Contamination of Heavy Metals (Pb and Cu) at Tin Sea Mining Field and Its Impact to Marine Tourism and Fisheries

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Abstract

The dynamics of heavy metals (Pb and Cu) distribution near sea mining locations can show a negative impact on fisheries resource management. The study was conducted at the coastal area of Tanah Merah Beach, Central Bangka Regency, the geographical location at 02o12'50 "S and 106o13'00" E. This study aims to determine the extent of heavy metals (Pb and Cu) distribution adjacent sea mining field and its impact on marine tourism and fisheries. Purposive sampling method was used to identify the sampling locations from 13 closest locations to the farthest from marine mining sources. The result show that the closest and farthest Pb and Cu values from the tin mining activities were 0.16 mg.L-1; 0.03 mg.L-1 and 0.02 mg.L-1; <0.003 mg.L-1. The Hydro-oceanographic conditions from the highest to the lowest water currents of 0.03 m.s-1 - 0.001 m.s-1. This research represented the east monsoon, which showed that the heavy metal distributions dynamics are not too distance-reaching due to weak water currents, so that the dilution and sedimentation rate is slow. It is stated that the waters are polluted where the highest contamination value is indicated by the location closest to the source of marine mining and further weakened at the location farthest from the source of pollutants. Environmental impact from that activity has significantly threatened marine tourism and fishery activities by reducing economic benefits that given from marine and coastal environmental. Urgently, it is necessary to regulate like zoning tin mining activities and sites for the sustainable common purposes and prevent conflicts.

Keywords: distributions, environmental impact, heavy metal, mining, Pb and Cu

Introduction

Tin mining (Sn) activity is a local economic activity that is one of Bangka Belitung Island's primary sectors. Bangka Belitung island is in the western Indonesia, known as a marine tourism site and most of the population in coastal areas depends on fisheries activities (Valeriani *et al.*, 2015; Bidayani *et al.*, 2019). In recent decades, tin mining activities continuously cause a decrease in water quality and marine biodiversity, and this could affect people's economic activities, including marine tourism and fisheries (Nurtjahya *et al.*, 2017; Yulianti, 2019). Policymakers face a trade-off between taking sides with mining activities or community economic activities in marine tourism and fisheries. To describe this problem, we need a solution based on the causal aspects of tin mining

on marine tourism and fisheries. One of them is by conducting research that focuses on suspected contamination of heavy metals in waters. All offshore mining including the tin mining activities have thrown away their tonnes waste and thus it becomes sediment covering coral reef, algae habitat, and other marine biota (Charlier, 2002). It is estimated that 50% of the coral reef in Bangka Belitung's waters is damaged due to sedimentation of mining waste. Small scale fishers feel the impact of this because their fishing ground has been damaged. Tin Mining activities in Bangka Belitung have been reported since 2015, causing conflicts between miners, fishers and tourism actors (Haryadi *et al.*, 2018). Mining pollution has led to the general degradation of coastal and marine ecosystems. Pollution along the coast and in the oceans has already altered the structure and function of phytoplankton, zooplankton, benthic, and fish

populations. The effect of pollution on fisheries (decreased productivity) and marine tourism (due to destroyed coral reefs and blocked access by mining facilities) is of particular concern (Islam *et al.*, 2004; Steel, 2013).

Tin mining activities in the land to the coastal and marine areas are thought to cause ecological damage to both areas. Furthermore, the water's function will be reduced if the beach and the sea waste more and more. The exploitation of tin mining in coastal and ocean areas naturally leaves waste such as tailings runoff, oil, damage to seabed land structure, and sea noise. Wastes, including heavy metals in the waters, flow from the surrounding land to the sea. It will change the quality of seawater, thereby reducing the carrying capacity of these waters. Heavy metals in waters related to marine biota according to Ministry of Environmental Decree of 2004 No. 51 such as Mercury (Hg), Chromium (Cr), Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn), and Nickel (Ni). The common heavy metals polluting waters in urban areas are Pb, Zn, Cu, Cd, and Co (Bibby and Webster-Brown, 2006; Cirik *et al.*, 2012). According to Thomann and Muller (1987), The United States for the Environmental Protection Agency (USEPA) has established a list of pollutants that are mostly wasted into the environment including Copper (Cu) and Lead (Pb). The increase in the content of heavy metal elements is one of the problems and water quality limitations.

