Zinc content in water, sediment, and soft tissue of green mussel *Perna viridis* in Demak, Indonesia

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Abstract. Coastal region of Demak is an important area for fishermen, for mussel fishing, mainly green mussels (*Perna viridis*). However, industrial activities and household waste disposal around the waters affects coastal water quality. This study investigates zinc content in water, sediment, and soft tissue of *P. viridis*, as well would like to determine safe limit consumption of the mussels collected from Demak coastal area. All samples (water, sediment and mussels) were collected from 5 stations, and each station was divided into 3 substations as repeated sampling. Stations 1 to 5 are located at Sayung River, river mouth, right breakwaters area, offshore, and left breakwaters area, respectively. *P. viridis* samples were divided into three groups based on shell length (SL) namely, small (<4 cm SL), medium (4-6 cm SL) and large (>6 cm SL). Analysis of heavy metal content was performed by using AAS (Atomic Absorption Spechtrophotometer). The results showed that Zn content of in the water at all stations exceeding the threshold value of sea water quality standard. Similarly, Zn content in the soft tissue of the mussels at each station has exceeded the threshold which has been determined by Indonesian Government. There is a positive relationship between shell length and heavy metal content in soft tissue of *P. viridis*. The maximum tolerance to consume small size of *P. viridis* (size that mostly caught by fishermen) for people with an average weight of 45 kg can consume small size of mussels up to 3,980.1 g/week. While for those with an average weight of 60 kg can consume small size of *P. viridis* up to 5,306.8 g/week.
Key Words: heavy metal Zn, pollution, threshold, bivalves, maximum consumption.

Introduction. Natural resources and services of coastal and marine environments have been utilized for many activities, including household and industries, which have caused various problems (Williams 1996; Dahuri 1998). Generally dangerous pollutants coming from industrial waste, particularly involving industry in the production process as well as from the settlement activities (Palar 2012). Several pollutants entering the sea among them are nutrients, heavy metals, oil, hydrocarbon, pesticides, etc. Small amount of nutrient in the water will give positive impact on organisms (Ambariyanto & Hoegh-Guldberg 1997, 1999). However, high levels of pollution will cause damage to the environment including organisms, as well as to the people who use them. Pollution impacts on organisms include the decline of natural populations towards extinction and declining production (Gray 1979; Ambariyanto 2017). While the impact upon the community, mainly result in health issues.

Demak coastal area is located in the northern coast of eastern part of Central Java island. The area has been used as a location for aquaculture and fishing of marine organisms, including mussels. In addition, Demak is also known as location where industrial and human settlements exist. Several industries that occur in the area are paints industry, furniture, household appliances, electronic equipment's, printing, metal, as well as garment industry (Maryuli et al 2012). The increasing number of human activities that generate heavy metal waste will also increase environmental pollution, including in marine areas (Islam & Tanaka 2004; Kucuksezgin et al 2006; Ambariyanto 2011). This allows the accumulation of heavy metals in marine organisms, including mussels. Many marine organisms are capable of accumulating heavy metals (Mikac et al 1985; Islam & Tanaka 2004; Handhani et al 2017; Nurjanah et al 2018; Supriyantini et al

2018). Pagoray (2001) reported that bivalves are capable of accumulating contaminants such as pesticides, hydrocarbons, heavy metals and others in the body tissues. They even can be used as biological indicators since they are sedentary (sessile) organisms and filter feeders.

There is a growing concern on the content of Zn on marine organisms particularly on mussels (*Perna viridis*) since they have been consumed by coastal community around the area. Utilization of polluted mussels will be harmful to human health, according to Widowati et al (2008), if the Zn accumulation in the human body exceeds the specified tolerance limits can cause acute toxicity where symptoms can include stomach pain, diarrhea, nausea, and vomiting. Previous study reported that high content of Zn in water, oyster (*Saccostrea cuccullata*) and sediment of Loskala estuary due to anthropogenic activities, industrial activities and household discharges (Emersida et al 2014). While Indriana et al (2011) reported that Zn content in *Isognomon ephippium* and *Crassostrea* sp. from East Flores was ranged between 73.21 and 4781.02 mg kg^{-1} and have exceeded the standards quality of Indonesian government through Health Ministry Decree 0375/B/SK/1989. Similarly, Damaianto & Masduqi (2014) states that high content of Zn at Tuban coastal waters is caused by human activities such as shipping, fishing port activities, fish markets and industries.

