INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 22, No. 2, p. 260-268, 2023

RESEARCH PAPER OPEN ACCESS

Cadmium pollution in waters and commercial Shellfish in Jakarta Bay

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Key words: Polution, Jakarta bay, Shellfish, Cadmium

http://dx.doi.org/10.12692/ijb/22.2.260-268 Article published on February 13, 2023

Abstract

This study aims to analyze the Cd content of commercial shellfish and their living waters. This study used survey and laboratory methods. Water and sediment samples were taken from 5 points (stations) in the Jakarta Bay waters. While shellfish samples were taken compositely from the points. Each water, sediment, and shellfish sample was taken three times (Triplo), then the collected samples were brought to the LIPI Cibinong Laboratory to be analyzed for Cd levels using flame AAS. The results showed that the Cd content of seawater (0.007-0.009mg/L East Monsoon and 0.006-0.009mg/L West Monsoon) except for the harbor pool (0.011mg/L) was still quite high and still exceeded the Cd content threshold determined by the decree of the minister of environment no 51 of 2004 for sea water biota (0.001mg/L). The Cd content in sediments is still quite high (Cd 0.302-1.509) but still below the threshold value for aquatic biota set by the Ministry of Environment in 2010 (6.2mg/kg) and Washinton Department of Ecological, 2013 (6.7mg/Kg). The lowest sediment Cd content was found around the location of mussel cultivation (0.318-4.75mg/Kg East Monsoon and 0.302-0.449mg/Kg West Monsoon). The Cd content in the soft tissues of shellfish (0.012-0.019mg/Kg for the East Monsoon and 0.013-0.016mg/Kg for the West Monsoon) is generally below the threshold determined by the SNI 2009 and CCFAC 1999 (1mg/Kg).

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Introduction

Technological and industrial developments always have a positive or negative impact. The positive impact, of course, is that the development of technology and industry has an impact on human welfare. But apart from these positive impacts, there are also negative impacts on the environment and human life. Industrial waste and domestic waste that are not managed properly can cause damage to many biotic components in an ecological niche and if this is allowed, it can cause harm to humans. Industrial waste and domestic waste that are not managed properly will also pollute the environment and end up in the ocean. This happens in Jakarta Bay, where many pollutants enter from various sources, especially industry and domestic. The high level of organic and inorganic pollutants such as heavy metals in the waters of the Jakarta Bay is mainly due to the frequent occurrence of floods that hit almost all areas of Jakarta every year. Of course, this situation makes industrial and domestic waste flow rapidly into the waters of the Jakarta Bay (Rumanta, 2014). Industrial and domestic waste can contain heavy metals which are very harmful to the ecosystem in the waters of Jakarta Bay. These heavy metals can enter the food chain and have the potential to harm marine plants and animals (Nursita *et al.*, 2005) and ultimately humans who consume them (Rumanta, 2005). Apart from being found in waters, heavy metals also accumulate in soil, sediment, and organisms in the waters (Colognesi *et al.*, 1997, Rumanta, 2014). The two main characteristics of heavy metals that distinguish them from other toxic pollutants are that they cannot be degraded biologically and their toxicity is influenced by their chemical-physical form (Walker, 2001).

Shellfish as benthic animals can reflect an increase in the bioavailability of heavy metals in the environment. Shellfish are widely used in activities as bioindicators and biomonitoring of pollution in the sea. This is because in general the organism have a wide geographic distribution, large populations, are relatively stable in locations with heavy contamination, have a long life, live sedentary, are tolerant to environmental changes and contaminants, have a high pollutant bioconcentration factor (BCF) mark, height and body size facilitate observations in the field and laboratory (Barka, 2012; Amiard *et al.*, 2006).

Bioaccumulation is a progressive increase in the concentration of a type of compound in an organism, because the rate of uptake of a compound is greater than the rate of its release (Fisher, 2002). Bioaccumulation of heavy metals in shellfish is affected by filter/suspension/deposit feeding, and limited mobility. Shellfish then act as biotransfer of heavy metals to a higher trophic level in the food chain (biomagnification), so that the dangers posed by pollutants in the environment will have an impact on human life. Several studies have shown that the accumulation of heavy metals at higher trophic levels (humans) has an impact on acute and cronic health problems (Rumanta, 2005).

