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RESEARCH PAPER

Heavy metal accumulation and risk assessment of lead and cadmium in cultured oysters (*Crassostrea iredalei*) of Cañacao Bay, Philippines

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Abstract. This study analyzed the lead (Pb) and cadmium (Cd) concentrations in the water and cultured oysters (*Crassostrea iredalei*) of Cañacao Bay, Philippines and assessed the health risks associated with these heavy metal contaminations. Oyster and water samples from three sampling stations were collected from October 2016 to January 2017 for heavy metal analysis using inductively coupled plasma optical emission spectrometry (ICP-OES). Results showed low Pb and Cd concentrations in water and *C. iredalei*, which were within the maximum limits set by the Food and Agriculture Organization (FAO), Food Standards Australia New Zealand (FSANZ) and Food Safety Authority of Ireland (FSAI). Pb concentrations in oysters ranged from < 0.1 to 0.4 ± 0.1 mg/kg while Cd ranged from 0.027 ± 0.006 to 0.083 ± 0.006 mg/kg. Pb and Cd bioaccumulated in oyster tissues, but only Pb exhibited seasonal variation in concentration. The Target Hazard Quotient (THQ) and Total Target Hazard Quotient (TTHQ) were used to estimate noncarcinogenic health risks for Pb and Cd through oyster consumption. All THQs were below 1.0 indicating that there was no appreciable risk to the general population for developing noncarcinogenic effects caused by Pb and Cd in cultured oysters. Continuous monitoring of heavy metals in aquaculture areas and seafood is warranted to ensure food safety among consuming public.

Keywords: heavy metals; *Crassostrea iredalei*; hazard quotient

1. Introduction

Heavy metals naturally exist in aquatic ecosystems due to leaching, atmospheric deposition, coastal sediment dissolution and other natural biogeochemical processes (Dan et al., 2014; Garrett, 2000). However, anthropogenic activities significantly contribute to the heavy metal pollution through point and non-point sources including agricultural, industrial, and urban effluents (Gupta & Singh, 2011). Heavy metals such as cadmium, chromium, lead, and mercury

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contaminate the aquatic environment, bioaccumulate in living organisms and cause toxicity even at low doses(Casas et al., 2008; Shaari et al., 2016).

Cadmium (Cd) and lead (Pb) heavy metals are among the significant environmental contaminants that may threaten ecosystem and human health. Cadmium has a half-life of 10-35 years in the human system and can be accumulated in kidney, lungs, and liver that can disrupt normal body functioning (WHO, 2008; FSAI, 2009; Hutton, 1987). Chronic exposures to cadmium can lead to renal, bone and cardiovascular diseases (Da Silva et al., 2005; Tellez-Plaza et al., 2012). Lead can cause mild retardation and cardiovascular complications (WHO, 2009). Chronic exposure to lead can harm the renal, reproductive and immune systems. In low levels, lead can cause problem in intellectual development among children (FSAI, 2009). Long term exposure of Cd and Pb can lead to cancer especially in susceptible populations (Bernard, 2008; IARC, 2006). Human exposure to Pb and Cd is often due to exposure to contaminated food (Da Silva et al., 2005). High levels these chemicals have been reported in edible bivalves including mussels, scallops and oysters (FSAI, 2009).

In the Philippines, oysters and mussels are the most important cultured bivalves providing high-quality protein and nutrients among Filipino households (FAO, 2016; Han et al., 2000). Oysters and mussels have been cultured in many parts of Luzon Island such as Bacoor, Manila, Cañacao, Tayabas, and Sorsogon bays (Andalecio et al., 2014; Cayabyab & Reyes, 2008; FAO, 1988). In Bacoor and Cañacao bays, bivalve production reached 1,578 metric tons in 2007 and provided livelihood to more than 17,000 fishermen in the province (Cayabyab & Reyes, 2008). Cultured oysters from these mariculture areas are being sold in Metro Manila and nearby municipalities.

