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INVENTORY OF WATERBIRD SPECIES WHICH ACCUMULATE MERCURY FROM MINING WASTE OF COASTAL AREA NORTH GORONTALO REGENCY, INDONESIA

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Abstract

Artisanal gold mining waste that still contain mercury (Hg) then discharged into rivers and coastal area. Mercury in ecosystem aquatic has influence the food chain of the waterbirds. The objective of this research was to inventory the water birds species in the coastal, and describe the exposure of mercury in the organs of birds. This research conducted to the coastal region of North Gorontalo regency. Collecting data was in the Buladu and Ilangata coastal area. Data analysis to concentration mercury in the body of the water birds using Atomic Absorption Spectrophotometer (AAS) on samples of the kidneys, liver and muscle chest tissue. This study find out four species of waterbirds in the coastal area, also mercury concentrations exposure in the organs of each species, namely: (1) *Butorides striatus*, exposure of mercury 0.22 ppm in kidneys, 0.17 ppm in liver, 12.12 ppm in muscle; (2) *Tringa melanoleuca*, exposure of mercury 0.43 ppm in kidney, 0.31 ppm in liver, 0.31 ppm in muscle; (3) *Actitis hypoleucos*, exposure of mercury 0.19 ppm in kidney, 0.18 ppm in liver, 0.10 ppm in muscle; (4) *Pluvialis squatarola*, exposure of mercury 0.11 ppm in kidney, 0.10 ppm in liver, 0.10 ppm in the muscle. This research indicated that there was mercury pollution in the river, also mercury in food chain of birds living. The research strengthening the scientific knowledge in addressing to threats the bird's biodiversity, also would be use for natural resources development and policy, as well community empowerment.

Keywords: coastal area, food chain, inventory of waterbird, mercury

INTRODUCTION

Gorontalo province has potential gold mining that is currently being traditional management. North Gorontalo regency is one of the areas with mineral potential gold is traditionally managed by the community. Mining activities traditionally processed primarily generate waste containing heavy metals such as mercury (Hg) to contaminate the environment, and ultimately affect the biota (living organisms). Increasingly heavy metal pollution cause public unrest because of the issues that have occurred in Buyat Bolaang regency of North Sulawesi Province, Indonesia. On the report of research carried out by the environmental agency of North Gorontalo regency that traditionally gold miners are indicated mercury poisoning [1]. Although concentrations of mercury very low, but methyl mercury accumulation processes in living things will be continue and enter into the food webs harmful to human health [2].

Gold mining activities in village Buladu North Gorontalo Regency has been done for decades by society. Mercury is used in amalgamation gold processing traditional caused surface tension of mercury higher than water but less than gold. This allows the properties of metals can absorb mercury into gold particles, in addition to more effective, easy, inexpensive and available in the market. The effectiveness of the uses of mercury is also due to the ability of mercury to bind the gold estimated 50-60%. Liquid metal mercury has the ability to bind the metals except

iron and platinum. Mercury is also a solid medium when gold binds with mercury [3].

On the traditional processing of gold, metal mercury from the amalgamation process partially joined with other sand particles thrown into the water bodies, rivers, coastal into the sea. This is due to the leaching of mercury which is mixing with fine-grained sediment so hard separated to the milling process is carried out jointly with the amalgamation process. Therefore, in the leaching process, the mercury in the waste will be carried with the water into water bodies. Estimated globally every year more than 300 tons of mercury evaporates into the air, 700 tons of polluting rivers, lakes and soil, and 100-150 tons of them occurred in Indonesia [4].

Waste of gold ore processing containing mercury discharged into water bodies that pollute coastal area. Mercury was used in gold processing will largely be lost to the atmosphere in the form of Hg(O), but approximately 20% of waste stored in soil and rock or tailing of the mining process . In the soil Hg(O) is oxidized to be Hg(II) and following chemical reactions into a form that is available and easily absorbed by plants and enter the food chain (Krisnayanti *et al*., 2012). Process of aerobic and an-aerobic bacterial decomposition helps mercury in sediments are transformed into methyl mercury [5].