Several studies have shown that in general Pb and Cd pollution in the Jakarta Bay has exceeded the normal threshold. However, it is very unfortunate that there are still many fishermen who earn a fortune in Jakarta Bay by cultivating and harvesting shellfish for sale and purchase. This is very worrying, because heavy metals are elements that are bioaccumulative and biomagnificative in the bodies of organisms in the food chain in these waters. As a result of the high levels of heavy metals in these sea waters, it is certain that the organisms in them will be contaminated with heavy metals. Research conducted by Bangun (2005), regarding the content of Pb and Cd in water, sediment and organs of the Sokang fish (*Triacanthus nieuhofi*) in Ancol waters, Jakarta Bay, revealed that the concentrations of heavy metals Pb and Cd in water and sediments were still within the limits of maximum set while the content of Pb metal in fish meat has exceeded the maximum limit that has been set.

The high concentration of heavy metals in the waters of Jakarta Bay is caused by high pollution from both industry and domestic on the rivers that flow into the Jakarta Bay. Rumanta *et al.* (2008) revealed that nine rivers that flow into the Jakarta Bay which were used as research samples were polluted by the heavy metal Pb in concentrations that exceeded the threshold determined by Minister of Environment Decree, 2004.

The highest concentration was found in the Ciliwung River which reached 0.067 ± 0.015µg /ml in the East Monsoon and 0.117±0.107µg/ml in the West Monsoon. This is due to the low awareness of the population and industrial managers in Jakarta regarding environmental health.

As revealed by Maryadi (2009) it is currently predicted that there are 14 thousand cubic meters of waste from domestic waste and industrial waste, which will pollute the 2.8 square kilometer bay.

Rumanta (2005), states that the levels of Pb and Cd pollution can be determined by examining their levels in marine biota that live in polluted environments. Research conducted by Otchere (2003), reported that compared to fish and crustaceans, shellfish has very low enzyme activity for metabolizing persistent organic pollutants (POPs), so that the pollutant concentrations in shellfish more accurately reflect bioaccumulation. The study of heavy metal bioaccumulation in marine shellfish has been studied more using the mussels group, especially the Mytilidae family (for example: the blue mussel *Mytillus edulis* and the green mussel *Perna viridis*), the oysters group (for example: Crassostrea and Ostrea), the clams group (for example: Corbicularia and Cerastoderma), as well as groups of scallops (especially Pecten) (Arockia *et al.*, 2012; Torres *et al.*, 2012; Priya *et al.*, 2011; Boateng *et al.*, 2010). Many studies on heavy metals in the waters and biota of the Jakarta Bay have been carried out, but did not focus on the analysis of Cd pollution. For this reason, this study aims to analyze the Cd content in waters and commercial shellfish in Jakarta Bay.

Materials and methods

Time and location of the research

This research was conducted in the waters of the Jakarta Bay in 2 stages of sample collection based on the Monsoon. The West Monsoon period is from November to March, and the East Monsoon is from April to October. Overall, this research takes place from March to December 2020. At the research location, five observation stations were determined, which were selected based on fishermen's information about the presence of shellfish. The position of the research location based on GPS coordinates is shown in Fig. 1.

Fig. 1. Location of the research

Station (sample point) 1 is located to the north of Muara Angke seaport at the DMS coordinates: Lat S-6º5' 4.51896" and Long E 106046' 50.76552". Station 2 at the green mussel cultivation site with DMS coordinates: Lat S-6º4' 10.26048" and Long E 106º44' 19.2714". Station 4 is in the pool of the Muara Angke seaport with coordinates Lat S-6°05'57.7"S and Long E 106°46'39.9". The final location, namely station 5, is near the mouth of the Angke River with coordinates Lat S-6ºC 5' 55.46508".

Water, sediment and shellfish samples were taken from each sampling location (stations 1-5). Water samples were taken compositely from the bottom, middle and surface of the waters; sediment is taken from the bottom of the waters; and samples of shellfish were taken simultaneously with sediment collection assisted by a diving fisherman who is used to harvesting shellfish in these waters. Each of the water, sediment, and shell sample was repeated 3 times (triplo), then each sample was brought to the LIPI Cibinong Laboratory, to be analyzed for Cd content using flame AAS. The data from this study were then processed statistically using one way ANOVA and the t-test using SPSS software version 20.

Results

Cd Concentration in sea water

The Cd concentration in seawater at each research sampling station is presented in Table 1 below.

Table 1. Cd concentration in sea water between monsoons.

Sampling locations	Cd concentration in sea water (mg/L) East Monsoon (X ± SD)	West Monsoon (X ± SD)
Station 1	0,008 ± 0,003A	0,007 ± 0,003A ns
Station 2	0,009 ± 0,001A	0,007 ± 0,002A ns
Station 3	0,009 ± 0,002A	0,008 ± 0,001A ns
Station 4	0,011 ± 0,001A	0,011 ± 0,002B ns
Station 5	0,007 ± 0,002A	0,006 ± 0,001A ns

Note: One way Anova: Different capital letters (A,B) in the same column indicate significant different (p<0,05) in Cd water concentration between Monsoons.

