Seasonal Monitoring of Ocean Parameter Over Green Mussel Cultivation area in West Part of Cirebon Seawater

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Abstract

West part of Cirebon in the past suffered an extraordinary event due to poisonous food found in green mussel. It is necessary to monitor current water quality over this region since this area still used for green mussel cultivation area. In-situ measurement and laboratory analysis were done to monitor the condition of seawater around Gunungjati as part of green mussel cultivation area in Cirebon regency. Several points had been measured through CTD Valeport Midas+ in prior to measure physical (temperature, salinity, pH, chlorophyll-a, turbidity) and chemical seawater (dissolved oxygen, Nitrate, Orthophosphate, Hg, Pb, Cd concentration) characteristics, meanwhile water sample had been brought to laboratory to be checked its heavy metal concentration. Additionally, past study and data related to green poison event in Cirebon was taken account into observation and analysis. Seasonal result show slightly different value though vertical distribution data where temperature (30.1°–32.3°C), salinity (26.9–32.0 psu), and pH (7.5–8.7) are high in December but lower in July, meanwhile, chlorophyll-a (0.2–20.9 mg.L^{-1}), dissolved oxygen (0.2–7.8 mg.L^{-1}), and turbidity (1.3–20.1 NTU) are increasing in October. Nitrate and orthophosphate concentration find in water sample is 0.097–0.537 mg.L^{-1} and <0.01–0.32 mg.L^{-1}, respectively. Parameters of Cd (<0.001 mg.L^{-1}), Hg (<0.00014 mg.L^{-1}), and Pb (<0.001 mg.L^{-1}) are still below the threshold. The condition of seawater of west part of Cirebon or at cultivation area is still in moderate condition based on the national standard. Although, turbidity and dissolved oxygen is still above the standard quality.

Keywords: *ocean parameter, seasonal, heavy-metal*

Introduction

One of fishery products cultivated by the coastal community in some district of Cirebon is green mussels which made this product as a leading marine aquaculture commodity in this district (Radiarta and Saputra, 2011). These mussels are found in abundance in tidal and subtidal areas, live in clusters and stick firmly on hard objects such as wood, bamboo, stone or hard substrates (Cappenberg, 2008). A study proved that green mussels have (9.6-31.6%) higher protein and (7-18%) lower fat than other meat sources compared to beef, chicken, lamb, and fish (Cappenberg, 2008). Apart from being a food source, green mussels are also classified as organisms that are resistant to pollution and commonly used as biomonitoring agents to determine the pollution in the coastal environment (Putri *et al.*, 2012; Prabhakaran *et al.*, 2017; Li *et al.*, 2019).

A poisonous food in the Suranenggala village had been reported on December 13, 2016. The investigation was carried out and it was found that 115 residents spread across 15 villages, 7 sub districts experienced symptoms of dizziness; tingling that started from lips then spread throughout the body, resulting in stiffness around lips, neck, and whole body; nausea and lethargic. It was reported that the poison sourced from green mussel as local fisheries product of Cirebon Regency (Nurlina and Liambo, 2018). Based on the study and victim interviewed by Nurlina and Liambo (2018), this extraordinary event which occurred within 9-13 December was caused by an increasing of biotoxin produced by dinoflagellates (*Pyrodinium bahamense*) due to a blooming in cultivation area. Although it was rare event, a shellfish poisoning also occurred and potentially found in other places in Asia, such as Malaysia (Ong *et al.*, 2015; Suleiman

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et al., 2017), Philippines (Ching *et al.*, 2015), Vietnam (Tong *et al.*, 2018), and Singapore (Tan *et al.*, 2016).

Nitrate and phosphate in seawater are used for algae growth as primary nutrients. Nitrate is dominant form of nitrogen in seawater and the increase of nitrogen content will increase microalgae's growth (Kadim and Arsad, 2016). Tarunamulia *et al.* (2016) observe the relationship between environmental quality and the presence of phytoplankton that potentially cause harmful algae bloom (HAB) at extensive brackish aquaculture. The abundance of phytoplankton in certain ponds is influenced by spatial variation and nutrient ratio of Nitrogen and Phosphorus in soil or bottom sediment. Water quality will be affected by coastal extensive aquaculture through impact ranging from increases in nutrient loads, high turbidity due to sediment to discharges of chemical substances. They observed Losari which is the east part of Cirebon regency. Although the poison accident was found mostly in Kapetakan, Suranenggala and Gunungjati (west part of Cirebon regency), many ponds located in those areas have the possibility of influencing the coastal water.

Several studies had been carried out regarding the condition of Cirebon seawater generally and the condition of marine biota locally, even before the event occurred. Sukarno (2014) identified lead (Pb) and cadmium (Cd) concentration in certain cultivation. It was found that Pb concentrations were above threshold (above 1.5 $mg.kg^{-1}$) meanwhile Cd was still below threshold (1 $mg.kg^{-1}$). The presence of Pb and Cd in green mussel is caused by its ability to accumulate heavy metal in its body. Metals that have undergone biotransformation and cannot be excreted by its body will generally be stored in certain organs, such as hepatopancreas, kidneys, and gonads (Apriadi, 2005). In short, green mussels in this area are not good for consumption.