Mono-methyl-mercury abbreviated methyl mercury (CH_3Hg) consisting of methyl (CH3-) bound with mercury atom, sometimes written as MeHg. Methyl mercury ions dissolved in water and are toxic. This compound will be absorbed by aquatic microorganisms and biologically impacts to decline the quality and quantity of aquatic biological resources. When the small organisms would become component of food chain of fish, crabs, shellfish then bioaccumulation will occur in the body of biota aquatic [6], [7], [8]. Along with the food chain of birds in coastal waters, then there is bioaccumulation of mercury in the body of waterbirds that eat aquatic biota.

Mercury, generally as methyl mercury in sea water is absorbed by algae. In aquatic ecosystems such as coastal areas, then the bioaccumulation and result of bioconcentration in adipose tissue aquatic organisms on tropic levels are: zooplankton - small nekton - fish, then larger organism which eat these fish also consumes the higher level of mercury of fish. In this process of predatory fish such as shark or waterbirds which eats fish likely to have higher concentrations of mercury in body tissues than organisms can directly contact with the water. This condition allows more length of mercury stored in the body's fat tissue and an increase toxicity of mercury in predator [9].

Metal mercury into the ecological system can provide successive effect on biota from the lower tropic levels to the top of tropic levels. Fish, crabs and shellfish that live in coastal waters may consume mercury from polluted waters by mercury. These chemicals enter the body of fish through the gills of fish, through the food chain, and the largest number founded in species of carnivorous fish. Birds have a liver organ that absorbs and stores energy reserves for the body. Metal mercury was consumed with meals and distributed throughout the body and partly stored as energy reserves in the liver [10]. This condition can cause abnormalities, diseases and death in birds [11], [12]. Waterbirds that uses the habitat of coastal area are particularly vulnerable to water pollution.

The objective of this study is to inventory of waterbirds and describe exposure to metal mercury in the organ of waterbirds. Other studies only on analysis of mercury in the water, or on the first level of consumer of organisms in direct contact the water. However, this study describes the presence of mercury in the organs of waterbirds as a second consumer level, so that it can be predicted that the food chain of aquatic birds have also contain mercury. If so, then the food webs in aquatic ecosystems have been contaminated by metal mercury. The results of this study contribute to prevent the impact of the flow of mercury in the food chain of aquatic organisms such as fish, shellfish, thereby preventing contamination and poisoning to human body and other fish consumers. Thus, this research strengthening the scientific knowledge in addressing to the environmental crisis by heavy metal waste, and addressing to threats the bird’s

biodiversity.

The government requires the data base of mercury pollution and its impact to the people and other living organisms. The results of this research is the data base, and is expected to become the policy of the local government in addressing to the environmental pollution, natural resources and minerals management, an effort to wildlife conservation and community empowerment based on ecology.

Further research will be done is to develop a model of bioaccumulation of mercury in the food chain based on the coastal area.

RESEARCH METHOD

This research uses a descriptive survey method. Research site was in the coastal area in Anggrek district and Sumalata district, North Gorontalo regency. This site was stated by purposive sampling, based on the reason that there was two major river that are Buladu river and Ilangata river. Both of the river empty into the coastal area in the sea of Sulawesi. The catchment area of the both river was used as a gold traditionally mining area has been managed by people using mercury. Gold mining waste in the form of mud and sand that still containing mercury flowed to the empties into the river and the coastal area. The survey data until to analysis data carried out on June to October 2013.

Primary data consist of waterbirds species that use habitat of coastal area where empties into the Buladu river at $122^0$31'20 "E, $00^0$85'10" N, and Ilangata river at $122^0$46'00 "E, $00^0$72'01" N. The bird sampling location in both the river, see in the map (Fig.1). Species of waterbirds and their intensity to use coastal habitats in the sites can be obtained from interviews to the people. The people who interviewed are resident who live on long time in the coastal, who knows and familiar local names of the waterbird foraging in coastal habitats.