T-test, ns= no significant difference Cd water concentration between Monsoons (p<0.05).

In Table 1 it is clear that the concentration of Cd in seawater in general has exceeded the allowable threshold determined by the decree of the minister of environment no 51 of 2004 for sea water biota (0.001mg/L). In general, the concentration of Cd in East and West monsoon seawater did not show a significant difference. However, there is a tendency that the concentration of Cd in seawater in the East Monsoon is higher than in the West Monsoon. In addition, there is a tendency that seawater Cd concentrations at each sampling station in the West and East Monsoons are not significantly different. However, the concentration of Cd in seawater in the West Monsoon at station 4 (0.011± 0.002mg/L) was significantly higher than at the other stations.

Cd content in sediments

The Cd content in the sediments of the Jakarta Bay Waters at each research sampling station is presented in Table 2 below.

Table 2. Cd content in sediment between monsoons

Sampling Location	Cd Content (mg/Kg) East Monsoon (X̄ ± SD)	West Monsoon (X̄ ± SD)
Station 1	1,509 ± 0,164A	1,434 ± 0,156A ns
Station 2	0,318 ± 0,097B	0,302 ± 0,092B ns
Station 3	0,473 ± 0,193B	0,449 ± 0,184B ns
Station 4	1,455 ± 0,138A	1,470 ± 0,088A ns
Station 5	1,299 ± 0,057A	1,344 ± 0,054A ns

Note: One way Anova: Different capital letters (A,B) in the same column indicate significant different (p<0,05) in Cd sediment content between stations.

T-test, ns= no significant difference Cd sediment content between Monsoons (p<0.05).

Table 2 shows that there is no significant difference in sediment Cd concentrations between the West and East Monsoons, but there is a tendency for Cd content in the East Monsoon to be higher than the West Monsoon. Meanwhile, the average content of Cd in sediments at station 2 and station 3 was significantly lower than the content of Cd at other stations, both in the East and West monsoons.

Cd content in mussel soft tissue between monsoons

The results of the Anova test on the soft tissue Cd content of 3 types of commercial shellfish, namely feather clams (*Anadara antiquata*), green mussels (*Perna viridis*), and tofu clams (*Meretrix meretrix*), are presented in Table 3 below.

Table 3. Cd content in shellfish soft tissue between monsoons

Species	Cd Content (mg/Kg) EEEast Monsoon (X± SD)	West Monsoon (X ± SD)
A. antiquata	0,019 ± 0,002AB	0,015 ± 0,002A
P. viridis	0,012 ± 0,002B	0,013 ± 0,001A
M. meretrix	0,018 ± 0,003A	0,016 ± 0,003A

Note: Oneway Anova: Different capital letters (A, B) in the same column indicate significant differences (p<0.05) in Cd content between shellfish species.

T-test, ns= no significant difference (p<0.05) in Cd content each shellfish species between Monsoons.

Table 3 shows that Cd content in the soft tissue of each clam species in the East and West Monsoons was not significantly different, but there was a tendency for the heavy metal content of shellfish in the East Monsoon to be higher than in the West Monsoon.

In the East Monsoon, the average Cd content in soft tissue was lowest in green mussel, *P. viridis* (0.012 ± 0.002mg/Kg) compared to the other two types of shellfish *A. antiquata* (0.019 ± 0.002mg/Kg) and *M. meretrix* (0.018 ± 0.003mg/Kg). Whereas in the western monsoon the Cd content in sellfish soft tissue was not significantly different between species. However, there is a tendency for the average Cd content in *P. viridis in* the East Monsoon to be higher than the Cd content in *A. antiquata* and *M. maretrix.*

Cd content in shelfish shell between monsoons

The results of inferential statistical analysis of the Cd content in shellfish shells, obtained data as shown in Table 4 below.

Table 4. Cd Content in Shellfish Shells between Monsoons.

Species	Cd content (mg/Kg)	
	East Monsoon ($\overline{X} \pm$ SD)	West Monsoon ($\overline{X} \pm$ SD)
A. antiquata	0,231 ± 0,015A	0,202 ± 0,013A ns
M. viridis	0,201 ± 0,030B	0,206 ± 0,010A ns
M. meretrix	0,236 ± 0,011A	0,222 ± 0,022A ns

Note: One way Anova: Different capital letters (A, B) in the same column indicate significant differences ($p<0.05$) in Cd content between shellfish species.
T-test, ns= no significant difference ($p<0.05$) in Cd content between Monsoon each shellfish species.