Since the disease appears in rainy season, Nurhayati and Putri (2018) calculated the bioaccumulation of mercury (Hg) in green mussel from Bondet cultivation area which were close to the poison indicated location. Hg concentration on sediment and water were above the standard. Further, Nurhayati and Putri (2019) measured heavy metal concentration in different seasons. The season affects Cd, but not much in Pb and Hg in the green mussel. Pb concentration on marine sediment which strongly correlates with heavy metal in green mussel is also influenced by season. Pb was found exceeded the standard threshold. Contradictory, referring to quality standard of Directorate Drugs Control and Food (BPOM) No. 03725/SK/VII/89, green mussel is still safe for consumption within the restricted amount of consumption.

This study aims to monitor current water quality over west part of Cirebon seawater since this area is still used for green mussel cultivation area, though the poisonous event emerged in 2016. A changing of ocean parameters such as ocean physical (temperature, turbidity) and chemical properties (pH, salinity, dissolved oxygen, heavy metal) are worth to be observed to see its relevance with the condition in those areas and its surrounding. In supporting the investigation, related data from recent studies also considered to see the continuation and connection of the parameter altering in those areas.

Materials and Methods

Water quality survey was conducted around Gunungjati, west part of Cirebon Regency (Figure 1.). Survey was done in December 2021, March 2022, July 2022, and October 2022 as the representative of each season. Ocean measurement instrument named CTD Valeport Midas+ was used to determine the parameters of temperature, salinity, pH, dissolved oxygen (DO), redox, fluorometer, and turbidity. CTD measured at each point location to represent Gunungjati seawater, however the instrument was submerged until 80% of the depth, instead reaching the seabed due to safety aspects.

The seawater samples were obtained from the sea surface (z= 0 meter) and bottom (z= 0.8 x depth) with equipment named horizontal water sampler. The samples for heavy metal analysis were then preserved in 500-600 mL sample bottle and were added 0.5-0.6 mL (10-12 drops) of nitrate acid (HNO_3) 65% to maintain the pH below 2. The bottles were preserved below 6°C inside a cooling box. The samples for nutrient analysis were filtered using syringe filter with 0.45 μm using disposable syringe to 15 ml tube. The water samples were analyzed at Water Quality Laboratory, Bandung Institute of Technology (ITB) and Chemical Laboratory of Korea-Indonesia Marine Technology Cooperation Research Center (MTCRC). The samples were analyzed for its Nitrate, Orthophosphate, Mercury (Hg), Lead (Pb), and Cadmium (Cd) concentration for heavy metal. The analysis method used were APHA-3112-B for Mercury (Hg), APHA-3111-B for Cadmium (Cd), APHA-3111-B for Lead (Pb), APHA-4500-NO_3-E for Nitrate (NO_3), and APHA-4500-P-D for Orthophosphate since the method become a standard of examination of water and wastewater (APHA, 2012). The method for examination of heavy metal at MTCRC used US-EPA method 6020B regarding Inductively Coupled Plasma-Mass Spectrometry (US EPA, 2014).

Total of 3 stations were measured by CTD on each season, meanwhile water samples for heavy metal were only taken in March and October 2022 only. Station 1 is located close to Bondet river, cultivation area located within station 1 and 2, meanwhile station 2 and 3 are located close to Pelindo harbor entrance area. Secondary data also collected through previous studies taken in similar area. Then, parameter is compared with water quality standard set by Government Regulation of the Republic of Indonesia (GRRI).

Result and Discussion

All parameters obtained from CTD are shown through vertical distribution on all locations as shown in Figure 2 to 5. Each parameter on each station is displayed within the 7.5 km transect line starting from Station 1 to Station 3. The depth on three locations is quite similar, around 7 m depth. Based on handheld echosounder, depth on station 1, 2, and 3 is 7.1 m, 6.6 m, and 7.7 m, respectively. Therefore, the measurement result shown in figures are from surface to 5-6 m depth as mentioned previously.

Salinity in Gunungjati seawater vary on each season with salinity range of 27.5–32 psu. The lower salinity (below 29 psu) always found in the surface of Station 1 which is easily influenced by river discharge from Bondet river. Station 2 also has lower salinity since the freshwater from river can get carried away due to sea current. The bottom layer at each station, the water column has higher salinity and stable around 30.5–32 psu. Through vertical distribution, it can be seen the stratification or gradual changes of salinity from surface to bottom layer, except on July. Result on July shows a mixed well condition indicated by almost similar value of salinity even in the location close to Bondet river. The strong wind and wave also frequent turbulence made the ocean salinity mixed evenly. On the other hand, the temperature in observation area changed seasonally. Higher temperature in water column found in December and March, meanwhile low temperature found in July and October. The high temperature in December is due to solar radiation where in this month or season, the southern hemisphere receives more sunlight than the northern part. Obviously, the surface temperature becomes higher with a reducing temperature in the