Due to its economic significance, information on the impact of heavy metals in the survival, growth and production of bivalves is warranted. Bivalves like oysters are susceptible to heavy metal contamination from water column and sediments due to their sedentary lifestyle (Góngora-Gómez et al., 2017; Gupta & Singh, 2011) and suspension feeding mechanisms (Burkhardt III & Calci, 2000; Dunphy et al., 2006). Rising sea surface temperature, varying salinity levels and increasing heavy metal pollutants in the aquatic environment affect bivalve growth and production (Chang et al., 2016; Petton et al., 2013).

Presence of heavy metals in edible oysters poses threat to public health. Oyster consumption exposes humans to heavy metals since these organisms act as vectors of toxic chemicals especially when consumed raw (Budin et al., 2013; Góngora-Gómez et al., 2017). Determination and risk assessment of heavy metals are important tools in maintaining food safety among seafood consumers (Sharif et al., 2016). The use of hazard quotients for heavy metal contamination of food sources is likewise important in effective health management strategies.

Thus, this study aimed to determine the Pb and Cd concentrations in the oyster (*Crassostrea iredalei)* tissues and aquaculture water of Cañacao Bay, Cavite City, Philippines and assessed the possible health risk related to the consumption by a typically exposed Filipino population.

2. Methodology

2.1. Description of the Sampling Area

Cañacao Bay (14°29'22" N, 120°54'41" E) is a section of the large Manila Bay that extends to the Southern Luzon region of the Philippines, wherein Manila Bay serves as the main center for economic activity such as shipping, industrial, commercial, fishing, aquaculture, and tourism activities that are a major contributor to water pollution. Cañacao Bay is a small bay located north of Bacoor Bay along the northeast portion of the Cavite Peninsula where traffic congestion in the

Bacoor city and Manila-Cavite Express way may contribute to chemical pollution due to vehicle emissions surrounding the water from increasing demand of population growth. Cañacao Bay is characterized by a Type I climate, based on the modified Coronas classification scheme, with the dry season spans from December to May and the wet season spans from June to November of the year (Monsalud et al., 2003).

Three sampling stations were established within the mariculture area of the bay. Coordinates of each station were determined using a Garmin GPSMAP 62s (Garmin Ltd., Kansas, United States). Station 1 (14°29'16"N, 120°54'21"E) is close to the coastal community where most of the fisherfolk residents are situated. Presence of fishing boats, nets and gears are evident in the nearby coastal area. Station 2 (14°29'12"N, 120°54'26"E) is close to the center of the bay and to the ferry lines from Cavite City to the City of Manila. Station 3 (14°29'11", 120°54'19"E) is situated near a steel corporation where industrial effluents may be discharged. All sampling stations were classified as Class SA based from the Department of Environment and Natural Resources (DENR) Administrative Order 2016-08 (DENR, 2016). This classification indicates that waters are suitable for propagation, survival and harvesting of shellfish for commercial purposes and direct consumption.