Based on the data in Tables 3 and 4, the Cd content in the shelfish shells is much higher than the Cd content in soft tissue. The Cd content in the East Monsoon and West Monsoon did not differ significantly; however, there is a tendency that the Cd content in the shells is higher in the East Monsoon than in the West Monsoon. The heavy metal content in *P. viridis* was much lower than the heavy metal content in other shellfish species, except for Cd in the West Monsoon which experienced a slight anomaly.

Discussion

Cd Concentration in Seawater

Table 4 shows that Cd concentrations ranged from 0.007-0.009mg/L in the East Monsoon and 0.006-0.009mg/L in the West Monsoon, except at station 4 (harbor pool). In general, this still slightly exceeds the threshold allowed by the Minister of Environment Decree for seawater biota and marine tourism, which are 0.001mg/L and 0.002mg/L respectively. Thus the waters of the Jakarta Bay are no longer suitable for aquatic life as well as for marine tourism and are more suitable for port activities. However, this condition seems to be better than the results of research in the 1990s, such as Diniyah (1995) Jakarta Bay waters contained Cd (0.084-0.096mg/L) and research by Lestari and Edwar (2004), where Cd content was detected in Ancol beach, Jakarta Bay 0.1mg/L. This can happen because there have been many repairs and normalization of the rivers that cross the Jakarta area by the DKI Jakarta government after the 1998 reform until now.

In general, the Cd concentration of water in the East and West Monsoons did not show a significant difference. This can happen, due to weather anomalies and high rainfall in 2020 in the Jakarta area and the occurrence of rain in the dry season (BMKG, 2020).

This causes the dry season to be very short. The Jabodetabek area during August should still be in the peak period of the dry season, but in the last few days, the Jabodetabek area has often been rained with light to moderate intensity accompanied by lightning and strong winds. Rainfall is getting higher in September and the following months so that Jakarta is often flooded. Thus the difference in weather conditions in the East and West Monsoons in 2020, is relatively low which also has an impact on the condition of the waters of the Jakarta Bay. However, there is a tendency that the concentration of Cd in the seawater during the East Monsoon is higher than its concentration in the West Monsoon. This is in accordance with the results of research by Rumanta (2005, 2008, 2014), that the content of heavy metals such as Pb in waters and marine fishery products during the East Monsoon tends to be higher than its content in the West Monsoon.

In addition, there is a tendency that seawater Cd concentrations at each sampling station in the West and East Monsoons are not significantly different. However, the concentration of Cd in seawater at station 4 (0.011± 0.002mg/L) was significantly higher than at the other stations. This can happen because station 4 is a pond of Muara Angke Harbor where many large fishing boats and transportation ships dock and carry out their activities, resulting in a lot of fuel contamination and other pollution. In addition, part of the Angke River also empties into the harbor pond (Rumanta, 2005). Thus it can be understood that the heavy metal content at the station shows the highest levels.

Cd Conten in Sedimen

Table 2 shows that the Cd content in sediments in the West and East Monsoons is still below the threshold value for aquatic biota set by the Indonesian Ministry of Environment Office in 2010 (6.2mg/Kg) and the Wahington Department of Ecology in 2013 (6.7mg/Kg). This is in accordance with the results of research by Edwar (2020), Budiyanto and Lestari (2017) and Barokah *et al.* (2013), which revealed that the average Cd content in Jakarta Bay sediments was still below the threshold determined by the Indonesian Ministry of Environment in 2010. Here there is a contradiction between the Cd content in sediments and in seawater where the content in these sediments is still below the quality standards set by the Decree of the Minister of Environment while in seawater it has exceeded the specified threshold. This usually occurs due to the mobility of Cd which is caused by several things, including salt content and pH (Mamboya, 2007). The Cd content in sediments between the West and East Monsoons (Table 2) did not show a significant difference, but there was a tendency for Cd content in the East Monsoon is higher than the West Monsoon. This can also happen, due to weather anomalies and high rainfall in 2020 in the Jakarta area so that rain often occurs during the dry season (BMKG, 2020). This condition allows the dynamics of heavy metal pollution in Jakarta Bay waters in 2020 to not be too high.

The mean Cd content in the sediments in the East and West Monsoons at station 2 and 3 was significantly lower than the content at other stations. This can also happen because in that location there is a lot of green mussel cultivation. Meanwhile, green mussels are one of the organisms that are able to absorb and accumulate heavy metals from waters which are quite effective (Rumanta, 2005; Prihatini, 2013; Boening 1999; El-Moselhy and Yassien, 2005).