The present study investigates the zinc content in water, sediment and soft tissue of *P. viridis* and also calculates the safe limit consumption of the mussels.

Material and Method. The study was conducted at Demak coastal area, north eastern coast of Central Java Island. Sampling of water, sediment and green *P. viridis* were done at five stations. Each station was divided into 3 points (substations) as repeated samplings. Station 1 was located at Sayung River, a location that is close to the residential and industrial areas that are suspected to contain heavy metals. Station 2 was located in the river mouth. Station 3 was located in the area of breakwaters at right side of the river mouth. Station 4 is located offshore. Station 5 in the area of breakwaters at left side of the river mouth. Selection of the stations was based on the movement of currents passing through the industrial area that contained borne waste from the land as well as possible natural resources (Figure 1).

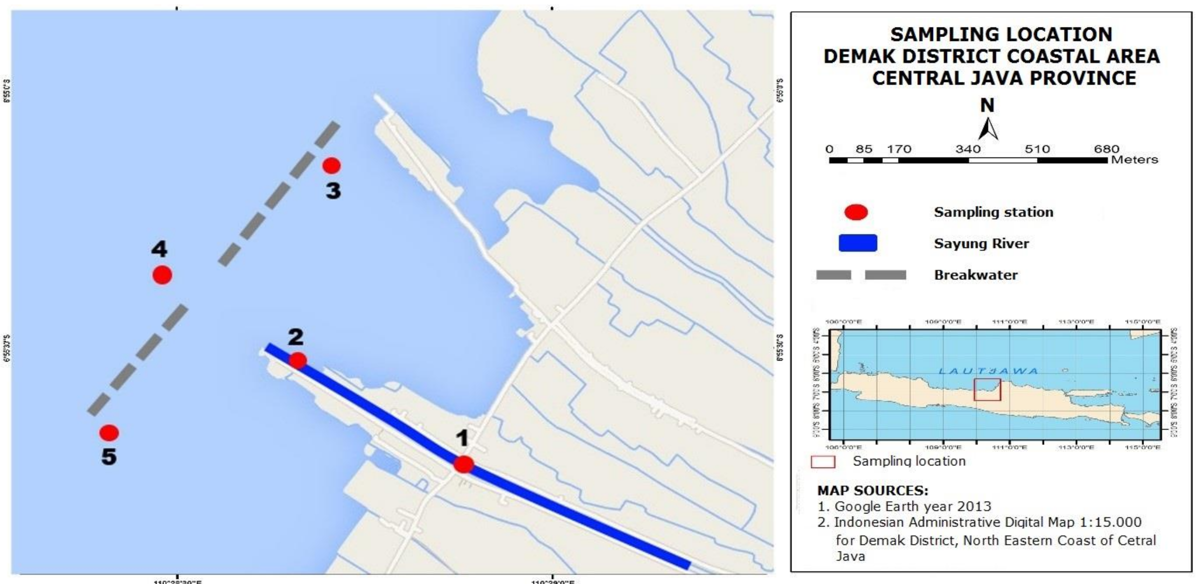

Figure 1. Location of the five sampling stations at Demak coastal area, Central Java Province, Indonesia.

Water samples were taken from surface waters at each station with three replication. The samples were kept into polyethylene bottles (600 mL) preserved by adding 0.5 mL of 65% HNO_3 (Lestari 2004). All filled bottles were stored in ice box and taken to laboratory. Sediment samples were collected using sediment Grab and the samples placed into polyethylene containers. Sediment samples used were taken from the middle of the sediment on the grab to avoid any metal contamination. All filled containers kept in ice box (Rochyatun et al 2006). *P. viridis* samples were harvested by hand (hand sorting) (Annurohim et al 2006) and they were placed in labeled bags. All the bags were also stored in ice box. The mussels were grouped into three sizes, i.e. small (<4 cm shell length/SL), medium-sized (4-6 cm SL) and large (>6 cm SL) (Poutiers 1998).