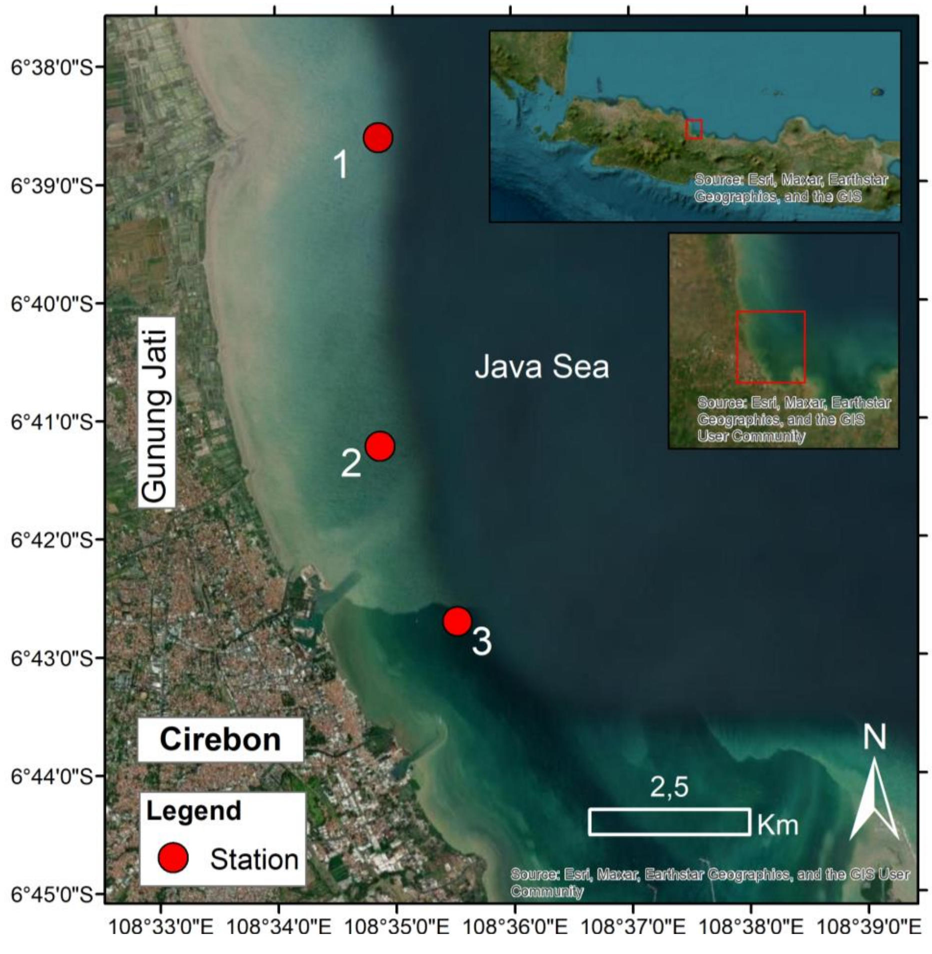


Figure 1. Water quality measurement location

increasing depth. In December (rainy season) and March (transition season), the ocean temperature relatively warmer and evaporates more, then rain commonly occurred inland. The measurement of temperature and salinity in 2022 is still in range that was measured by Zahroh *et al.* (2019) and Rachman *et al*. (2019), although salinity in 2015-2016 in Zaroh *et al.* (2019) can reach 36 psu.

The pH parameter is likely similar between each season data. It is found the water is more alkaline on wet season (December) than dry season. On December, pH on seawater, particularly on surface can reach 8.6 meanwhile the more acidic pH found in July with value can reach 7.6. The lower pH value found in Station 2 and 3 which indicates the influence of harbor activity and ship entrance/exit track. The condition in the surface has higher pH compare to bottom area. Overall, the water pH found in range 7.8–8.6 is in normal condition as in quality standard for sea biota set by Indonesia government (GRRI, 2021). Other study, Hidayah *et al.* (2021) measured the stability of pH even in different month (March, July, November) which stays on 7.3-7.4. The result was a bit lower than Zahroh *et al.* (2019), meanwhile in April (Rachman *et al.*, 2019) the pH reached 8.5. Measurement results on 2022 found vary within 0.6 difference in value along the depth difference. The distinct vertical distribution can be found on turbidity parameter in each measured month. Turbidity in December and March was found relatively low compared to July and October. The average turbidity range is around 1.3–13.7 FTU, and 2–7.9 FTU, 0.3-13.8 FTU, and 2.2-20.1 FTU for December, March, July, and October, respectively. It is obvious that higher turbidity commonly found close to bottom considering Cirebon seabed in general has a lot of mud and sand. However, the high concentration indicates many ship activities in those areas and a prevalent mixing by strong wind may occur. On July, the strong wind happened which made the turbidity high and even in comparison to other months. In rainy season (December), fishermen in this area prefer to do other activities, such as farming, working in fishpond, or cultivating green mussels, rather than go fishing due to unpredictable weather. Thus, the low turbidity measured even in the bottom part of seawater.

Chlorophyll-a in March and October (transition season) tends to be higher than in December and July. The value can reach more than 10 $\mu g.L^{-1}$ ($\mu g.L^{-1} \approx mg.m^{-3}$) in certain depth, however on general the chlorophyll-a of each station is within 0.2-20.9 $\mu g.L^{-1}$. The lowest value found in December which was measured only 0.2-4.3 $\mu g.L^{-1}$. Such a difference is considerable since the concentration of chlorophyll-a is changing more fluctuate due to phytoplankton and algae activities. It is natural for chlorophyll-a to fluctuate over time since the concentrations are often higher after rainfall due to flushed nutrients into seawater or commonly higher during summer months due to increasing water temperature and light levels. Thus, higher value of chlorophyll-a sometimes found close to river or estuary area. The peak of chlorophyll-a found in October close to Bondet river (Station 1.) indicating more nutrient input from the river. This condition may influence biota alongside the area in this month since DO in October was rich compare to another measured month. The DO in October can reach 6.6-7.8 $mg.L^{-1}$, meanwhile in other month the value are below the threshold. The lowest DO found in July close to harbor area (Station 3.) which make the water unsuitable for marine life. This result in this location is peculiar due to ship activity when the measurement taken. Linear with Hidayah *et al.* (2021), the DO in this area on July is very low (3.1 $mg.L^{-1}$). DO value should be at least 5 $mg.L^{-1}$ based on national standard (GRRI, 2021), thus the surrounding water (except on March and July) met the criteria, either for sea biota or for sea tourism.