The geochemical fraction of heavy metals are essential in biological processes in ecosystems. This fraction component is intended to be absorbed by creatures that live on life (Wang *et al.*, 2015), which can be accumulated in the body of marine biota directly through the food chain. These heavy metals also meet the safe limits of what represents an essential aquatic source for human food (Puttiwongrak *et al.*, 2019). The distribution of Pb and Zn dissolved may vary according to season and tidal conditions. The presence and effect of metals in the system are determined by several main factors such as heavy metals and the composition of soluble fractions and heavy metal particulates in the waters (Hamad *et al.*, 2012). Further, Najamuddin *et al.* (2016) stated that the concentrations were influenced by season, with the Pb and Zn's sources derived mainly from rivers and natural sources. Therefore, waters that contain metal pollutants can spread in all directions and it is necessary to know their value.

The dissolved metal concentrations of Pb, Cd, Cu, and Zn in the Bangka Regency especially Kelabat Bay, are generally relatively low and safe for biota life. The concentration of Pb, Cu, and Zn in sediments is twice as high as the outer bay and is not influenced by factors season (Arifin, 2011). Previous research of the same type on Bangka Island needs to be done elsewhere to compare the impacts of mining activities. In terms of the importance of the problem for ecosystems and aquatic resources, it is very essential to know the dynamics of heavy metal pollutants' distribution due to mining activities at sea. This study aims to determine the dynamics of the distribution of heavy metals (Pb and Cu) waters at tin sea mining field and its impact for marine tourism and fisheries activities.

Materials and Methods

The study was conducted in April 2019 with the location in the waters around the coast of Tanah Merah, Central Bangka Regency, the geographical location at 02°12'50 "S and 106°13'00" E (Figure 1). The selected sampling location is the fishing ground area for most fishers on the coast of Tanah Merah and Tanjung Gunung. There are coral reefs in the selected area, which are one of the attractions of local marine tourism.
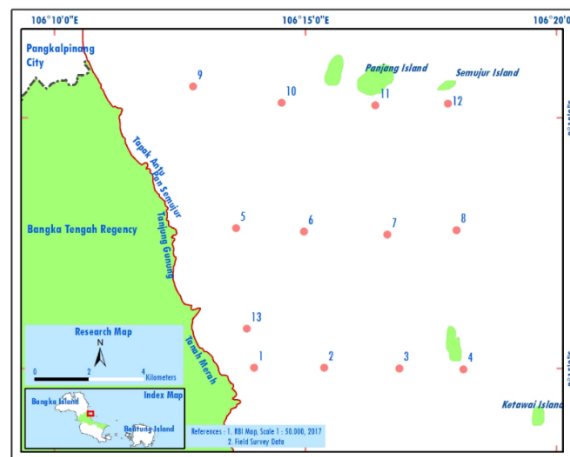

Figure 1. Map of Sampling Area on The Coast of Tanah Merah, Bangka Belitung Islands Province, Indonesia

Purposive sampling method from the 13 closest locations to the farthest from marine mining sources with Pb and Cu parameters. Equipment for measuring hydro-oceanography and water quality, namely current meters, DO-meters, hand refractometer and salinometer, Secchi disks, ±5 GT vessels equipped with GPS map 585 Garmin (measuring time, coordinates, temperature, and water depth), sample bottles to analyze content lead (Pb) and copper (Cu) in waters.

The samples were taken then analyzed by the laboratory in Baristand Palembang. Data analysis with Indonesian Standard (SNI 6989.6.2009 for Cu and SNI 6989.8.2009 for Pb) for quality control (Baristand Laboratory, 2019). The results of the Pb and Cu analysis are then compared with the seawater quality standard for marine tourism and marine biota according to the Ministry of Environmental Decree of 2004 No. 51.