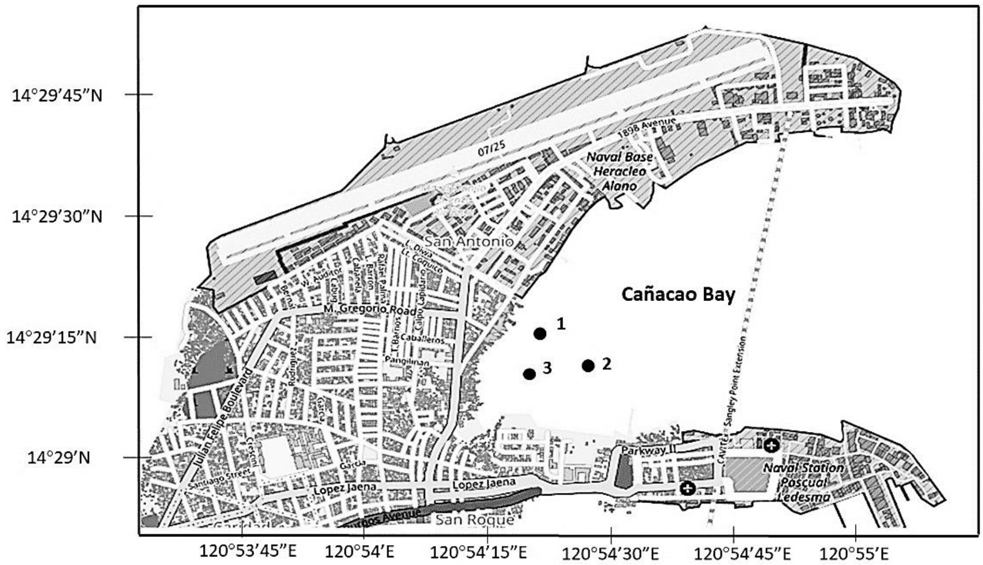

Figure 1. Cañacao Bay, Cavite Province, Luzon, Philippines. Dots indicate the three sampling stations. Base map and data from OpenStreetMap and OpenStreetMap Foundation © OpenStreetMap contributors.

2.2. Oyster and water sampling

A total of 214 oysters (*Crassostrea iredalei*) were collected from three sampling stations from October 2016 to January 2017. Samples of 52-57 oysters (15-20 samples per station) were collected per month. Oyster shell length was measured using a Vernier caliper. Oyster shell length ranging from 45-55mm was considered since it was the typical marketable oyster size and ensured uniform samples for digestion (Han et al., 2000). Surface water samples within 2-meter depth were also collected for physicochemical analysis. Water samples were placed in black polyethylene bottles earlier washed with 10% nitric acid (HNO_3) (2.24 Molarity (M)) to preserve the water samples and then rinsed with deionized water (Liu et al., 2007).

Oyster samples were placed in polyethylene transport bags with appropriate tags indicating the sites where they were collected. Both oyster and water samples were kept below 4°C to preserve and to maintain the integrity of the water and oyster samples during transport to the laboratory for heavy metal analysis.

2.3. Heavy metals analysis using inductively coupled plasma optical emission spectrometry (ICP-OES)

Collected oyster samples were thawed at room temperature and carefully washed with deionized water to remove particles within the mantle cavity and gills (Bilos et al., 1998). The whole soft tissues were shucked, pooled, and homogenized using a stainless-steel blender (Han et al., 2000).

Dry ashing was performed for heavy metal analyses of water and oyster tissues. Ten grams (10g) of fresh sample was placed in an evaporating dish and dried in the vacuum oven. One (1) mL of concentrated nitric acid (HNO_3) was added and evaporated in the dish. The dried sample was then ashed in a muffled furnace up to 450°C for 5 hours. If the ashing was incomplete, another 1 mL of concentrated nitric acid was added to the sample. The sample was dried again before being ashed for 2 hours. Once dry ashing was completed, the ash was dissolved in 50% hydrochloric acid, volumed to 25 mL, and diluted to at least 1:5 ratio for Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) examination (McClements, 2003).

Diluted solution samples and water samples were analyzed for Pb and Cd concentrations by ICP-OES using a Shimadzu ICPE-9810 (Shimadzu Scientific Instruments, Inc., Kyoto, Japan). Working wavelengths for Pb and Cd were 220.353 nm and 226.502 nm, respectively (US EPA, 1996). The wavelengths considered for both Pb and Cd were based on the standard calibration (Morrison et al., 2020).

2.4. Physicochemical Parameters

The water temperature, dissolved oxygen (DO) and pH were determined *in situ* using ExStik® II DO600 Meter and pH Meter (FLIR Systems, Inc., Oregon, United States) in triplicates per sampling station during the sampling periods. The turbidity of the water samples collected from each site were analyzed using an APEL PD-303UV Spectrophotometer (APEL Co., Ltd., Saitama, Japan) at 540 nm in the laboratory.

