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Research Article

Quality assessment of mangrove growing environment in Pasuruan of East Java

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Abstract: The occurrence of pollution in mangrove land is due to changes in physical, chemical and biological properties of water because of the increasing human activities that produce problems due to residential and industrial wastes and other related activities, or due to seawater tide. The existence and presence of residential and industrial wastes in soil sediments can disturb the environment that in turn will threaten mangroves growth. This study was aimed to reveal the presence of heavy metals in sediment shown by environmental changes of water polluted by residential and industrial wastes. The study was conducted in field plots located at five watershed areas of Andil, Porangan, Kacar, Gombal and Krondo in Tambak Lekok Village of Pasuruan District, East Java. Field exploration and observation was started from waterfront and riverside vegetations. The exploration was made 300 m toward inland, perpendicular to the edge of the waters. The sediment samples of mangrove stands were collected at three points for each plot. The thickness of the collected sediment samples was ± 10 cm from the surface. Sediment samples were analyzed for heavy metals (Pb, Cr, Zn and Cu) and texture. The results showed that the Pb severely polluted the Gombal watershed with a concentration of 7.24mg/kg. The lowest Pb concentration of 7.24 mg/kg was observed for Andil watershed. Except for Andil watershed, Cu heavily polluted all the watersheds studied.

Keywords: *heavy metals, mangrove, polluted watershed*

Introduction

The occurrence of pollution in mangrove land is due to changes in physical, chemical and biological properties of water because of the increasing human activities that produce problems due to residential and industrial wastes and other related activities, or due to seawater tide. The existence and presence of residential and industrial wastes in soil sediments can disturb the environment that in turn will threaten mangroves growth and biota in the ecosystem.

Heavy metals that are dissolved in the water bodies under certain conditions can change into toxic sources to aquatic life. Although the toxicity caused by one type of heavy metal to all aquatic biota is not similar, the destruction of a biota group can make the breaking of life chain. This situation can certainly destroy the order of aquatic ecosystems. The absorption capacity of heavy metals is associated with the size of particles in the sediment. The type and form of the most toxic heavy metal is Pb with a range of toxic levels (1.000-10.0000 ppb), Cd (0.1-50 ppb), Hg (5-4.000 ppb). In relation to the above matter, it is necessary to study the presence of heavy metals in aquatic environments that are harmful to the growing environment of mangroves.

Heavy metals that are produced as main materials, auxiliary materials or wastes of a variety of activities such as mining, industry and transportation, are classified as hazardous and toxic materials known as B_3. The B_3 wastes can be found in water, soil and air such as arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd) and chromium (Cr).

Mangrove forest is a group of plants that grow along the coastline of the tropics to the sub-tropics. Mangrove forests have a special function in the environment containing salt and landforms of coast areas with anaerobic soil reaction. Mangrove forest is dominated by several tree species that are able to live in salty waters. Sustainability and ecological function of mangrove forest ecosystems in a series of ecological research is needed because ecological data are sustainable resource database (Kusmana, 2006). According to Kitamura et al. (1997), the spread of true mangrove forest (main and additional components) ranges from 70 species, divided into 40 species in Southeast Asia, 15 species in Africa, and about 10 species in the United States.

Based on Law Number: 41 of 1999 on Forestry, mangrove is a forest ecosystem. Therefore, the government is responsible for the management based on the benefits and sustainability, democracy, justice, solidarity, openness and integrity. Ritohardoyo et al., (2017) pointed out that the emergence of development in coastal regions can result in erosion and mangrove ecosystems damage. This disaster can destroy settlements, agricultural land, and public infrastructures. According Indawan et al. (2012), efforts to conserve mangrove forests are desperately needed considering the decreasing area of mangrove forests.

The damage of mangrove forests is mainly caused by the increasing pollution of seas and rivers by pollutants originating from households, industries, and agricultural activities in the form of organic compounds such as hydrocarbons and heterocyclic (Indawan, 2008). Biggan and Poonam (2014) stated that concentrations of heavy metals in waters and sediments because of human activities on land and spatial distribution in the sediment could be used to predict the danger of pollution on aquatic ecosystems.

This study was aimed to reveal the presence of heavy metals in mangrove growing environment in Pasuruan of East Java.

Materials and Methods

The study that was conducted from March to December 2014 was divided into two phases, i.e. exploration and field sampling, and laboratory analyses. The research location is located in the coastal mangrove areas in Tambak Lekok Village of Pasuruan District, East Java (112^{o}33’5”-113^{o}05’37” E and 7^{o}32’34”-7^{o}57’20” S). Fieldwork was conducted on plots of five watersheds (Andil, Porangan, Gombal, Kacar and Krondo).