Result and Discussion

The fact is that location of station 13 is a source of sea mining that has the opportunity to pollute the sea waters where around there are fishing locations from the closest (stations 1, 2, 5, 6) to the farthest (stations 4, 8, 9, 12) from the source (Figure 1). The results of the analysis are presented in Table 1. The location of marine tourism is on small islands, especially Ketawai Island and Semujur Island. Field data shows that the survey was conducted during relatively weak water currents in the morning (Table 2). Information on the content of heavy metal elements (Pb and Cu) in the sediment at five stations (9-13) around the Tanah Merah coast, namely Pb with a range of 2.19-15.09 ppm and Cu with a range of 1.35-2.56 ppm (Ahmad, 2013).

The utilization of small islands in Indonesia is prioritized for conservation, education and training, research and development, marine culture, tourism, fisheries and marine business and sustainable fishing industry, organic agriculture, animal husbandry, and/or national defense and security (Law of 2007 No. 27 juncto Law of 2014 No. 1). Coastal research and development can be carried out in marine areas where there is already another activity at that location, for example mining activities in the sea. Where is Bangka Island, which has abundant tin ore resources, has no zoning regulations until March 2020. Therefore, the area from the coastline up to 12 miles to the sea has no legality of permanent land use. This is what supports the need to control regional governance so that the pace of development can be controlled and not degrade the environment, especially coastal areas. Offshore mining can reduce water quality and change the seabed, which can cause changes in biodiversity, including damage to coral reefs as fish habitat. Onshore mining activities can reduce biodiversity and cause flooding and infrastructure damage (Nurtjahya et al., 2017). Of course, mining activities in the sea will reduce the quality of marine biodiversity.

Marine mining activities on the Tanah Merah coast (Figure 1) show community tin mines and the presence of suction boats. Current patterns strongly support the dynamics of the distribution of heavy metal pollutant content (Pb and Cu). The presence of heavy metals Pb, Cd, and Cu is strongly influenced by the sediment's organic matter content and grain size. Heavy metal content will increase with increasing organic matter in sediments (Maslukah, 2013). Relative abundance of trace metals in sediments was in the order of Zn > Cu > Ni > Cr > Co > Pb > Cd. Zn, Cu, and Ni (Ahmed et al., 2017).

Table 1. Heavy metals content from each station

No	Station Survey	Pb (mg.L^{-1})	Cu (mg.L^{-1})	Quality Standards*)		Annotation	
				Pb	Cu	Pb	Cu
	22 April 2019						
1	001	0,12	0,03	0,005a;0,008b	0,050a;0,008b	>ab	>ab
2	002	0,12	0,02			>ab	>ab
3	003	0,05	<0,003			>ab	<ab
4	004	0,11	<0,003			>ab	<ab
5	005	0,13	<0,003			>ab	<ab
6	006	0,14	<0,003			>ab	<ab
7	007	0,08	<0,003			>ab	<ab
8	008	0,07	<0,003			>ab	<ab
9	009	0,10	<0,003			>ab	<ab
10	010	0,16	<0,003			>ab	<ab
11	011	0,14	<0,003			>ab	<ab
12	012	0,16	<0,003			>ab	<ab
13	013	0,02	<0,003			>ab	<ab

Note: * Quality Standards based on Ministry of Environment Decree of 2004 No. 51 Appendix II and III (a = for marine tourism and b = for marine biota).

Table 2. Hydro-oceanographic conditions on Tanah Merah Beach

No	Station Survey	Temperature (^oC)	Salinity (%o)	Water current (m.s^{-1})	Water clarity (%)
1	001	30.4	29	0.15	56.0
2	002	30.6	28	0.23	35.6
3	003	30.2	26	0.23	35.9
4	004	30.2	27	0.23	28.9
5	005	29.0	28	0.15	42.6
6	006	30.2	27	0.18	37.0
7	007	30.7	26	0.09	35.1
8	008	30.3	30	0.16	65.8
9	009	29.6	29	0.09	43.4
10	010	29.7	30	0.08	81.4
11	011	29.7	30	0.12	51.4
12	012	29.9	29	0.07	40.3
13	013	29.2	29	0.12	52.4

Note: * Weak current speed (<0.25 m.s^{-1}), normal (0.25-0.3 m.s^{-1}), strong (> 0.3 m.s^{-1}) (Adibrata *et al*., 2013)

