MWQCS, the 3 mg L^{-1} of DO was under Class III which is the class suitable for port areas. The result was by the actual situation where Station 1 located near to the river mouth and becoming the main route for auxiliary boats and fishing vessels. DO level in Station 2 and Station 3 was ranged from 5 to 6 mg L^{-1} and suitable for mariculture activity. The results of two way ANOVA test showed that all physical parameters were significantly different ($p < 0.05$) based on the sampling stations and sampling dates.

Table 1

Mean ± standard deviation (range) for physical parameters from three sampling stations at Lot 63, Cockle Farm, Kuala Selangor from July 2013 to June 2014

Parameters	*Station 1*	*Station 2*	*Station 3*
Temperature (°C)	30.98±1.12	30.41±0.67	30.59±0.52
	(29.62-32.48)	(29.54-31.38)	(29.88-31.4)
pH	7.165±0.361	7.518±0.277	7.552±0.184
	(6.566-7.604)	(7.102-7.816)	(7.238-7.752)
Salinity (‰)	24.44±5.34	29.62±1.784	29.89±1.182
	(13.86-28.07)	(26.13-31.18)	(27.63-30.88)
DO (mg L^{-1})	4.028±1.309	5.671±0.950	5.895±1.441
	(2.276-5.452)	(4.956-7.392)	(4.048-8.464)
TDS (mg L^{-1})	25033±5648	29840±1626.5	29069±2742
	(15004-28434)	(26670-31265)	(28042-31018)
TSS (mg L^{-1})	0.2376±0.0973	0.2524±0.1275	0.2249±0.1626
	(0.1393-0.376)	(0.1083-0.4288)	(0.1228-0.552)

Figures 2-7 presents the results of organic and inorganic parameters from the three sampling stations. The TOC levels of the sediment samples in all sampling stations were between 0.100 (mg L^{-1}) and 2.37 (mg L^{-1}) with the mean values 0.95±0.73. TOC reached the highest level at Station 1 and the lowest level recorded at Station 3. A two factor ANOVA test showed that the TOC levels among the sampling stations and dates of sampling were significantly different ($p < 0.05$). At all stations, the COD levels ranged from 18.00 (mg L^{-1}) to 87.00 (mg L^{-1}) with the mean values 47.01±18.58. The highest level of COD was observed at Station 3 and the lowest level was at Station 1. A two factor ANOVA test showed that the COD levels among the sampling stations and dates of sampling were significantly different ($p < 0.05$). O & G concentration levels ranged from 0.0016 (mg L^{-1}) to 1.6878 (mg L^{-1}) with the mean values 0.101±0.396. The highest and lowest level of O & G was recorded at Station 2 and Station 3, respectively. The O & G levels among the sampling stations and dates on sampling were significantly different (p < 0.05) based on the result of two-way ANOVA test.

Meanwhile, at all sampling stations, the concentrations of NO_{3-} ranged from 0.10 (mg L^{-1}) to 16.28 (mg L^{-1}) with the mean values 1.21±1.15. Station 1 showed a higher NO_{3-} level in July 2013 compared to the other sampling stations during the same month. PO_4^{3-} ranged from 0.10 (mg L^{-1}) to 0.63 (mg L^{-1}) with the mean values 0.19±0.17. The highest level of PO_4^{3-} was observed at Station 1 on July 2013 and the lowest level was also at Station 1 in June 2014. SO_4^{2-} concentrations ranged from 19.00 (mg L^{-1}) to 180 (mg L^{-1}) with the mean values 71.00±49.67. A two-way ANOVA showed that NO_{3-}, PO_4^{3-}, and SO_4^{2-} were significantly different ($p < 0.05$) among the sampling stations and dates of sampling.