Redox value ranges in positive and negative values. Redox or oxidation-reduction potential shows how easily electrons are transferred within the solution through specific conditions. By monitoring the redox value, biological reactions which are occurring on seawater and dissolved chemical metals can be determined (VanLoon and Duffy, 2017). In the observation points, positive redox dominant in the transect area with value at least +50 mV.

It is also found to have a smaller redox value around 30–50 mV in station 2 in March. The vertical distribution of redox is not so different. In the redox range of +100 or more, nitrification process occurred. The bacteria are nitrified since the oxidation of ionized ammonia (NH_4^+) to nitrate (NO_3^-) is performed. In the lower positive value, biological phosphorus removal and the decreasing BOD also happened. The negative value indicates denitrification where the nitrate is reduced, acid fermentation, even the production of methane (Gerardi, 2007). Thus, the oxidation and nitrification process always happen in each measured month. This phenomenon might be related to algae bloom happened in the poison event in December 2016 beside the presence of industrial waste due to fishery products (Nurlina and Liambo, 2018) however further investigation is necessary.

The result of measurement from seawater sample can be seen in Table 1 and also compared with quality standard for sea biota based on GRRI (2021). Natural for temperature and salinity means the normal condition of an environment which can vary at any time (day, night and season). Both of the parameters are within seawater standard since it has small variation range. Also, the value is quite reasonable and similar with common temperature or salinity in tropical seawater. Parameter pH is within national standard threshold, but not for DO (value only meet the standard for measurement on October). Turbidity in December indicates good conditions for seawater, however in July and October, the turbidity was getting higher. Turbidity should be below 5 NTU for marine tourism and marine biota, meanwhile there is no specific value for harbor. Turbidity value can be influenced by any activities in the sea, such as ship transportation, sediment transportation, mixing due to surface wind, more sediment input from rivers, etc.

Seawater samples in March show small values of Cadmium (Cd) and lead (Pb) with concentration of less than 0.001 $mg.L^{-1}$. Both of the values are still below the national standard. Moreover, mercury (Hg) found in samples is far below the standard with value of less than 0.00005 $mg.L^{-1}$ (<0.05 ppb). The concentration of heavy metal in sample water taken in October have more detail value compare to previous result. The difference equipment utilized in October made the result have more accuracy into smaller value found. The concentration of Cd, Pb, and Hg in water sample are 5.8-24.6 x 10^{-8} $mg.L^{-1}$, 2.148-24.6 x 10^{-6} $mg.L^{-1}$, and 4-14 x 10^{-5} $mg.L^{-1}$, respectively. Generally, the result for each heavy metal concentration in March and October are considered good for sea biota as mentioned by GRRI. Although, the heavy metal is less than expected, the measurement of heavy metal in sediment and green mussel should be considered more. It is found that heavy metal in sediment and green mussel is higher than in