Further, the heavy metal concentrations of the sediments were found to decrease in the sequence Fe>Ti>Mn>Zn>V>Cu>Cr>Ni (Syakti *et al*., 2015). According to Table 1, where there is the lowest Pb data at stations 3, 7, 8, and 13 with respective values of 0.05; 0.08; 0.07; and 0.02 mg.L^{-1}. This low value may indicate that when the data was collected, the water flow conditions were weak so that pollutants were not stirred, and tin mining was not operating. At other stations, there is a Pb value of more than or equal to 0.10 mg.L^{-1}. The Pb value at all stations is stated above the seawater quality standard for marine tourism and marine life. The amount of Pb content in the sample exceeds the National Standard threshold for the Pb content in seawater for marine biota of 0.008 mg.L^{-1} and causes Pb pollution around the mining area. The disposal of waste water from mining activities continues into the waters without the filtering process causes the pollution of Pb in the mining environment. Although the Cu value is not as high as the Pb value at the same station, one of the waters' heavy metal elements has provided evidence that the waters have experienced environmental pollution. Environmental pollution is the entry or inclusion of living things, substances, energy, and other components into the environment by human activities so that they exceed the established environmental quality standards (Law of 2009 No. 32). The evidence indicates that marine mining activities cannot be conducted side by side with activities for marine tourism and fisheries.

Marine tourism activities that have developed around the Tanah Merah coast waters are on the island of Ketawai with swimming, snorkeling, diving, panoramic views of the small island, and turtle landing tours. Evaluation of the condition of coral reefs in the East of Ketawai Island is Good so that it can be recommended for diving tourism locations, in the South and North of the island are Good and Bad (Medium) so that it can be recommended for the location of the prospective core zone for marine protected areas (Adibrata, 2013), further stated that the threat to the health of coral reefs around Ketawai Island mainly comes from anthropogenic activities. Besides, mangrove tours around the mouth of the Kurau river. This marine tourism activity is closely related to good water quality conditions where the most influential hydro-oceanographic parameters include chemical content (Table 1), turbidity or clarity (brightness) of seawater, temperature, salinity, water current (Table 2), and depth. Turbidity from seawater can affect coral reefs growth, where the biota is one of the most attractive marine tourism objects. The more turbid waters, the growth of coral reefs can be hampered, and the more siltation, siltation can occur and coral polyps can be closed so that the chance of bleaching and damage to coral reefs will increase. The movement of water affects coral growth because the movement of water for aquatic organisms is related to oxygen supply (Osinga *et al*., 2011) and food (Sebens *et al*., 1998). Also, the process of hydrodynamics (currents and turbulence) can reduce the level of attack on coral-eating biota (Lenihan *et al*., 2015). Although corals have a mechanism for cleaning up sediment deposits, excessive sediment deposition will affect coral growth (Roy and Smith, 1971). The content of heavy metals (Pb and Cu) in the waters can cause bioaccumulation and biomagnification in marine biota including in especially filter-feeding bivalves (Ip *et al*., 2005) and coral reefs (Setiawan, 2013). In addition to coral reefs, heavy metals can accumulate in mangroves. Avicennia marina is a type of mangrove that absorbs the heaviest metals with a Pb content of 24.2 ppm and Cu of 71.2 ppm (Setiawan, 2013).

Fishery activities that have developed around the coast of Tanah Merah are fishers who catch various types of fish and land around the West