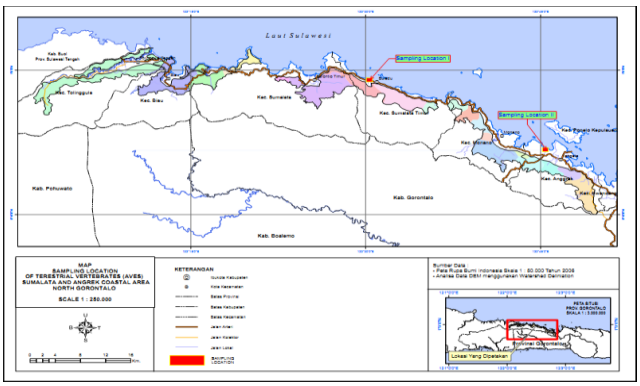

Fig. 1 The map of Sampling Location

The samples of waterbird species adapted to the species that more commonly found by the local people. Each species of waterbird is taken of each bird of two adults. Samples collected by the bird target. Organ of waterbirds which used for the analysis of mercury consists of: kidney, liver, and breast muscle tissue. First handling of organ samples and identification of bird species were conducted in the laboratory of Zoology Department of Biology State University of Gorontalo. Materials and equipment for data analysis are plastic sample storage, sample label paper, alcohol, distilled water, cool box, dissecting sets and identification keys of waterbird. Analysis of concentration mercury levels, then the samples of kidney, liver and muscle tissues of birds sent to the Laboratory Industry Standardization Research Institute in Manado.

Laboratory analysis using AAS (Atomic Absorption Spectrophotometry).

Secondary data is required in the form of a map of the gold mining processing, data of waste disposal and the habitat area where concentrated the waterbirds. This data was obtained in form of document regional environmental status from the government of North Gorontalo regency.

RESULT AND DISCUSSION

Topography of North Gorontalo regency of Gorontalo Province is a flat area between 0-2000 m above sea level, slope covers 46% of land area is surrounded by several large rivers and small. The region has an area of 1777.03 km^2 or 177 703 ha, 198 km long coastline along the coast of Northern Sulawesi. Mining area in North Gorontalo regency consists of area of rock and sand mining quarrying, and the gold mining area. Potential resources of mining and energy consists of gold potential area has 14,800 ha spread over to 8,500 ha in Sumalata district and 5,000 ha in Atinggola district.[13].

Gold mining activities in Buladu area has begun since the Dutch Indies government in the 18^{th} century. Gold mining activities at the site was reopened by the local people traditionally along the river Buladu, estuaries and coastal area. Gold mining activities started by simple mechanization of new mining pits and continued the former mine pits. Buladu river is a large river that across the Sumalata district and empties into the Sulawesi Sea. Based on field observations find out that the river has sedimentation due to activities in the upstream such as cultivation, settlements area causes an increase in the volume of domestic waste into the river through runoff. In addition, around Buladu riparian and coastal estuaries there is artisanal gold mining. Tailing of gold mining though into the river and Buladu empties into the sea of Sulawesi.

Currently processing of gold ore by amalgamation was using mercury. Base on the report of the Environmental Agency of North Gorontalo Regency, that the year of 2010 gold mining activities developed rapidly and the miners approximately 500 people [13]. Field observations in coastal around the empties into Buladu river that there was activities of gold panning by local people. Mining activity is done at some point containing gold by making holes sand. While the gold mining in the Ilangata river region also, the people using the same ways with Buladu. Field observations indicated that the river water containing high sediment due to tailings disposal, as well as farming of the birds.

The tailings put back into the sack average weight of 15 kg/sack, and then reprocessed (second phase) to obtain bullion by amalgamation on tank driven by a waterwheel. Tailing from the second phase of processing is fed back in the river to obtain mercury. Based on reference [13] that amount of mercury that is wasted every month was 30 kg /month or 360 kg/year. Currently, handling process of tailings has not been carried out correctly, due to the lack of awareness of the miners, and mercury pollution control equipment has not been used.

Metal mercury that contaminate water river and coastal area causing organisms in coastal exposure of mercury. When the organisms include in a component of marine food chain and food web of any species of waterbirds, then the body of waterbirds will be exposed by mercury.

The results of this research obtained four of waterbird species that was using aquatic habitat in coastal areas of North Gorontalo regency, those species namely: (1) *Butorides striatus*, (2) *Tringa melanoleuca*, (3) *Acitis hypleucos*, and (4) *Pluvialis squatarola*. This research indicated that all of the waterbirds are predator species of fish and other invertebrate that is related to the morphology of birds and food resources in the coastal region.