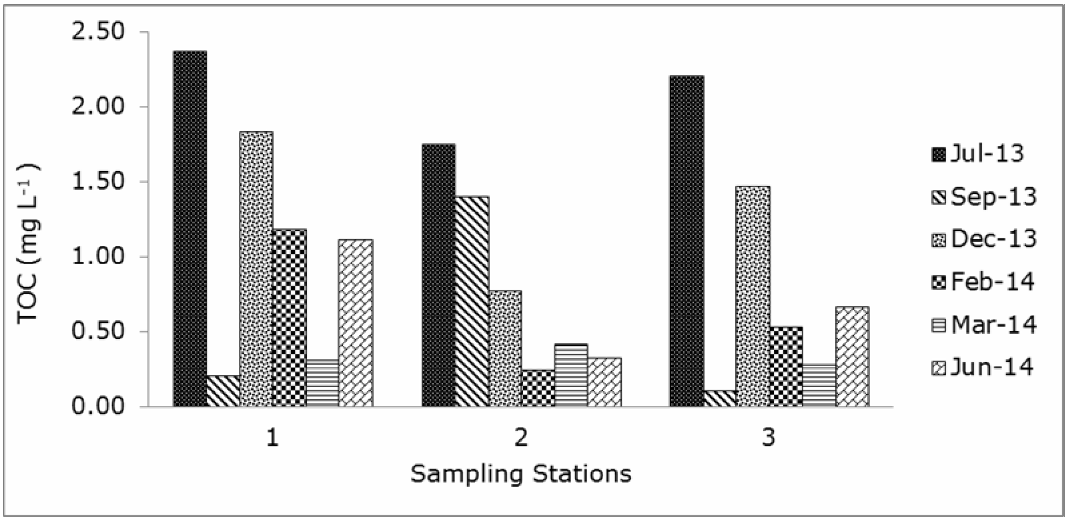

Figure 2. Variation of TOC for the different sampling stations.

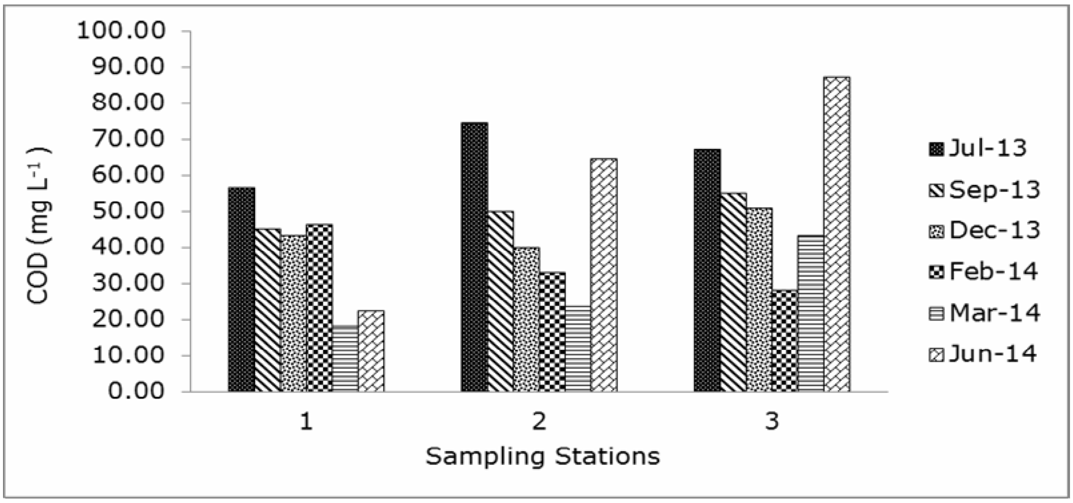

Figure 3. Variation of COD for the different sampling stations.