Cd Content in Shellfish soft tissue

Based on Table 3, it was revealed that the Cd content or levels in the soft tissues of all shellfish were still below the threshold set by SNI (2009) and CCFAC (1999) 1mg/Kg. This is in accordance with the results of research in recent years such as Wahyuningsih *et al.* (2015) and Barokah *et al.* (2019) which reveal that Cd pollutant levels in Jakarta Bay are still below the allowable thresholds of SNI (2009) and BPOM Head Regulation No. 5 of 2018. This may occur in line with the improvement in the management and improvement of the rivers that cross the city of Jakarta, since the 1998 RI Reformation (Rumanta, 2005).

From these data it also appears that the Cd level in the soft tissue of *P. viridis* was significantly lower than that of *M. meretrix* and *A. antiquata*. This is possible because *A. antiquata* and *M. meretrix* live by immersing themselves in the mud, while *P. viridis* is by sticking to hard substrates, such as wood, bamboo, hard mud, fish farming nets, and ship hulls with byssus thread (Cappenberg, 2008). In addition, there is a tendency that the Cd content in *A. antiquata* is higher than other shellfish. This is because *A. antiquata* lives by immersing its body half-buried in mud (Aprilia and Sudibyo, 2019), while *M. meretrix* lives by immersing itself in sediment or sand with a fine texture (Novita, 2018).

Cd content in shellfish soft tissue between monsoons in this study did not show a significant difference. This may be due to the climatic conditions in 2020, rain occur almost all year round and the dry season is quite short and wet in the East Monsoon. However, there is a tendency that the Cd content in shellfish soft tissue in the East Monsoon is higher than its content in the West Monsoon. This is in accordance with the results of research by Rumanta (2005) which shows that the heavy metal content of marine fishery products in the East Monsoon tends to be higher than the West Monsoon. This occurs because Cd in seawater (Table 1) and sediment (Table 2) also tends to be higher in the East Monsoon than the West Monsoon.

Cd content in shellfish shells

Table 4 shows that the Cd content in shellfish shells is much higher when compared to the Cd content in soft tissues (Table 3). This happens because heavy metals such as Pb or Cd can substitute and disguise themselves as calcium ions in the process of forming shell structures, such as the formation of bone tissue in fish (Rumanta, 2015).

Thus shellfish shells can accumulate Cd properly. This is very beneficial for the life of shellfish, because the high absorption capacity of shells for heavy metals can reduce the accumulation of heavy metals in the soft tissues of shellfish.

The Cd content in shellfish shells in the East Monsoon and West Monsoon was not significantly different, but there was a tendency that the Cd content in shellfish shells in the East Monsoon was higher than its content in the West Monsoon. This can also happen, due to weather anomalies and high rainfall in 2020 in the Jakarta area as well as the occurrence of rain in the dry season (BMKG, 2020). Thus the weather conditions in the East and West Monsoons in 2020 are relatively the same which also has an impact on the condition of the waters of the Jakarta Bay.

The content of heavy metals in the shell of *P. viridis* was also significantly lower than that in *A. antiquata* and *M. Meretrix* species. This is also possible because *P. viridis* and *M. meretrix* live by immersing themselves in the mud, while green mussels live attached to hard substrates, such as wood, bamboo, hard mud, fish farming nets, and ship hulls with threads byssus (Cappenberg, 2008).

Conclusion

Based on the results and discussion above, several conclusions can be drawn that the concentration of Cd in seawater still slightly exceeds the threshold determined by Minister of Environment Decree No. 51 of 2004 for seawater biota, namely 0.001mg/L. The content of the heavy metal pollutant Cd in the sediments of the Jakarta Bay waters is quite low, still below the threshold value for aquatic biota set by the Ministry of Environment in 2010 (6.2mg/Kg) and the Wahington Department of Ecology in 2013 (6.7mg/Kg). The water and sediment around the green mussel cultivation area has the lowest Cd content among other sampling stations, this is due to the absorption of green mussels for pollutants, especially heavy metals, which is quite high. The Cd content in the soft tissue of shellfish is generally still below the threshold specified by SNI 2009 and CCFAC 1999. The Cd content in shellfish shells is much higher than its content in the soft tissue, because heavy metals are very easily accumulated by the parts of the shell whose forming structure is mostly composed of calcium compounds.

Acknowledgements

This research was funded by the Open University Research and Community Service Institute (LPPM UT). I would like to thank all parties who have helped and collaborated in this research, especially Mrs. Anna Ratnaningsih, a lecturer at the Open University FKIP, Mr. Rony M. Kunda, a lecturer at Patimura University, LIPI laboratory staff and Mr. Yani, a Muara Angke fisherman, who assisted in taking research samples.

Conflict of interest:

The author declares that there is no conflict of interest.

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