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Heavy metal pollution and its relation to the malformation of green mussels cultured in Muara Kamal waters, Jakarta Bay, Indonesia

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ABSTRACT

Jakarta Bay has become contaminated by both organic and inorganic pollutants, including heavy metals. This study aimed to examine the effect of heavy metal pollution on green mussels cultured in Muara Kamal Waters, Jakarta Bay over seven months. In this research, the water quality was assessed, through measuring the concentrations of the heavy metals, Hg, Pb, Cd, Cr, and Sn in the water, and in the tissue of green mussels that had been cultured there for seven months. The percentage of congenital abnormalities (malformations) in the green mussels was analyzed descriptively and the relationship between the water quality, heavy metals, and green mussel malformation was studied through principal component analysis (PCA). The result showed that the heavy metals concentrations in the water and sediment exceeded the quality standard at Muara Kamal but that in other respects the water quality was quite good. The green mussels cultured there for seven months had accumulated high concentrations of heavy metals, and ± 60% of them had malformations of their shells. Based on the heavy metal concentrations in their bodies, the main cause of malformations in green mussels was suspected to be Pb, Hg, and Sn. However, the result of PCA showed it was the interaction between nitrogen compounds, phosphate, turbidity, salinity, pH, as well as the heavy metals in the water that determined the green mussel abnormality.

1. Introduction

Nowadays, technology is progressing rapidly, but its development often puts stress on the environment, leading to the degradation of the land, water, and air, resulting in the disruption of environmental functions. Technology often uses materials that are not environmentally friendly and that cause pollution due to the production of hazardous and toxic waste. These hazardous and toxic materials can cause various problems, not only health issues, but also economic loss. Because the sea is lower than the land and air, pollutants from everywhere end up in the sea.

Jakarta Bay is contaminated by hazardous and toxic waste (Cordova and Riani, 2011) because of the increasingly widespread development in the city and hinterland areas of Jakarta Province (Riani, 2009). Additionally, the high intensity of activities in residential and industrial areas, transportation, the seaports, hospitals, the fishing industry, trading, services, etc., increasingly worsen the pollution in Jakarta Bay (Cordova and Riani, 2011). According to Kumar et al. (2015), besides domestic and industrial waste, pollutants may also come from agricultural drainage, chemical waste spills, and the gasoline used for fishing boats. In addition, the residential areas, both in the main areas and the hinterland of Jakarta, generally discard their liquid waste directly into the rivers which empty into Jakarta Bay (there is no Waste Water Treatment Plant (WWTP)) (Riani et al., 2015). According to Napitupulu (2009) there are still many industries that do not have any WWTP and not all industries with a WWTP operate it all the time; so that the amount of waste produced is more than can be adequately treated (Riani et al., 2005; Riani, 2015). This happens in Muara Kamal, in which parts of the land are industrial zones and the waters are used for green mussels farming.

Riani (2009) stated that Muara Kamal waters had been contaminated by heavy metals. Heavy metals, in addition to causing a decline in water quality, can also accumulate in the body of living organisms (Frazier, 1979; Gregory et al., 1995; Feraro et al., 2006; Weber, 2006; Riani, 2009; Cordova, 2011; Takarina et al., 2013). Even metals that are essential for the body can, in a high concentration, cause toxic effects (Qin et al., 2015), because those heavy metals inside the body will bind to the sulfhydryl groups and then cannot be released (Goyer, 1986; Manahan, 1995). In Muara Kamal, the biota that are accumulating the most heavy metals are green mussels (Riani, 2009). These heavy metals cause damage to the gills and hepatopancreas in the green mussels and also interfere in their reproduction (Riani, 2011). Heavy

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metals are also teratogenic, which means they cause congenital defects (Gooding et al., 2003; Horiguchi et al., 2006; Feraro et al., 2006; Lugowska, 2007; Riani et al., 2014). The heavy metals in Muara Kamal waters have resulted in 13.33% of immature green mussels having malformations (Cordova, 2011).

The pollution in Jakarta Bay tends to be high (Riani, 2010), which is believed to explain why the occurrence of abnormalities in green mussels is high too. The abnormality (malformation or deformation) seen in green mussels is in the abnormal shape of their shells. However, information regarding this subject was available only from the research done by Riani (2006) and Cordova (2011). This study aimed to reveal the potential impact of pollution on green mussels cultured for seven months in Muara Kamal, Jakarta Bay.

2. Material and methods

2.1. Location and equipment

The research was conducted in Muara Kamal, Jakarta Bay, Jakarta Province, in the estuary area, at a distances of ± 1000 m, ± 2000 m, ± 3000 m and ± 4000 m from the coast, at the time of the lowest tide, as well as in Onrust Island (± 5981 m). The materials used in this study were samples of water, sediment and green mussels from each observation site, as well as chemical compounds for analyzing the water quality, the heavy metals and for preservation.