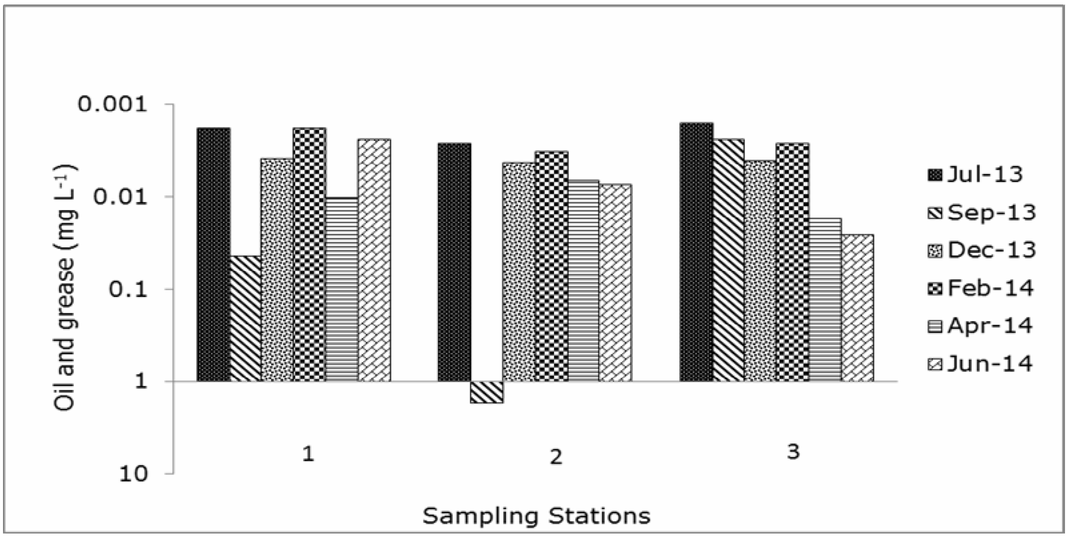

Figure 4. Variation of oil and grease for the different sampling stations.

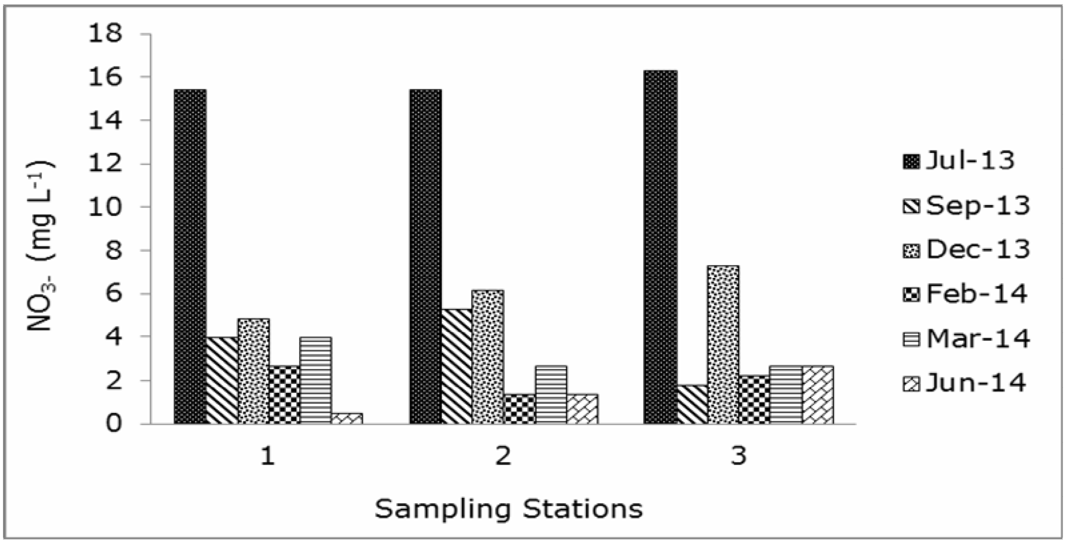

Figure 5. Variation of nitrate for the different sampling stations.