Field exploration and observations were started from the waterfront and riverbank vegetations. The field exploration was made 300 m toward inland, perpendicular to the edge of the waters. Sediment samples from heavy metals contaminated mangrove stands were collected using a stainless steel grab sampler. The thickness of the collected sediment samples was ± 10 cm from the surface. The sediment samples were then put into polyethylene bottles and stored in an icebox for laboratory analyses. At each survey location, samples were collected from three points for each plot. The sediment samples were placed into Teflon beakers and dried in an oven at a temperature of 105^{o}C for 8 hours. The dried samples were then rinsed with free heavy metals distilled water. After drying, 5 g of rinsed samples were homogenously ground and destructed in a Teflon beaker with HNO_3/HCl (1:3) at a temperature of 100^{0}C for 8 hours (Loring and Rantala, 1977).

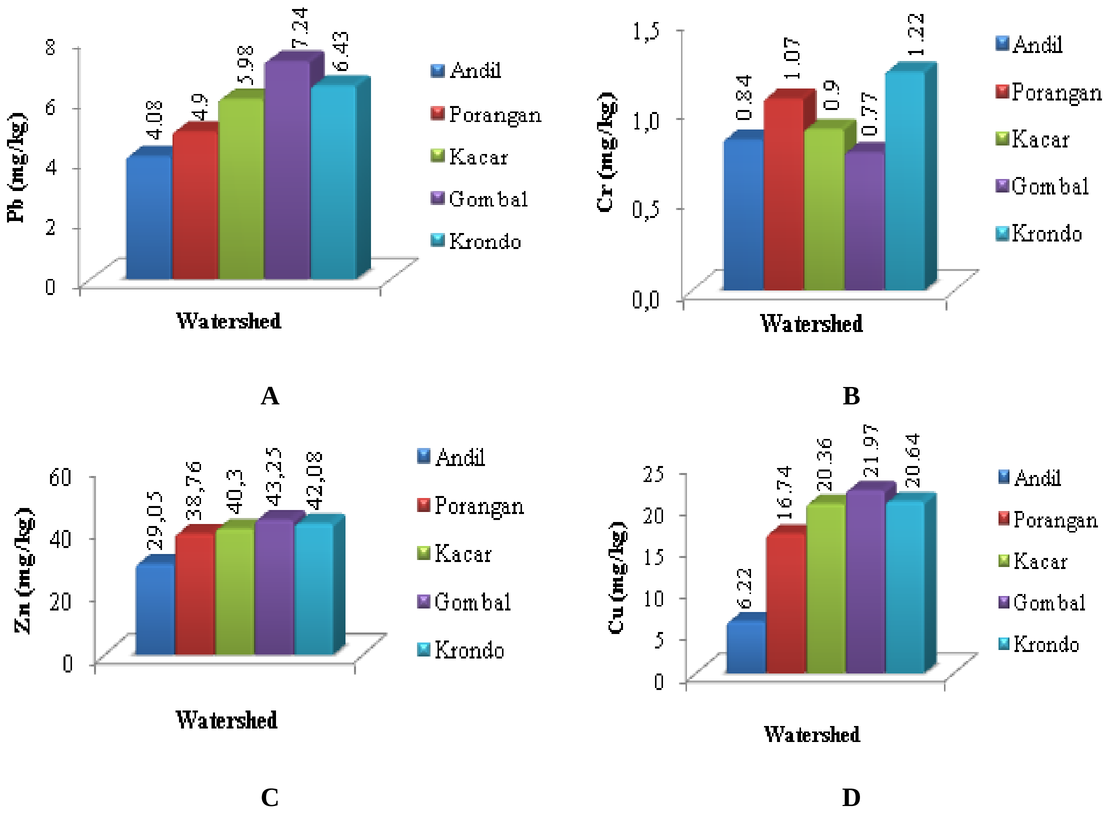
Composite sediment samples were analyzed for pH- H_2O (pH meter), organic-C and total N (atomic absorption spectrophotometer), available P (Bray II), cation exchange capacity and base saturation (Flame photometer, atomic absorption spectrophotometer, calorimeter). Heavy metals (Pb, Cr, Zn and Cu) contents in the sediment samples were determined using AAS with a mixture of air-acetylene flame. Texture of sediments was analyzed by wet sieving method (Rahayuningsih, 2007).