In this study, all the green mussels were to be cultured in Muara Kamal for seven months. However, the green mussels cultured in the mouth of the river died. It might as a result of particularly high level of pollution, so the locations of green mussel farms from which the samples could be obtained are shown in Table 1.

The equipment used for the chemical and water quality analysis were, AAS (Atomic Absorption Spectroscopy - Perkin Elmer PinAAcle 900 H), GPS (Global Positioning System), mussel culture equipment and calipers to measure the thicknesses of the shells.

2.2. Water samples

The analysis of water quality was done at the beginning, middle and end of the observation. Water quality parameters i.e., salinity, temperature, pH and turbidity were measured in the field (in situ), whereas chemical oxygen demand (COD), nitrate, nitrite and heavy metals (Pb, Hg, Cr, Cd and Sn) were analyzed in the laboratory. The water samples for the heavy metals examination, were analyzed using the standard methods of APHA (2012).

2.3. Green mussel samples

At the end of the observation, as many as 10 green mussel samples were taken randomly from each site, then the entire bodies of these 10 green mussels were mixed, after that the subsamples were taken to be analyzed for the content of Pb, Hg, Cr, Cd and Sn, using AAS, with reference to APHA (2012). The malformation of the green mussels in the sample was observed using the methods from Riani (2006) by measuring the height/thickness of the shells at 300 samples/site, 3 times. Subsequently, the percentage of mussels that had a malformation was calculated.

Table 1
Sites of green mussel sampling in Muara Kamal waters.

	(1000 m)	(2000 m)	(3000 m)	(4000 m)	(Onrust)
S	06° 05′ 12.0″	06° 05′ 01.9″	06° 04′ 26.6″	06° 04′ 13.2″	06° 02′ 05.7″
E	106° 43′ 51.9″	106° 45′ 10.2″	105° 45′ 11.6″	106° 45′ 10.2″	106° 44′ 05.7″

2.4. Quality control and quality assurance

As a quality control and quality assurance of heavy metals analysis on AAS, certified reference material (CRM) was measured from ERA (for sediment) and FLUKA (for water). The analysis of CRM measured as a sample, still within the standard range of both CRM. AAS recovery rate showed =95%. The value indicates AAS by the method being in a valid and controlled condition.

2.5. Analysis of data

The data of water quality was descriptively analyzed by comparing it with the seawater quality standard contained in the State Minister for Environment (2004). The relation between the water quality, the heavy metals and the malformation of green mussels was analyzed by principal component analysis (PCA).

3. Results and discussions

In this study, the average water quality at each observation site is listed in Table 2, and the average heavy metal concentrations in the water are shown in Table 3.

The turbidity, salinity, water temperature and pH of the sites within 1000 m of Onrust Island were in a good condition. However, the nitrate, phosphate, and ammonia in all observation sites exceeded the threshold, except at Onrust Island where phosphate was still below the threshold. It was also found that the turbidity in the estuary had exceeded the threshold. Only in Onrust Island was the COD low. The presence of nitrite was detected in the estuary, at distances of 1000 and 2000 m from the shore.

Temperature, salinity and pH of the water were normal (Table 2). However, the nitrate, phosphate and ammonia in almost all sites exceeded the thresholds/quality standard (State Minister for Environment, 2004). This finding reinforces the result of a study done by Damar (2004) indicating that Jakarta Bay has been heavily contaminated by organic waste; as well as Riani (2010) who stated that Jakarta Bay has been heavily polluted by organic waste originating from anthropogenic activities on land.

The heavy metals Pb, Hg and Cd that are dissolved in the water, generally have exceeded the specified quality standard (Table 3). But the Cr^{6+} was still below the threshold, and the Sn was very low. These high heavy metals concentrations supposedly come from industrial activity in the industrial zone of Muara Kamal as well as from its hinterland with a very dense population and many diverse economic activities. As stated by Patel (2015), the high heavy metal concentration in waters, is generally derived from the substantial anthropogenic input from the densely populated surrounding areas. According to Shivakumar et al. (2014) heavy metals in waters commonly come from industrial and urban wastes that are discarded into rivers. Riani et al. (2015) said that in 13 watersheds which empty into Jakarta Bay, the number of domestic WWTPs is minimal and none of the existing domestic/home industries have a WWTP. According to Napitupulu (2009) it is very evident that many industries in Jakarta do not have a WWTP, and many of those that do, do not use it. Shivakumar et al. (2014) stated that the disposal of industrial and municipal wastes into the rivers, has resulted in the accumulation of metals in fish.

The marine contamination of green mussels by heavy metals is very dangerous to anything that eats the mussels, especially to human, especially in the hepatopancreas and gills (Riani, 2004). It also can interfere in their continuing survival, due to the interference in the process of spermatogenesis (Jalius et al., 2008a) and oogenesis in green mussels(Jalius et al., 2008b), which can change the community structure in aquatic ecosystems.

In this study, there was no data available on the heavy metal concentrations in green mussels cultured in the estuary of the river, because all the mussels died in the first month of observation. The heavy