The Maximum Weekly Intake (MWI) and Maximum Tolerable Intake (MTI) were calculated by using the formula proposed by Azhar et al (2012) as follows:

$$MWI\ (g) = Weight \times PTWI$$

$$MTI = MWI / Ct$$

Where:
Weight - body weight assumptions (for people with 45 kg or 60 kg body weight);
PTWI - Provisional Tolerable Weekly Intake issued by related food agency (mg/kg body weight);
Ct - Concentrations of heavy metals found in the soft tissues in mussel (mg/kg).

Results and Discussion

Zn content in water. Zn content in water column at all 5 stations were ranged from ND (not detected) to 0.0687 mg/L, with the highest concentration at station 2 i.e. 0.0687 mg/L, followed by station 4, 3 and 1 and with the lowest concentration at station 5, i.e. ND (Figure 2). The high concentration of Zn stations 2, 4 and 3 was probably due to the fact that most of the pollutant originating from artificial sources of anthropogenic, land based activities as well as from natural resources (Palar 2012). In addition, concentration of heavy metal in water is also influenced by current direction, current speed, salinity, pH and other factors (Moriarty 1988; Hoshika et al 1991; Halang 2007; Rahayu et al 2009).

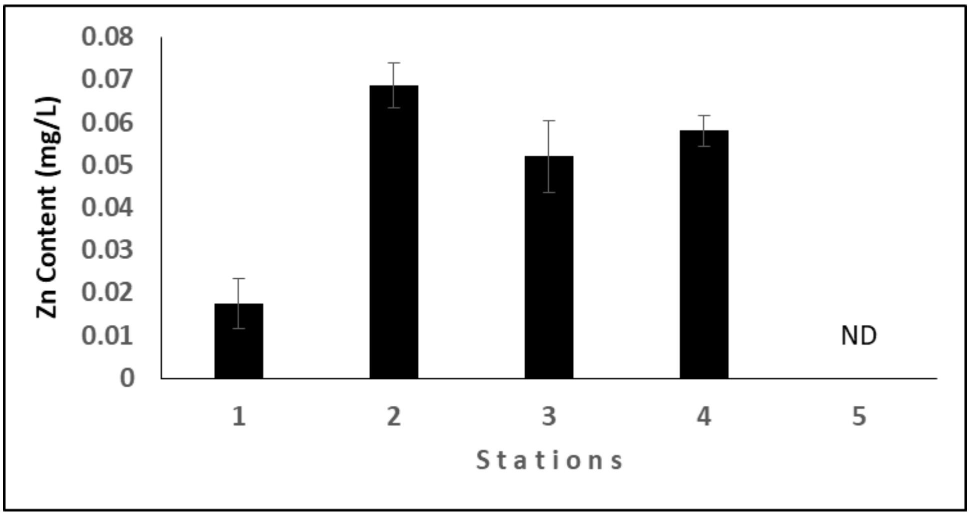

Figure 2. Average (±SD) Zn content in the water of each station at Demak coastal area. (ND= Not Detected; St. 1 = Sayung river; St. 2 = river mouth; St. 3 = right breakwater area; St. 4 = offshore station; St.5= left breakwater area).

It is interesting to find that the concentration of zinc at station 1 and 5 were low. The possible explanation is the fact that at station 1 we found high water temperature i.e. 32.9^{O}C, the highest compare with other stations. According Rahayu et al (2009) at warm water conditions or high temperature, dissolved oxygen capacity is reduced. In the water that lack of oxygen (anoxic), heavy metals will be difficult to dissolve and they easily settle. This resulted in lower Zn concentration of the water at station 1 because it settles on the sea floor or sediment. In addition, the content of ZN at station 5 was not detected by AAS (Atomic Absorption Spectrophotometer). This is possibly because of the dynamic movement of sea water that is influenced by several physical factors such as wind, currents, waves and tides, causing continuous dilution that resulted in low Zn content at station 5. According to Moriarty (1988) the cause of the decrease in the quantity of heavy metals of waters are the tidal cycle.