Results and Discussion

Based on the results laboratory analyses of the sediment samples, the highest content of Pb (7.24 mg/kg) was found in Gombal watershed (Figure 1A), followed by Krondo (6.43 mg/kg), and Kacar (5.98 mg/kg). This indicates that the three watersheds were severely polluted with Pb. While Andil and Porangan watersheds were lightly polluted with Pb. With the highest Cr concentration of 1.22 mg/kg (Figure 1B), sediments from all watersheds studied were not polluted with Cr.

Zinc slightly polluted the studied areas. The highest concentration (43.25 mg/kg) was observed for Gombal watershed (Figure 1C). Copper severely polluted the watersheds studied, except Andil watershed. The highest concentration of Cu (21.97 mg/kg) was observed at Gombal watershed (Figure 1D). Mangrove forest ecosystems are complex and dynamic. However, the ecosystems are unsteady and unstable. Soils underneath the mangrove forests are categorized as young soils having high clay content, high base saturation, and high cation exchange capacity.

Results of soil chemical analyses showed that the mangrove forest soils of the studied areas had the following characteristics: pH (H_2O) 7.6, organic C 1,13 %, total N 0,11%, available P 14.77 mg/kg, base saturation 33%, cation exchange capacity 30.44 mg/100 kg, and silty clay loam texture (12% sand, 56% silt, 33% clay). Visual conditions in the field showed that Andil watershed soil was sandy clay, Porangan watershed soil was sandy clay, muddy, and humus. Gombal, Kacar, and Krondo watersheds soils were clayey, muddy, and humus. These differences are related to plot locations that are mostly influenced by the tides, waves, substrate, salinity and depth. Organic matter, total nitrogen, and ammonium contents are medium in sections near the sea and high toward the inland (Kusmana, 2006). Mangroves mainly grow in muddy soils; but various mangrove species can grow well in sandy soils, coral, gravel, and even peat. In general, mangrove forest soils are always wet, salty, low oxygen content, and rich in organic matter. The composition and density of species in the mangrove forests are affected by soil texture and ion concentrations (Hamzah and Setiawan, 2010). Results of soil analysis showed that the mangrove forest soil had 83% base saturation (high. The soil sorption complex was dominated by Ca^{2+} 9.94 m/100 g (medium), Mg^{2+} 10.93 me/100 g (very high), K^{+} 2,53 me/100 g (very low) and Na^{+} 1,77 me/100 g (very high). Water salinity and soil salinity are important factors affecting growth and species of mangroves. Mangroves grow well in estuaries with salinity ranging from 10 to 30 ppt. Very high salinity that exceeds surface seawater salinity (± 35 ppt) can adversely affect mangrove vegetation because of negative osmotic pressure that results in stunted mangrove canopies and low mangrove species compositions.



A B

C D

Figure 1. Heavy metals in five watersheds studied

Based on Pb, Zn, Cu concentrations, the watersheds studied were in the following order Gombal > Krondo > Kacar > Porangan > Andil. The highest Pb, Zn and Cu concentrations of 7.24 mg/kg, 43.25 mg/kg, and 21.97 mg/kg, respectively, were observed in Gombal watershed. The lowest Pb, Zn, and Cu concentrations of 4.08 mg/kg, 29.05 mg/kg, and 6.22 mg/kg, respectively, were observed in Andil watershed (Figure 1A, C, D). Based on Pb concentrations of 7.24 mg/kg, 6.43 mg/kg, and 5.98 mg/kg for Gombal, Krondo, and Kacar, respectively, the three watersheds were severely polluted with Pb, while the Andil watershed and Porangan watersheds were only slightly polluted. A similar status of Cu also occurred in all watersheds, except in Andil watershed (6.22 mg/kg). According to Government regulations number : 85/1999, the watersheds studied were not polluted wit Zn and Cr. Heavy metals that are dissolved in water bodies under certain conditions can change into sources of toxic materials for the aquatic life. Although the toxicity caused by one type of heavy metal to all aquatic biota is not the same, the destruction of a group can make the breaking of life chain. This will in turn destroy the order of aquatic ecosystems. Mangrove communities often get supplies of pollutants such as heavy metals originating from industrial, household and agriculture wastes (Indawan et al., 2012). Heavy metals dissolved in water will move into the sediment if they bind to free organic matter or organic material that coats the surface of the sediment. Vidya and Patil (2016) reported that the level of heavy metals in the sediments showed significant correlations with pH, calcium carbonate and organic matter.