2.5. Target hazard quotient (THQ) and total target hazard quotient (TTHQ)

The equation for calculating THQ was adapted from the US EPA Region III Risk-based Concentration Table (US EPA, 2016):

$$THQ = \frac{EFx\ ED\ x\ FIR\ x\ C}{RFD\ x\ WAB\ x\ TA} \times 10^{-3} \quad (1)$$

where *EF* is the exposure frequency, equal to 365 days/year; *ED* is the exposure duration, which is 71 years equivalent to the life expectancy of Filipinos (United Nations Department of Economic and Social Affairs, 2019); *FIR* is the food ingestion rate, which for oysters is 3.50 g/person/day (FNRI-DOST, 2013); *C* is the metal concentration in seafood in mg/kg; *RFD* is the oral reference dose, which is 0.004 mg/kg-day for Pb (US EPA, 2000) and 0.001 mg/kg-day for Cd in the diet (US EPA, 2016); *WAB* is the average body weight, which is 65 kg for the Filipino adult (Molina, 2012);

and TA is the average exposure time for non-carcinogenic contaminants (365 days/year x exposure years).

Total THQ (TTHQ) for individual seafood is the sum of the THQs of the individual contaminants (Storelli, 2008) with the equation:

$$TTHQ = THQ\,(Pb) + THQ\,(Cd) \tag{2}$$

THQ and TTHQ values of less than 1 is an indicator that daily oral exposure level to the contaminant will most likely result in no appreciable risk for developing deleterious effects during a lifetime, while above threshold value of 1 may indicate a potential adverse health effect (Molina, 2012; Wang et al., 2005). Hence, the estimated value of TTHQ for heavy metals, such as Pb and Cd greater than 1.0 may indicate a non-carcinogenic health risk to consumer (Ezemonye et al., 2019). The possible health risks were highly dependent on the particular contaminant being assessed (Molina, 2012).

2.6. Statistical Treatment of Data

Unpaired and paired T-tests were used to determine the significant differences between heavy metals concentrations and physicochemical parameters in wet and dry seasons. Analysis of variance was utilized to calculate differences among the sampling sites and Pb and Cd concentrations. Linear regression analysis and Pearson's correlation were employed to determine significant relationships between shell lengths and Pb and Cd concentrations in oysters. For r and R-squared values, the following equations were utilized:

$$r = \frac{\Sigma(x_i - \bar{x}) - (y_i - \overline{y})}{\sqrt{\Sigma(x_i - \bar{x})^2 \Sigma(y_i - \bar{y})^2}} \tag{3}$$

where r = correlation coefficient; x_i = values of the x-variable in a sample; $\bar{x}$ = mean of the values of the x-variable; y_i = values of the y-variable in a sample; $\bar{y}$ = mean of the values of the y-variable

$$R^2 = 1 - \frac{RSS}{TSS} \tag{4}$$

where R^2 = coefficient of determination; RSS = sum of squares of residuals; TSS = total sum of squares.

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) Statistics 20.0 (IBM, Armonk, NY) and GraphPad Prism 7 (GraphPad Software, Inc., La Jolla, CA).

3. Results and Discussion

3.1. Heavy metal analysis

Heavy metal concentrations in seawater were < 0.05 mg/L for Pb and < 0.01 mg/L for Cd during the entire study period. These Pb and Cd concentrations conform to the criteria set by the Department of Environment and Natural Resources (DENR) of Philippine for Pb and Cd levels for Class SA water (DENR, 1990) and Association of Southeast Asian Nation (ASEAN) Marine Water Quality Criteria (ASEAN, 2002). The values of Pb and Cd in the water of Cañacao Bay were less than the values obtained by Sia Su et al. (2009) where they found high Cd concentration and lower Pb level in Manila Bay. Heavy metals undetectable or in low values in the water column were most likely to be bound in sediments therefore might not be bioavailable. Dissolved heavy metals in the aquatic environment could undergo sediment deposition (Atkinson et al., 2004). Typically, it was difficult to accurately quantify the concentration of pollutants in the water because they were usually low under field settings and might be below analytical detection limit (Gobas, 2001) which was observed in Pb levels in October and January data that were below detection limit of 0.1 mg/kg level. Cd concentrations ranged from 0.2 mg/kg to 0.9 mg/kg levels.