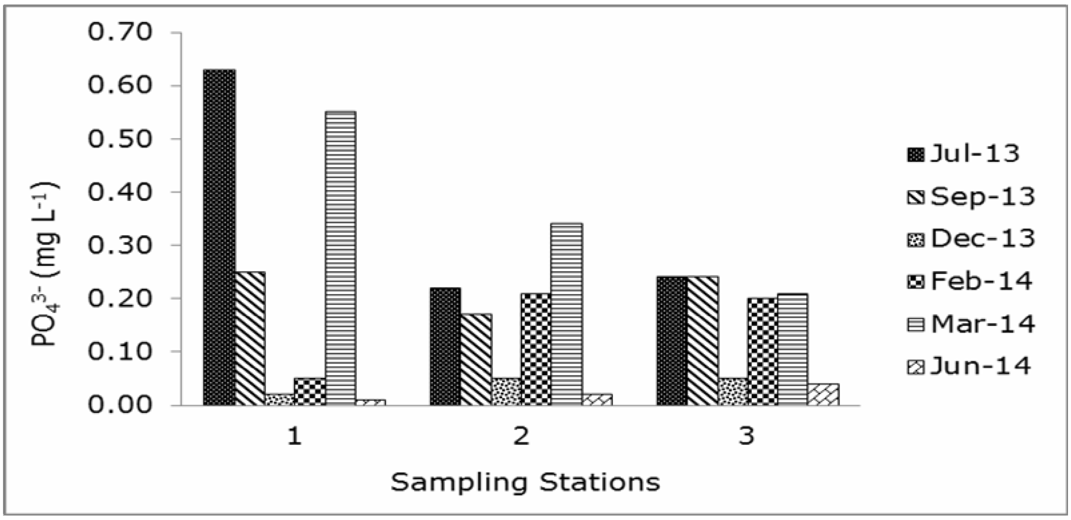

Figure 6. Variation of phosphate for the different sampling stations.

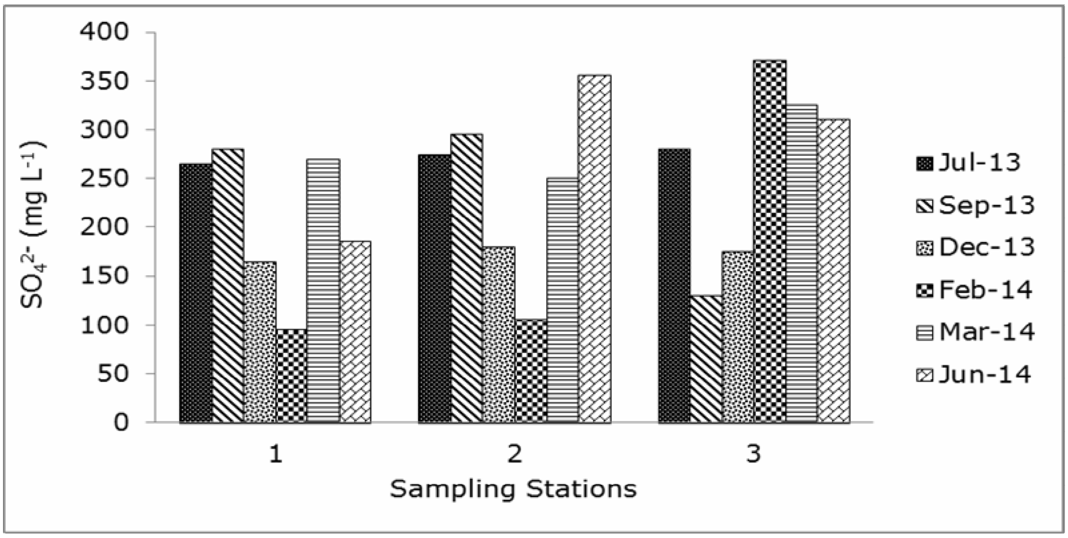

Figure 7. Variation of sulfate for the different sampling stations.

Cockle farming area in this study is located near to Buloh River estuary. Buloh River estuary has been classified as moderate in the year 2014 under the Marine Water Quality Index (DOE 2014). Meanwhile, Buloh River has been categorized as a polluted river in the year of 2014 based on the Water Quality Index (DOE 2014). The current water quality status for the respective areas indicates a risk of the unhealthy ecosystem for cockle farming activity. The standard reference for the suitable values of TOC and COD for shellfish farming is lacking. However, a study by Asami et al (2005) concluded that COD value in the intensive shellfish culture area was higher than the area outside the aquaculture farm. This condition is similar to this study, where the mean values of COD for Station 2 (47.56±19.27) and Station 3 (55.17±20.55) which located within the cockle farm were higher than the Station 1 (38.58±15.05).