The results also showed that Zn concentration at station 2, 3, and 4 were 0.0687 mg/L, 0.0527 mg/L, and 0.058 mg/L, respectively. These values have exceeded the threshold value for marine water quality standards for marine life set by the Ministry of Environment of Republic of Indonesia No. 51/2004 which is ≤0.05 mg/L (Kepmen L H 2004). While Zn concentration at station 1 and 5 were below the maximal admissible limit.

Zn content in sediment. Zinc content in sediment collected from all 5 stations at Demak coastal area were ranged from 32.91 to 76.31 mg/kg. The highest Zn concentration was found at station 4 (79.31 mg/kg) and the lowest concentration was at station 1 (32.91 mg/kg) (Figure 3).

According to Odum (1971), the river mouth and its surrounding is an area of the waste and the landfill materials carried by the river flow. The high concentration of heavy metals in the station 4 is closely connected with the activity in the mainland areas such as industry, agriculture and domestic waste which are carried away by water flow of river. Settlement of heavy metal into sediment also depends on the water current. Heavy metal in the clay particles will be settled when water current is very low. In addition, the presence of heavy metals is influenced by the dynamic movement of water such as currents, tides, and wind (Suprapti 2008).

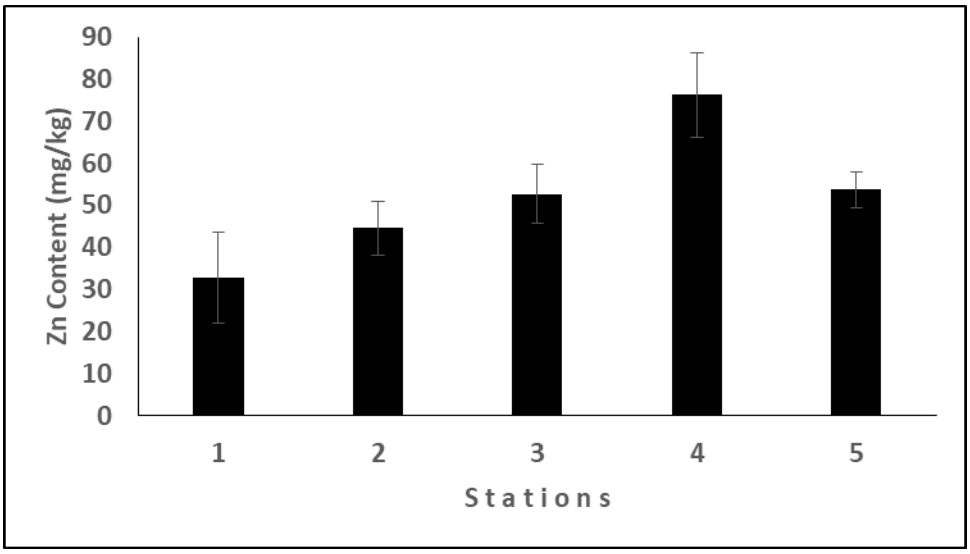

Figure 3. Average (±SD) Zn content in sediment of each station at Demak coastal area St. 1 - Sayung river; St. 2 - river mouth; St. 3 - right breakwater area; St. 4 - offshore station; St. 5 - left breakwater area.

Zn content in soft rissue of *P. viridis*. The value of zinc content in soft tissue of *P. viridis* varied with size and station (see Table 1). Smaller size tends to have smaller zinc content (mg/kg). Riget et al (1996) stated that in mussel, *Mytilus edulis,* there is a positive correlation between size and the ability to accumulate heavy metals. It is believed that during their growth, the ability to accumulate metals also increases. Interestingly, the highest average content of zinc in the present study was found in middle size *P. viridis* (1,258.85 mg/kg). This result is in accordance with the opinion of Amriani et al (2011) who states that the soft tissue of blood clams (*Tegillarca granosa*) have a tendency for high levels of zinc on the shells that have medium or large size. Annurohim et al (2006) stated that during the process of metabolism, when it reaches its peak, the capability to accumulate heavy metal also increased. This is what allows the higher concentration of heavy metals in bivalves during the productive period (medium and large sizes); while the decline in the concentration of heavy metals thought to be caused by the process of physical depuration of heavy metals based on time. This process may cause the concentration of heavy metals in the soft tissue decrease Prasetya (2007).