Lead concentrations in the *C. iredalei* oysters varied throughout the study period. Pb concentrations were less than 0.1 mg/kg in October 2016 and increased to 0.4 ± 0.1 mg/kg in December 2016 and then dropped again below 0.1 mg/kg in January 2017. Cd concentration was highest in October with 0.083 ± 0.006 and lowest in November and January with 0.027 ± 0.006 (Table 1). The Pb and Cd concentrations in *C. iredalei* obtained during the sampling periods (Table 1) conform to the standard parameters set by the Food and Agriculture Organization (FAO), Food Safety Authority of Ireland (FSAI) and Food Standards Australia New Zealand (FSANZ). FAO permissible limit for bivalve food is 1mg/kg for both Pb and Cd (FAO, 2003). FSAI set limits to 1.5 mg/kg for Pb and 1.0 mg/kg for Cd (FSAI, 2009) while FSANZ maximum limits are set to 2mg/kg for Pb and Cd (FSANZ, 2013).

Table 1. Pb and Cd concentrations (mg/kg) in *C. iredalei* oyster from October to January

Sampling Station	Wet Season				Dry Season				Max Standard Limits	
	October		November		December		January			
	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd
1	< 0.1*	0.08	0.1	0.03	0.5	0.04	< 0.1*	0.03	1.0-2.0	1.0-2.0
2	< 0.1*	0.09	0.1	0.03	0.3	0.05	< 0.1*	0.02	1.0-2.0	1.0-2.0
3	< 0.1*	0.08	0.2	0.02	0.4	0.04	< 0.1*	0.03	1.0-2.0	1.0-2.0
Mean	<0.1*	0.083 ± 0.006	0.133 ± 0.056	0.027 ± 0.006	0.4 ± 0.1	0.043 ± 0.006	<0.1*	0.027 ± 0.006		

* below detection limit

Results of this study showed Pb and Cd values in *C. iredalei* oyster were 15 times lower than the Pb concentration and 19 times lower than Cd concentrations obtained from *Mercenaria sp.* clams in Manila Bay, which were 7.38 mg/kg and 1.72 mg/kg, respectively (Sia Su et al., 2009). In another study, Sia Su et al. (2014) reported low Pb concentrations in an edible bivalve, *Katelysia hiantina* sampled from three major market places in Metro Manila and Pb levels were within the maximum limit allowed by the Food and Agriculture Organization (FAO, 2003). Low Pb concentrations in oyster tissue were also calculated by Apeti et al. (2005) in Apalachicola Bay, Florida. However, high Pb and Cd concentrations were observed in black mussels (*Mytilus galloprovincialis*) thriving in Cape Town harbor of South Africa. These bivalves accumulated 7.3 mg/kg of Pb and 1.98 mg/kg Cd concentrations, which were higher than the maximum standard limit set by FAO (Fatoki et al., 2012).