Organic matter in sediments and metal absorption capacity are closely related to particle size and surface area of absorption, so the concentrations of metals in sediments are usually influenced by the particle size in the sediment. According to Rochyatun and Rozak (2007), environmental factors such as pH, hardness, temperature and salinity also affect the toxicity of heavy metals. Decrease in pH will increase the toxicity level of heavy metals, while the high hardness will form complex compounds that settle down in the bottom waters. The presence of Pb in the coastal region can probably come from batteries, PVC, pigment paints, fertilizers, cigarettes and shellfish containing Cd element.

The serious threats from the outside are derived from watershed management, and the increase of industrial and domestic pollutants entering into the hydrological cycle. The increase of quantities of sediment deposited in the environment can cause the death of mangrove due to the clogged lentil cells. Based on analysis of sediment on Gombal, Krondo and Kacar watersheds, Pb, Zn and Cu heavily polluted the watersheds. The increase of metal in estuarine areas is influenced by sediment factors that affected by pH, organic matter, cation displacement, mangrove species, and mangrove age. Results of soil chemical analysis showed meaning slightly alkaline pH of 7.6. The degree of acidity affects metal toxicity. Water pH is affected by several factors such as photosynthesis activity, temperature, and salinity.

Generally, Pb found in the soil is in the form of organic compounds, hydroxides, oxides, carbonates, and sulfides. These compounds are highly soluble in water, but in water bodies having a pH range of 7-8 tend to be stable. Based on analysis of sediment, Cu heavily polluted all watersheds studied. The existence of Cu is in the form of ionic compounds $CuCO^{3+}$ and $CuOH^{+}$. Usually the amount of Cu dissolved in seawater body ranges from 0.002 to 0.005 ppm. When the solubility of Cu in the seawater body increases exceeding the threshold value, there will be biomagnifications against aquatic biota. According to Simpson et al. (2011), Cu is strongly associated with organic matter in sediments thus reducing the potential for absorption of biota (Simpson et al., 2011). The highest concentration Cr of 1.22 mg/kg was found in the Krondo watershed, and the lowest of 0.77 mg/kg was in the Gombal watershed (Figure 1B). It is suspected that the chemical processes that took place in the water body reduced highly toxic Cr^{6+} into Cr^{3+} less toxic compounds, especially in acidic environments. This condition is determined by a high pH, sediment-shaped clay and high organic matter content (Yoon et al., 2006). According to Amin (2002), the heavy metal content is influenced by sediment, namely: mud > sandy mud > sandy. Maslukah (2013) reported that the concentrations of Pb, Cd and Cu in sediments are positively correlated to the organic matter and sediment grain size.

Suspected source of heavy metals such as Pb, Cr, Zn and Cu, can be derived from the use of fertilizers, pesticides, or of rock or parent material of the soil. The interference of heavy metal pollution in the soil can lead to deterioration of soil productivity that is generated by the accumulation of pollutants. In addition, heavy metals endanger human health from heavy metal contaminated soil. The influence of the dynamics of heavy metals on soil quality standards is closely related to soil properties, especially pH, organic matter, clay minerals, cation exchange capacity, and status of soil oxidation and reduction.

Based on the analysis done, it is known that the sediment samples posed the following characteristics: silty clay loam texture, the ratio C/N 10, organic substances of 1.94%, and CEC value of 30.44 me/100 g. The size of the fine sediment fraction in the form of clay (56%) was larger than the silt (33%) and sand (12%) particles. It is thought that the lands where the mangroves grow in the watersheds studied were formed from the accumulation of sediments from rivers, coastal erosion or carried away from the highlands along the river. Most of the soils came from the accumulation and sedimentation of colloidal substances and particles. Sediment from the river was in the form of muddy soil, while sediments originating from the coastal area were in the form of sand. Degradation of organic materials over time is also parts of the mangrove land that are generally rich in organic matter and have high nitrogen value, depending on the fertility of alluvial material deposited.

Conclusions

The highest Pb concentration (7.24 mg/kg) found in the watershed studied was in Gombal watershed, while the lowest Pb concentration of 4.08 mg/kg was found in Andil watershed. Except for Andil watershed, Cu heavily polluted all the watersheds studied. The highest concentration of Cu of 21.97 mg/kg was also found in Gombal watershed. The overall Pb and Cu contents in the watersheds studied have exceeded the threshold. Suggested efforts that can be made to improve quality of heavy metals polluted mangrove growing environment are growing metal hypperaccumulator plants such as *Elodea canadensis* Michx., *Ceratophyllum demersum* L., *Potamogeton natans* L., *Eichhornia crassipes* (Mart) Solms., *Ipomea aquatic* Forssk., *Rhaphanus sativa* L., *Pisum sativum* L.

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