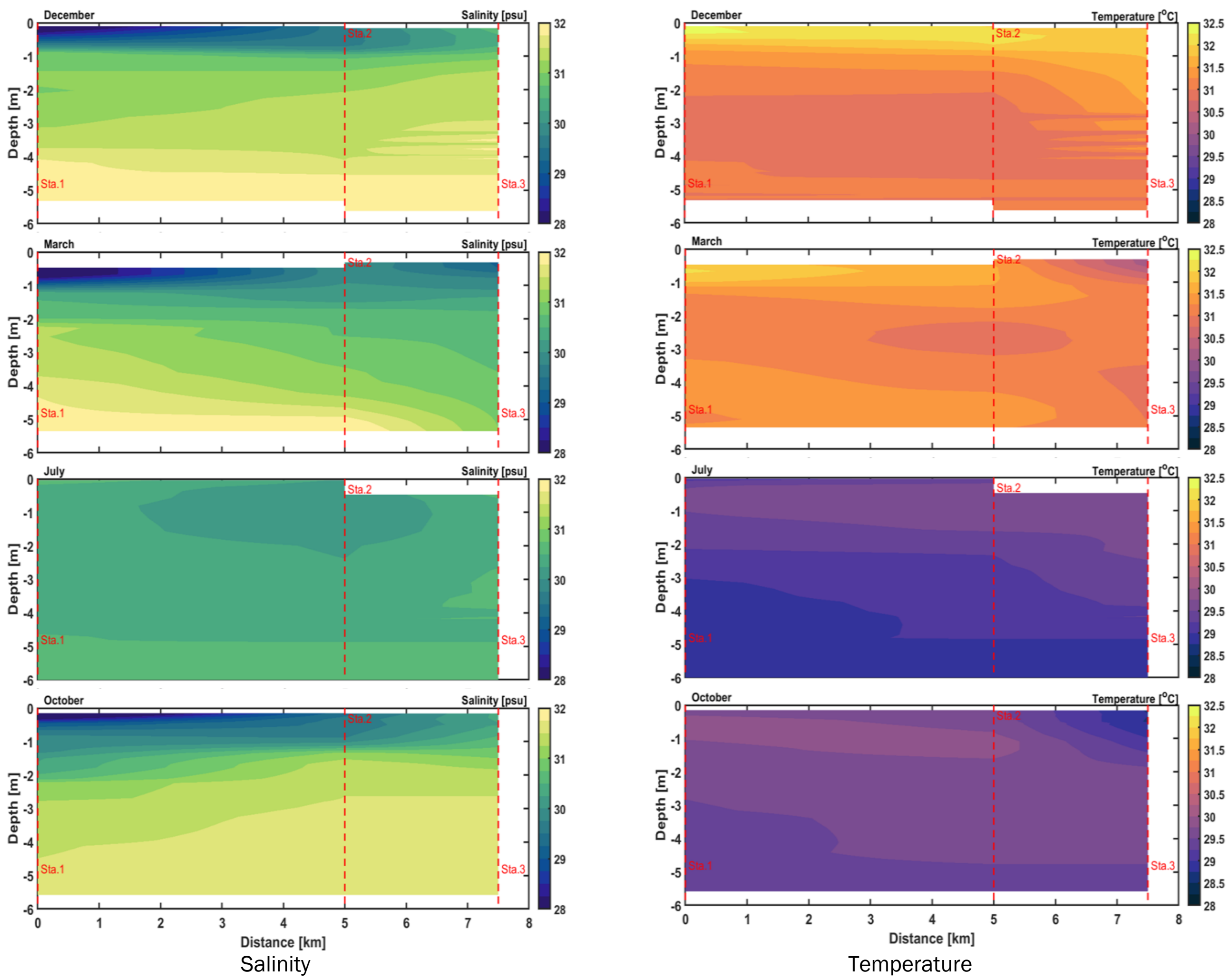


Figure 2. Vertical distribution of salinity and temperature on each season (December, March, July, October), transect from point 1 to point 3

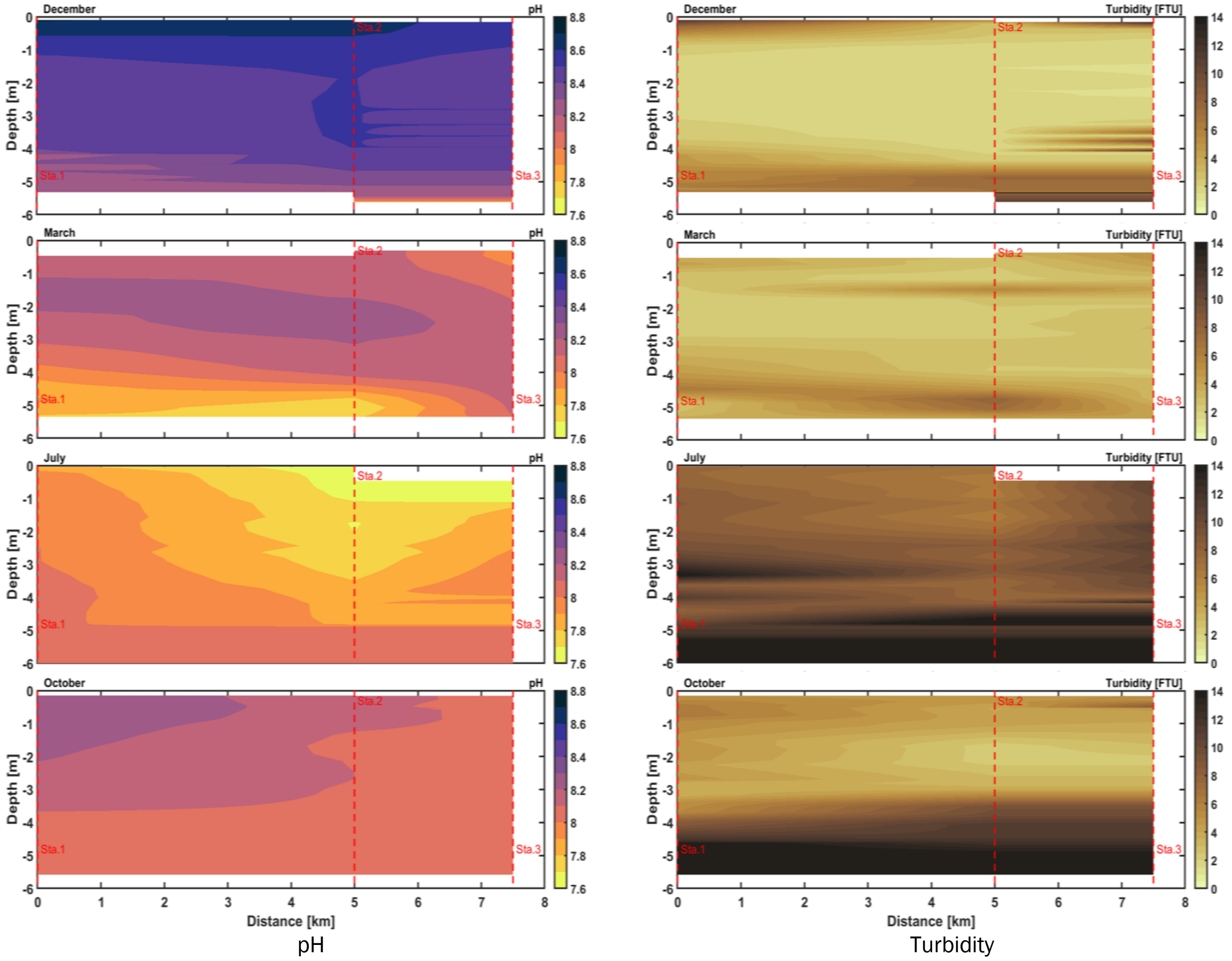


Figure 3. Vertical distribution of pH and turbidity on each season (December, March, July, October), transect from point 1 to point 3.