Kurau river's mouth. Also, there is fish farming around Semujur Island, including grouper farming. In that situation change, conservation of biodiversity and degradation of fish habitat assumes the highest priority gradually (Mohan *et al*., 2016). This fishery activity is closely related to the condition of good water quality, where the most influential hydro-oceanographic parameters include turbidity or clarity (brightness) of seawater, chemical element content, temperature, salinity, and depth. Turbid seawater can affect the distance of fish caught by fishers. The more turbid waters in a wide area, the chances of catching fish are increasingly complicated and further its reach, which can increase fishers's fuel costs. However, we have little evidence if the fisher's catch from each fishing ground point at the sampling location (station) is different because fishers generally reveal that their catch has decreased. Aquaculture requires good water quality conditions, including clear, and does not contain heavy metal elements in the waters. The content of heavy metals (Pb and Cu) in the waters can lead to bioaccumulation and biomagnification in marine biota, including grouper farming. Economically, this condition has impacted decreasing income for fisher and grouper farmers (Nurtjahya *et al*., 2019; Ramadona *et al*., 2020). Research by Sulista *et al* (2019) states that income from fishing activities is higher (IDR 100,000/day) compared to income from tin mining (IDR. 150,000/3 months)**.** The value of heavy metals (Pb) in grouper meat of 6,500 mg.L^{-1} indicates that this value is far above the quality standard threshold value of 0.050 mg.L^{-1} with a difference of 6,450 mg.L^{-1} above the quality standard, it is suspected that grouper may have experienced biomagnification from the food he ate (Adibrata *et al*., 2013), found heavy metal concentrations (Pb and Cu) in fish and shellfish (Arifin, 2011). Besides, the presence of fish parasites such as ectoparasites attached to the fish skins of floating net cage systems (KJA) is thought to be related to the hydro-oceanographic dynamics such as current conditions and water temperatures (Adibrata *et al*., 2020). The weaker water currents and the lower the water temperature can increase ectoparasites against fish in floating cage, this is certainly very detrimental to grouper fish farmers.

The distribution of heavy metals in the sea under conditions of weak water currents is homogeneous for the east monsoon (April - October). Comparative research is needed to determine the condition of heavy metals distribution in the western season, where the flow of waters is greater (Arifin, 2011) states that seasonal factors do not influence the distribution of heavy metals. Tidal water plays (a significant role where this research is carried out on the tide's condition to the tide so that tidal currents strongly influence the water flow. Waters at high tide indicate that the mass transfer of water from the edge tends towards the middle with a certain angle. This mass of water certainly carries the burden of heavy metal pollutants that have been stirred due to mining at sea.

Furthermore, Arifin (2011) states that dissolved heavy metals are generally relatively low with the following ranges, Pb (1.0-26.0 µg.L^{-1}) and Cu (1–2.0 µg.L^{-1}). Levels of heavy metals Pb, Cd, Cu, Hg, and As the surface of Natuna waters are so small that they are still below the quality standard and concluded that they are still not polluted (Sagala *et al*., 2014). Ahmad (2013) states that the heavy metals in sediments based on the Pollution Load Index and Geoaccumulation Index are still lower than the permitted threshold value for sediments. Some literature shows it dissolved heavy metals in the water column are affected and scattered according to water flow patterns. The dynamics of the distribution of heavy metals are not too far-reaching because of weak water currents so that the rate of dilution and sedimentation rate is slow, and stated that the waters had been polluted where the highest contamination value is indicated by the location closest to the source of marine mining and is weakening at the location farthest from the source polluter.

Conclusion

This study provided the closest and farthest Pb and Cu values from the community tin mining sources were 0.16 mg.L^{-1}; 0.03 mg.L^{-1} and 0.02 mg.L^{-1}; <0.003 mg.L^{-1}. Hydro-oceanographic conditions in the form of the highest to lowest water currents of 0.03 m.s-1 - 0.001 m.s-1 indicate that heavy metals in the waters are slow to be diluted caused by weakness of water current. However, according to seawater quality standards for marine tourism and marine biota, as dominantly the Pb value is above the water quality threshold and Cu values that are already above, and some are still below seawater quality standards applicable in Indonesia. This condition has threatened the sustainability of marine tourism and fishery activities, especially in areas located near tin mining sites. The research in the east monsoon, the dynamics of heavy metals' distribution are not too far-reaching due to weak water currents, the dilution and sedimentation rate is slow. It is stated that the waters are polluted where the highest contamination value is indicated by the location closest to the source of marine mining and further weakened at the location farthest from the source of pollutants. Tin mining pollution, especially Pb and Cu, has accumulated and has contaminated the waters in the target area, the impact of which is directly felt by fisheries and

marine tourism actors in the case of water clarity down indicated that decreased productivity of catches and aquaculture, as well as damage to coral reefs which are a marine tourist attraction. The findings of this study have supported the literature, the evidence provided confirms that zoning is needed to regulate activities and the location of tin mining as a win-win solution so that industrial interests and local community activities can coexist sustainably and avoid conflicts in the use of open waters areas, thus reducing the environmental impact of these activities.

Acknowledgements

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