Pb and Cd concentrations in the water column were lower compared than those of in the oyster tissues, suggesting bioaccumulation (Apeti et al., 2005). Lower concentrations of Pb and Cd may have been affected by the biological processes of oysters present in the water column where the samples were collected. This may also be affected by the chemical processes in the water column, wherein heavy metals may have been accumulated in the coastal sediments considering their highly reactive nature (Sharifuzzaman et al., 2016). The increased accumulation of Cd in the soft tissues of oysters might be due to the biochemical processes within its body (Shirneshan & Bakhtiari, 2012). The Cd binds to the metallothionein and proteins of low molecular weight that may reduce the toxic effects of heavy metals (Apeti et al., 2005; Engel, 1999; Shirneshan & Bakhtiari, 2012). However, Pb was found to have low tendency to be accumulated within the soft tissues of oysters because of its tendency to accumulate in the shell (Peer et al., 2010; Shirneshan & Bakhtiari, 2012). Large amounts of Cd might be due to peroxidation of lipids and formation of DNA adducts, thereby affecting the overall metabolism of the oyster (Jakimska et al., 2011). Significant Cd bioaccumulation factor was also reported by Mok et al. (2014) compared to other heavy metals they assessed. Cd tends to be excreted in minute quantities due to metallothionein binding (Jakimska et al., 2011).

Pb concentrations in *C. iredalei* samples were statistically different between wet and dry seasons ($p<0.05$), while Cd concentrations in oysters were not significantly different between seasons ($p<0.05$). No statistical differences were observed among the sampling stations ($p<0.05$) in terms of Pb and Cd concentrations. Temporal variations of heavy metal levels were also described by Yesudhason et al. (2013) in *Saccostrea cucullata* oyster from Arabian sea. Aside from natural biogeochemical processes, anthropogenic input may cause variation in the levels of heavy metals. Cañacao Bay is part of the large Manila Bay and flanked by the Manila-Cavite Expressway. The presence of this main thoroughfare can be a source of vehicular and industrial emissions. Anthropogenic input from the nearby residential community encroaching upon the bay itself can be a source of inadequately treated sewage. The steel corporation approximately 500 meters away from the sampling station (Station 3) may also contribute to Pb and Cd effluents released into the bay.

The higher Pb concentration during the dry season than that of the wet season may be due to precipitation rates and salinity. High precipitation rates during the wet season cause dilution effect that lowers the heavy metal levels in the water (Paez-Osuna & Osuna-Martinez, 2015). Reduced salinities typical during wet season was due to the large amount of freshwater released into the estuarine and coastal waters causing water dilution effect (Mclusky, 1989). Salinity profiles of a water column vary seasonally (Sy et al., 2017). Bakri et al. (2020) argue that increased in salinity level is influenced by high tide which brings in ocean water. He said that the mixing of riverine and marine waters during high tide may increase the salinity level of the water column. Hence, he made a conclusion that the interaction of riverine and seawater may affect the salinity distribution because of the density differences between the two water bodies. Lower salinity in the aquatic environment favors absorption and accumulation rates of Pb (Denton & Burton-Jones, 1981).

3.2. Target hazard quotients and total target hazard quotients

The highest mean target hazard quotients computed were 5.385×10^{-3} (Pb) and 4.487×10^{-3} (Cd). The highest total target hazard quotient was only 7.718×10^{-3}. All hazard quotient results were very low and less than 1.0 (Table 2), indicating that the cultured oysters from the Cañacao Bay were safe for consumption with low health risks that might develop in a lifetime as a result of oyster consumption. However, these results can vary in the future depending on the water quality of the mariculture area. In addition, future changes in the target and total target hazard quotients will be highly influenced by climate changes, biogeochemical processes, urbanization and waste management activities.

In the study by Molina (2012), target hazard quotient for mudfish (*Ophicephalus striatus*) in Laguna de Bay was less than 1.0 for Cd, similar to the THQs obtained in this study. Mok et al. (2015)

also calculated low THQ values ranging from 0.001 to 0.1702 for all toxicants, such as Zn (154.38 μg/g) > Cu (32.48 μg/g) > As (2.690 μg/g) > Cd (0.591 μg/g) > Cr (0.215 μg/g) > Ni (0.153 μg/g) > Pb (0.150 μg/g) > Hg (0.009 μg/g) in the oyster species studied in the southern coast of Korea. Lower than 1.0 values of THQs of various fish species were obtained in Tianjin, China which estimated for adult population. However, Wang et al. (2005) found that the THQs estimated for children inhabiting the same locality were found to be higher. Their results indicate health risks might vary among age groups and localities, in that, children were among the susceptible sector of the population for food health hazards.