Table 1. Measurement result from water sample and GRRI (2021) quality standard

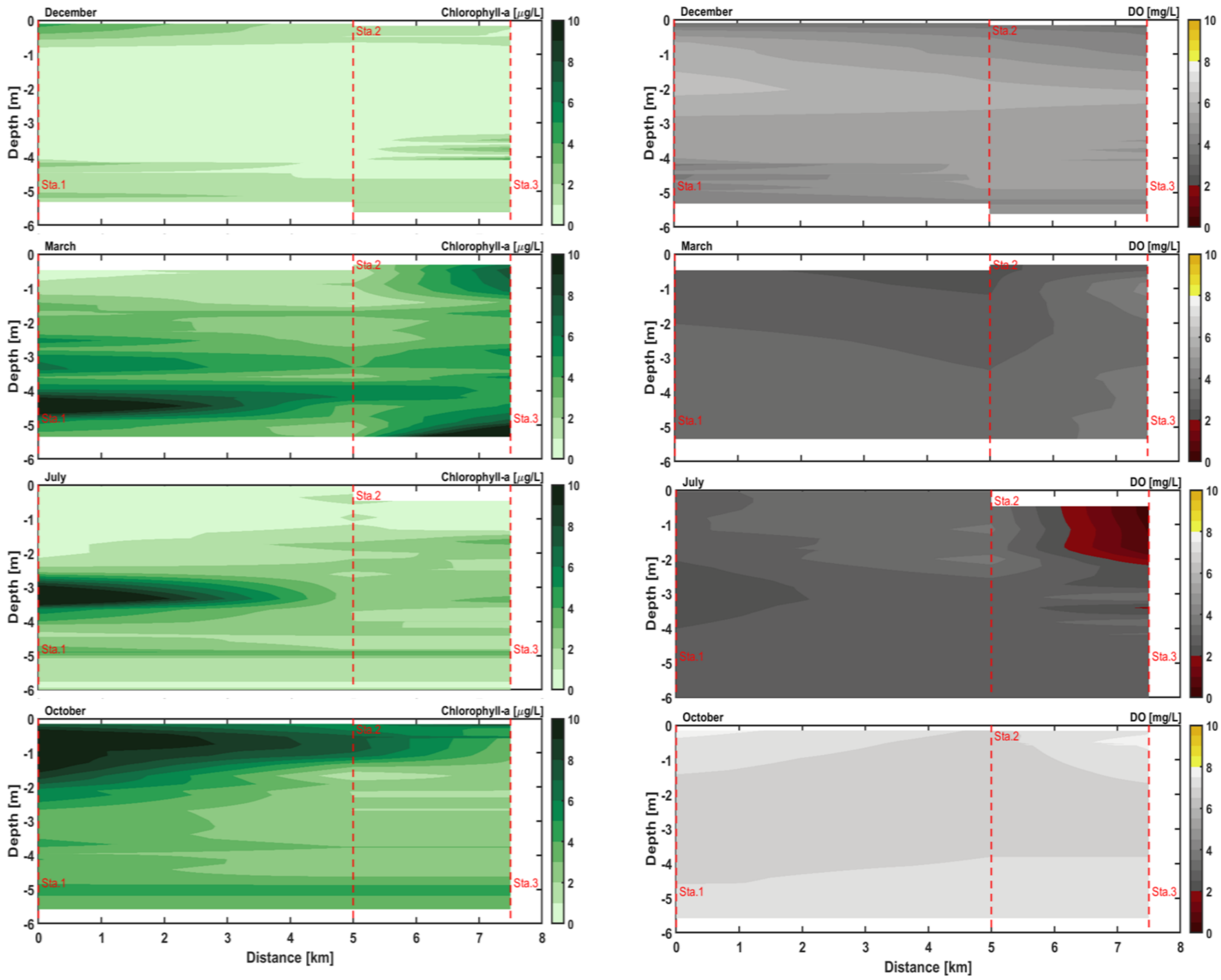
Parameter	Measurement	Standard for marine organisms (GRRI, 2021)
Temp. (°C)	28.7 – 32.3	Natural
Salinity (psu)	27.5 – 32.0	Natural
pH	7.9 – 8.4	7.0 – 8.5
Turbidity (NTU)	1.3 – 20.1	<5
Nitrate (mg.L^{-1})	0.097 – 0.261	0.06
Orthophosphate (mg.L^{-1})	< 0.01	0.015
DO (mg.L^{-1})	0.2 – 7.8	>5
Cd (mg.L^{-1})	< 0.001	0.001
Pb (mg.L^{-1})	< 0.001	0.008
Hg (mg.L^{-1})	< 0.00005	0.001

seawater itself (Nurhayati and Putri, 2019). This low heavy metal concentration in solute form might be due to a high metal absorption by suspended particulate matter, phytoplankton and mollusks or seaweed cultures (Arifin *et al.*, 2012). On July, nitrate value is in range of 0.097-0.261 mg.L^{-1}, meanwhile orthophosphate parameter has low concentration with value below 0.01 mg.L^{-1}. The value of both parameter increased on October with 0.23-0.537 mg.L^{-1} of nitrate and 0.044-0.32 mg.L^{-1} of orthophosphate. A past study suggest optimal growth of phytoplankton require 0.9-3.5 mg.L^{-1} and orthophosphate at 0.09-1.80 mg.L^{-1} (Kadim and Arsad, 2016). Other study done by Yuliana (2015) shows the optimal of phytoplankton's growth is 0.27-5.51 mg.L^{-1}.