Table 1
Average (±SD) value of Zn content in soft tissue of *Perna viridis* collected at Demak Coastal Area

Stations	*Zn Content (mg/kg)*		
	Large size	*Middle size*	*Small size*
1	904.6±50.54*	1261.1±19.5*	109.1±2.8*
2	871.36±29.18*	2703.4±43.8*	58.25±1.14
3	257.8±40.98*	842.36±22.3*	65.6±3.04
4	1245.03±36.62*	1045.7±26.33*	53.41±1.51
5	356.27±10.9*	441.7±6.4*	109.2±2.63*
Average	727.01±411.80	1258.85±826.12	79.11±27.76

The standard quality according to Decree of Health Ministry of Republic of Indonesia No.0375/B/SK/1989 for human consumption (100 mg/kg).
***** Exceed the standard quality.

Based on the Decree of Health Ministry of Republic of Indonesia No. 0375/B/SK/1989, the content of Zn in soft tissue of most *P. viridis* collected from different stations of Demak coastal area exceeded the standard quality. According to this decree, the maximum concentration is 100 mg/kg.

Shell length and Zn content relationship. The average size of the mussels collected from the 5 stations at Demak coastal area are relatively similar (see Table 2). The average value of length, width and thickness are 4.12±0.17 cm, 2.03±0.09 cm, and 1.31±0.08 cm, respectively. The results of the regression test for the size of all mussels and zinc content found the equation: Y= 4.295 + 0.001X, with the value of the correlation coefficient (r) = 0.396. There is a positive relationship between mussel size (SL) and Zn content in their soft tissue even though in low category.

Table 2
Average morphometric values of *Perna viridis* collected from Demak coastal area

Station	*Length (cm)*	*Width (cm)*	*Thickness (cm)*
1	3.89±1.28	1.91±0.66	1.19±0.43
2	4.27±1.66	2.09±0.76	1.40±0.60
3	4.22±1.52	2.09±0.82	1.38±0.44
4	4.24±1.67	2.08±0.82	1.29±0.51
5	4.01±1.12	1.96±0.60	1.29±0.33

Maximum weekly consumption. Demak coastal community understanding on the effect of heavy metal pollution on human health is very limited. When they intake of heavy metals is in a high quantity it can be harmful to their health (Manullang et al 2014). Zn metal acute poisoning can cause disturbances in the digestive tract, stomach pain, diarrhea, vomiting and nausea (Widowati et al 2008). The value of Maximum Weekly Intake (MTI) and Maximum Tolerable Intake (MTI) varied between human body weight and size of the mussels (see Table 3). The results showed that MWI value for zinc that can be consumed by people with an average body weight of 45 and 60 kg are equal to 315 and 420 mg/kg, respectively. Therefore, the value of MTI for small mussels collected from Demak coastal area that can be consumed by person that have 45 and 60 kg body weight are 3,980.1 and 5,306.8 g/week, respectively.

Table 3

Maximum intake of *Perna viridis* for human consumption per week

Size class	*Weight (Kg)*	*MTI (g)*	*MWI (μg)*
Large	45	727.02	315000
	60	969.36	420000
Middle	45	250.22	315000
	60	333.63	420000
Small	45	3980.1	315000
	60	5306.8	420000

MWI - Maximum Weekly Intake (μg for humans with average weight 45 and 60 kg);
MTI - Maximum Tolerable Intake (g/week).

Conclusions. Zinc content of the water from the 5 stations of Demak coastal area ranged between Not Detected (ND) and 0.0687 mg/L and in 3 stations has exceeded the threshold of seawater quality standard of the Indonesian government. While zinc content in sediment in all stations were relatively high ranged between 32.91 and 79.31 mg/kg. Zn content in soft tissue of *Perna viridis* collected from all stations varied between stations and size of the mussel, and the average highest zinc content was those with medium size mussel (4-6 cm SL). The relation between zinc content and mussel size (SL) showed week positive correlation. The maximum tolerance for human to consume *P. viridis* from Demak coastal area especially for small size mussel (<4 cm SL) were established at 5,306.8 and 3,980.1 g/week for people with an average weight of 60 and 45 kg, respectively.

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