Table 2. Mean target hazard quotients and total target hazard quotients for Pb and Cd

Sampling Period	Target Hazard Quotients		Total Target Hazard Quotients
	Pb	Cd	
October	$1.346 \times 10^{-3} \pm 0$*	$4.487 \times 10^{-3} \pm 0.0003$	$5.833 \times 10^{-3} \pm 0.0003$
November	$1.795 \times 10^{-3} \pm 0.0008$	$1.436 \times 10^{-3} \pm 0.0003$	$3.231 \times 10^{-3} \pm 0.0005$
December	$5.385 \times 10^{-3} \pm 0.0013$	$2.333 \times 10^{-3} \pm 0.0003$	$7.718 \times 10^{-3} \pm 0.0011$
January	$1.346 \times 10^{-3} \pm 0$*	$1.436 \times 10^{-3} \pm 0.0003$	$2.782 \times 10^{-3} \pm 0.0003$

*computed at 0.1mg/kg

3.3. Physicochemical parameters

The pH values were slightly alkaline with a mean range of 8.29 ± 0.35 to 8.15 ± 0.23 (Table 3) and it generally conformed to the standard range set by (DENR, 1997). A pH range of 7.5 to 8.5 was favorable for biological processes among marine organisms such as photosynthesis and respiration (Ude, 2012). The seawater temperature was found in higher levels during the wet season compared to the dry season which may be attributed to the prevailing monsoon winds. The wet season was naturally characterized by the Southwest Monsoon while the dry season was characterized by the Northeast Monsoon. The maximum temperature is higher during SW monsoon season (i.e., wet season) than during NE monsoon season (i.e., dry season) (Amirabadizadeh et al., 2015).

The mean dissolved oxygen ranges from 5.58 ± 1.40 to 11.77 ± 7.37 (Table 3) were above the minimum standard set by ASEAN water quality criteria of 4 mg/L (ASEAN, 2002). High DO levels may be due to wind-assisted surface mixing and freshwater influx (Ladipo et al., 2011). Elevated DO favors the formation of iron hydroxides that can act as sinks for Pb, Cd, Cu and Zn (Houba et al., 1983). Water turbidity indicates the quantity of suspended particles which provide substrate for greater adsorption of heavy metals in the water (Cuvin-Aralar, 1990). Turbidity is also influenced by seasonal phytoplankton blooms and resuspension of sediment particles (Shi & Wang, 2010). Water pH, dissolved oxygen (DO), and turbidity were not statistically different in wet and dry seasons ($p<0.05$). Water temperature is significantly different in two seasons (Table 3).

3.4. Correlation between oyster shell length and heavy metal concentration

The mean of shell lengths of *C. iredalei* ranged from 48.79 ± 4.42 mm to 50.79 ± 3.86 mm during the sampling period. A very weak positive correlation was observed for Pb concentrations in oyster tissue and shell length (R^2 = 0.1067, r = 0.327) and was found to be insignificantly different (p>0.05) (Figure 2). No correlation was observed for Cd concentrations in oyster tissue and shell length (R^2 = 0.034) (Figure 3). Sia Su et al. (2014) and Hamidian et al. (2013) had observed that bivalve shell lengths influence the Pb concentration within the organism.

Contrastingly, no correlation was found between Cd concentration in *Saccostrea cucullata* oyster and shell length (Hamidian et al., 2013).