To see the continuation of parameters observed, the latest measurement is compared with past studies which can be seen also in Table 2 and Table 3. Parameters of temperature and salinity have a small variance within each season, even compared with past studies.

The result of pH in 2021 is similar with 2017 result, however it was found in 2015-2016 and 2019 that pH was a bit lower or more acidic than the measurement. This parameter is sensitive to the environment condition, therefore further analysis and relation with another parameter is needed. The dropped value of DO is found in 2019, particularly in July and November. In normal situations, seawater has DO with value of 5 mg.L^{-1} at least. Meanwhile in 2019, the value was decreasing. Hidayah (2019) measured the water close to river or in estuary and stated it as lightly polluted water. The result might occur due to many activities or waste in the river that makes the oxygen less than it should be dissolved or algae blooms happen at this time. The reduction of DO may relate to the reducing pH in the previous analysis. Further investigation is required to ensure the falling value of DO.

One of complete study regarding seawater condition in Cirebon had been record in Supriadi (2020), although it almost two decades ago. However, the upcoming study in the following years commonly focus on specific with less parameter. It can be seen this old data taken in October is still similar with current measurement. Based on Government of Cirebon Regency (2014) report, the seawater quality in Gunungjati stated as bad category since the level of TSS (Total Suspended Solid), BOD (biological oxygen demand), turbidity, NH_3, Fenol and Zn had been above the threshold.



Chlorophyll-a DO

Figure 4. Vertical distribution of chlorophyll-a and dissolved oxygen on each season (December, March, July, October), transect from point 1 to point 3.

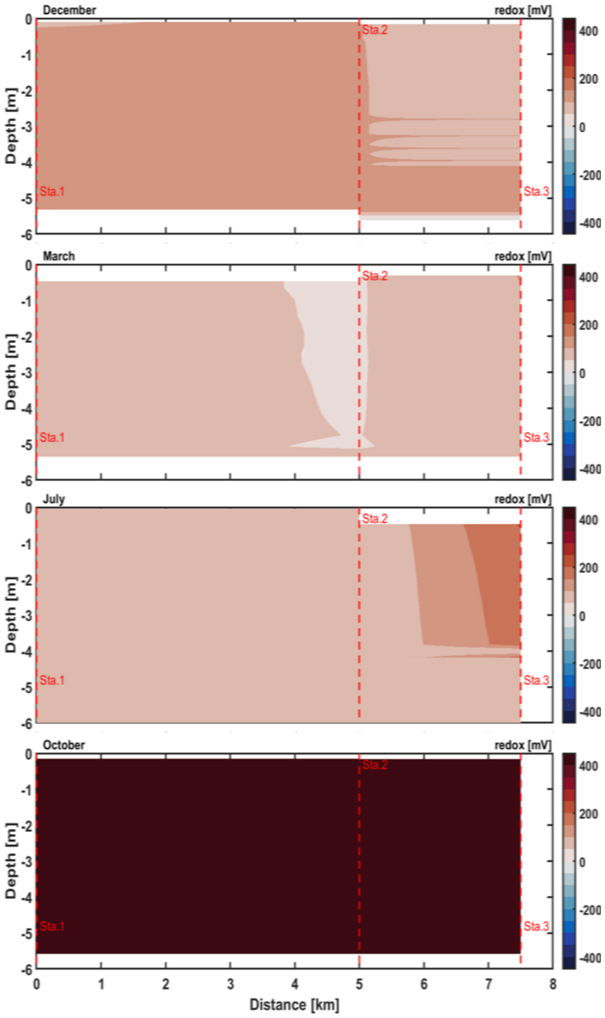


Figure 5. Vertical distribution of redox on each season (December, March, July, October), transect from point 1 to point 3.

Table 2. Measurement comparison 2002-2020

Parameter	2002[a] Oct	2015–2016[b]	2017[c] Apr	2018[d] Feb	2018[d] Dry season	2019[e] Mar	2019[e] Jul	2019[e] Nov	2020[f] Sep
Temp. (°C)	28.9–30.6	29–31.2	30.5–32.1	-	-	-	-	-	-
Salinity(psu)	29.8–34	31.8–36.4	29.7–31.7	-	-	-	-	-	-
pH	8.0–8.4	7.6–7.8	8.5	-	-	7.4	7.4	7.3	-
Turbidity (NTU)	2.4–60	-	-	-	-	-	-	-	-
Chl-a (μg.L^{-1})	-	-	-	-	-	-	-	-	-
Nitrate (mg.L^{-1})	0–0.183	-	-	-	-	0.2-0.3	0.1-0.3	0.04	-
Orthophosphate (mg.L^{-1})	0–0.02	-	-	-	-				-
DO (mg.L^{-1})	5–7.1	-	5.7–5.9	-	-	5.5	3.1	2.6	-
Cd (mg.L^{-1})	0.01–0.09	< 0.001	-	0.00	0.00	-	-	-	-
Pb (mg.L^{-1})	0.00–0.01	< 0.006	-	0.00	0.04	-	-	-	0.024
Hg (mg.L^{-1})	< 0.001	< 0.0009	-	0.03	0.07	-	-	-	-