The highest level in O & G was recorded at 1.688 mg L^{-1} at Station 2, exceeding the MWQCS permissible limit at 0.14 mg L^{-1}. This value is believed to be associated with the frequent use of auxiliary boats for cockle farming, recreational fishing, and fishing vessels. The potential to cockle farming area been affected by any of oil spill incident is higher as cockle farming area is situated on the west coast of peninsular Malaysia, facing the Straits of Malacca, which is recognised as a major shipping lane that is witness to an oil pollution incident (Thia-Eng et al 2000). Zakaria et al (2000) studied the originality of the oil pollution in the Straits of Malacca and discovered that the majority of the crude oils found in the Straits of Malacca had the Middle East oil signature that was used in formulating Malaysian lubricating oils. Tavakoly Sany et al (2014) discovered the presence of carcinogenic polyaromatic hydrocarbons in the edible tissues of cockles collected in the Klang Straits, Malaysia. The crude oil tainted the shellfish species within an extremely short period (Jackson et al 1989).

According to the inorganic parameters of the MWQCS, the recorded NO_{3-} levels exceeded the permissible limit of Class II MWQCS which refers to the classification for marine life, fisheries, and mariculture activities. In fisheries and aquaculture activities, a high concentration of nitrate can be the effect of NOx emissions released from the combustion of diesel used by fishing vessels (Thrane 2006). Nitrate intrusion could also originate from anthropogenic sources, such as fertilizers for agriculture, and other inland activities (Agusa et al 2005; Phong 2010). Phosphate and sulfate are two important parameters for reflecting the nutrient cycle in an aquaculture ecosystem (Treece 2000). In this study, the highest reading for PO_4^{3-} was recorded at Station 1, which was situated outside the cockle farming area. However, the mean values for PO_4^{3-} at all sampling stations still belongs to Class II of the MWQCS.

The mean values for sulfate at Station 1, Station 2, and Station 3 were 64.00±51.45, 72.66±55.14, and 76.33±51.03 respectively. This trend shows that the sulfate reading was getting higher from the vicinity of the mainland to the cockle farm area in the sea. Treece (2000) suggested that normal seawater contains 2,684 ppm to

2,712 ppm of SO_4^{2-}, whereas the average sulfate levels for brackish water are 995 ppm, and freshwater with an average of 16 ppm. Sulfur has always been connected with acid sulfate soil conditions; wherein sulfur could lead to the formation of a hard substratum, a surface that is not suitable for any aquaculture activity (Shamsuddin 1992). A study conducted by Asami et al (2005) found that the sulfate level was significantly higher in the non-farming area. Thus, the admission of organic materials at the sampling station located outside the farming area is heavily influenced by other anthropogenic factors and not by the aquaculture itself.

The other water quality parameters such as carbon, nitrate, phosphate, and sulfate are heavily influenced by natural factors such as weather and seasonal change (Zhu et al 2005). For example, the dry season can increase the intrusion of nutrients, such as nitrate, from the groundwater and reduce the dilutive effects of nutrient content on water bodies (Van Vliet & Zwolsman 2008). Meanwhile, the rainy season potentially brings massive runoff from inland areas into the water bodies (Delpla et al 2009). The minimum distance between the cockle farming area and the river mouth is also a critical factor that must be considered to determine the effect of disturbance coming from the mainland. Ling et al (2012) concluded that an effluent coming from the shrimp farm could affect the marine sediment within 1.5 km from the discharge site. Thus, the monitoring of organic and inorganic parameters within the cockle farming area should be covering a longer period than that covered in the present study to observe the trend of organic and inorganic parameters in the cockle farming area.

Conclusions. Water quality monitoring is crucial in cockle farming. Apart from ensuring that cockles are a safe source of protein for humans, water quality monitoring during cockle farming activity is also essential to reduce the mortality rate of cockles and to sustain cockle production. We found that the risks of oil pollution caused by anthropogenic factors could still be present. The distance between cockle farming area and river mouth is crucial in determining the effect of any non-point or point sources of pollutants towards the farming area and the cultured species. Further research must be undertaken to determine the organic and inorganic parameters in the cockle farming area. Such research should have a comprehensive term, cover a longer period than the present study, and consider the influence of both anthropogenic and natural factors. This step could lead towards a better cockle farm management by providing a thorough data in predicting any effects caused by the natural and anthropogenic factors in the cockle farm area.

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