Table 3. Mean and range of physicochemical parameters in wet and dry seasons

Season	Parameter	Range	Mean ± SD
Wet	Laboratory pH	8.05 – 8.80	8.29 ± 0.35
	Temperature (°C)	30.10 – 32.80	30.97 ± 0.78
	DO (mg/L)	6.40 – 23.10	11.77 ± 7.37
	Turbidity (Absorbance)	0 – 0.66	0.11 ± 0.15
Dry	Laboratory pH	7.92 – 8.37	8.15 ± 0.23
	Temperature (°C)	27 – 29.2	27.88 ± 0.71
	DO (mg/L)	4.15 – 8.59	5.58 ± 1.40
	Turbidity (Absorbance)	0 – 0.09	0.04 ± 0.03

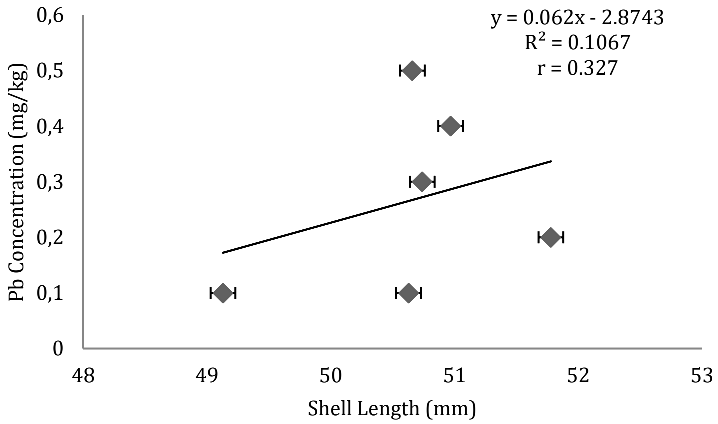

Figure 2. Relationship between Pb concentration in oyster and shell length

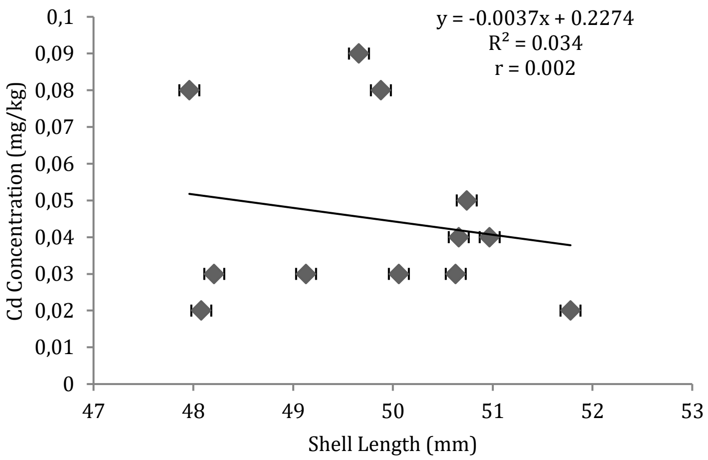

Figure 3. Relationship between Cd heavy metal concentration in oyster and shell length

4. Conclusion

Heavy metal concentrations of Pb and Cd in coastal waters of Cañacao Bay during the study period were within the standard limits for aquaculture. Pb and Cd concentration in oyster tissues likewise conformed to the FAO, FSANZ and FSAI standards for seafood safety. Noncarcinogenic health risk assessment using the target hazard quotient (THQ) for the separate heavy metals and total target hazard quotient (TTHQ) for both metals yielded values less than 1.0. This may indicate that the cultured oysters in Cañacao Bay were fit for consumption by the typical Filipino population, with negligible noncarcinogenic health risks that may develop in a lifetime as a result of consuming these oysters. However, target hazard quotient (THQ) values may vary for those individuals consuming more seafood and those belonging to susceptible populations. No significant correlations were found between Pb and Cd concentrations in oyster tissues and oyster shell lengths. Presence of heavy metals in the aquaculture areas must be continuously assessed and monitored to prevent detrimental effects to aquatic organisms and reduce health risks among consuming public.

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