Note: a) Supriadi (2020); b) Zahroh *et al.* (2019); c) Rachman *et al.* (2019); d) Nurhayati and Putri (2019); e) Hidayah *et al.* (2021) f) Wahyuningsih *et al.* (2021)

Ocean parameter measured in observed area can be compared with ecology parameter to see the suitability level (Radiarta *et al.*, 2011) for development of green mussel cultivation (Sagita *et al.*, 2018) as can be seen in Table 4. Based on the suitability, measurement in Gunungjati include in the "most suitable" and "suitable" category in term of depth, temperature, and salinity. Although Radiarta *et al*. (2011) did not consider pH on the suitability, but the measurement on each season still within ideal value range. Parameter DO is in "moderate" category although high DO is shown in October and become "unsuitable" in harbor area, particularly on July. Cirebon coastal sediments in the harbor area have a negative effect on the development of mussel larvae characterized by an abnormality of larval development that reaches almost 100% compared to normal conditions (Puspitasari, 2011). The current was not taken account in the 2022 measurement activity, however the current condition in Cirebon seawater had been observed by Ismail and Taofiqurohman (2012) also by Leksono *et al.* (2013). Current in Cirebon coastal sea water is around 0.02-0.32 ms^{-1} while in the offshore can reach 0.99 ms^{-1}. The velocity speed is within ideal value for green mussel development.

Only few studies exist regarding the heavy metal concentration in green mussel samples from poison post-incident. In the pre-event (2015-2016), it was found that the concentration of heavy metal in seawater is below the threshold. The concentration of Cd is always found in very small values, meanwhile Pb increased in 2018, though it reduced in the increasing time. However, Pb in dry season 2018 and in September 2020 has a concentration above the standard limit. Moreover, Zahroh *et al.* (2019) found that heavy metal (Pb and Cd) inside sediment samples in Suranenggala is quite high, around 1.5 times higher from the threshold. Lastly, mercury (Hg) concentration always exceeded the limit after the poison accident, though recent measurements show a decrease in its concentration in seawater. Despite the algae bloom acting as the main reason that poison happened (Nurlina and Liambo, 2018), heavy metal concentration in sediment or green mussel samples should be considered, particularly around cultivation area in Gunungjati. Zahroh *et al.* (2019) in their data found high concentration of Pb and Cd from sediment sample but in Suranenggala area and stated those location as heavily polluted. Andayani (2020) study the heavy metal concentration of green mussel through its dry weight, but in Suranenggala and Losari. It is found a high level of Pb and Cd (above the threshold set by National Agency of Drug and Food Control) in the meat of green mussel, although the Hg level is still low. The existence of heavy metal can affect a malformation or abnormality in the green mussel itself, such as thicker shells than

Table 3. Measurement data in 2021-2022

Parameter	2021	2022		
	Dec	Mar	Jul	Oct
Temp. (°C)	30.7-32.3	30.1-32.0	28.8-29.7	28.7-29.9
Salinity(psu)	27.5-31.9	27.6-32.0	30.0-30.6	26.9-31.6
pH	7.8-8.7	7.7-8.2	7.5-8.0	8.0-8.3
Turbidity (NTU)	1.3-13.7	2.0-7.9	6.2-18.0	2.2-20.1
Chl-a ($\mu g.L^{-1}$)	0.2-4.3	0.8-20.9	0.3-13.8	1.2-11.0
Nitrate ($mg.L^{-1}$)	-	-	0.097-0.261	0.23-0.537
Orthophosphate ($mg.L^{-1}$)	-	-	< 0.01	0.04-0.32
DO ($mg.L^{-1}$)	3.2-6.2	2.4-4.15	0.2-3.7	6.6-7.8
Cd ($mg.L^{-1}$)	-	< 0.001	-	5.8-24.6 $.10^{-8}$
Pb ($mg.L^{-1}$)	-	< 0.001	-	2.148-3.938 $.10^{-6}$
Hg ($mg.L^{-1}$)	-	< 5.10^{-5}	-	4-14 $.10^{-5}$

Table 4. Ecology parameter for green mussel cultivation

Parameter	Suitability level[a)]				Ideal value based on other reference [b)]
	Most suitable	Suitable	Moderate	Unsuitable	
Depth (m)	3-5	5-7	2-3; 7-10	<2; >10	-
Temp. (°C)	25-30	20-25; 30-33	14-20 33-35	<14; >35	27-30 25.3-34.6 11-32
Salinity (psu)	30-32	29-30; 32-34	27-29; 34-35	<27 >35	18-33 24-30
pH	-	-	-	-	7-9
DO ($mg.L^{-1}$)	>6	4-6	2-4	<2	2-12
Current (ms^{-1})	-	-	-	-	0.1-0.9

Note : [a)] Radiarta *et al.* (2011) ; [b)] Sagita *et al.* (2018)

normal, hatching time, congenital abnormalities in its embryo, etc. (Riani *et al.*, 2018). Consuming food contaminated by heavy metal not only gives short-term suffering, but also long-term impact to the body (Engwa *et al.*, 2019).

Conclusion

Seasonal data results show different values for each season where temperature, salinity, and pH are higher in December and lower in July, chlorophyll-a and turbidity are low in December, meanwhile DO is low in March-July but high in October-December. The shifting value is influenced by season, ocean and atmosphere behavior, ocean activities, and discharge from rivers. The condition of seawater around west part of Cirebon or around cultivation area is still in moderate condition based on the national standard, except its chemical properties (dissolve oxygen). All heavy metal parameters measured are in good condition. Turbidity in each month is still above the standard.

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