Exposure of mercury in each organ of waterbirds based on the results of analysis laboratory samples using AAS method, are summarized in Table 1.

Table 1
Result Analysis of Mercury Exposure in Waterbird Species

Nu.	Name of Species	Average of Mercury Exposure in the Organ of Waterbirds (ppm)		
		Kidney	Hearth	Chest muscle
1	*Butorides striatus*	0.22	0.17	0.12
2	*Tringa melanoleuca*	0.43	0.31	0.31
3	*Actitis hypoleucos*	0.19	0.18	0.10
4	*Pluvialis squatarola*	0.11	0.10	0.10

1) *Butorides striatus*

This species included in the family of Ardeidae and genus of Butorides, the local name known as Kokokan (local name: Tou). This birds eats the fish, insects, and shrimp in coastal habitats, estuaries and ponds. Usually, this species fly foraging alone, sitting on a rock or the edge of the embankment of water while waiting for prey. Based on the analysis of mercury obtained in the kidneys of *Butorides striatus* that is 0,22 ppm, liver 0,17 ppm, and muscle 0,12 ppm. (*see Fig.2*)

Fig. 2 *Butorides striatus*

2) *Tringa melanoleuca*

This species known as Sandpipers, included in the family of Scolopacidae and genus Tringa. Sandpipers is a kind of waterbird eatis crustaceans, insects and invertebrates that live in coastal waters and estuaries. Results of the analysis of mercury in the kidneys of *Tringa melanoleuca* 0,43 ppm, liver 0,31 ppm, and the muscle 0,31 ppm. (*see Fig. 3*)

Fig. 3 *Tringa melanoleuca*

3) *Actitis hypoleucos*

This species included in the family of Scolopacidae and the genus Actitis. *Actitis hypoleucos* known as Sandpipers, a species of waterbird eats crustaceans, insects and other invertebrates that live in sand habitats, mud and estuaries. Results of the analysis of mercury in the kidneys of *Actitis hypoleucos* 0,19 ppm, liver 0,18 ppm, and the muscles 0,10 ppm. (*see Fig.4*).

Fig. 4 *Actitis hypoleucos*

4) *Pluvialis squatarola*

This species known as a big pot included in the family of Charadriidae and genus pluvialis. This waterbird eats invertebrate in muddy and sand habitat in the tidal area, usually foraging in small groups. Based on the result of laboratory analysis, that the exposure of mercury in the kidneys of Pluvialis squatarola 0,11 ppm, liver 0,10 ppm, and the muscles 0,10 ppm. (*see Fig.5*).

Fig. 5 *Pluvialis squatarola*

Species of *Butorides striatus*, *Tringa melanoleuca*, *Actitis hypoleucos*, and *Pluvialis squatarola* are predatory, were living and foraging in the Northern coastal of North Gorontalo. These species feed some fish, insects and other invertebrates in the coastal. The birds were found in coastal areas, especially at low tide which occurs on average two times a day. Most of the birds make their nests on the coast of the Raja islands closest to the northern coastal.

The coastal habitat which used by the birds has impact to exposure of metal mercury in the body. Species Tringa sp. is kind of a higher exposure of mercury in the kidney. The kidney of *Tringa melanoleuca* higher exposure to mercury 0,43ppm then the *Butorides striatus* 0,22 ppm, followed by *Actitis hypoleucos* 0,19 ppm, and *Pluvialis squatarola* 0,11 ppm. In the liver, the largest mercury exposure is still on the bird species of *Tringa melanoleuca* 0,31 ppm, *Actitis hypoleucos* 0,18 ppm, followed by *Butorides striatus* 0,17 ppm, and *Pluvialis squatarola* 0.10 ppm. Mercury is also exposed to the chest muscle tissues, *Tringa melanoleuca* still the largest exposure of mercury in muscle of 0,31 ppm, for *Butorides striatus* 0,12 ppm, then the *Actitis*

hypoleucos and *Pluvialis squatarola* exposed to mercury in their muscles 0,10 ppm respectively.

The habitat of the waterbird species in the coastal district Sumalata and Ilangata district North Gorontalo regency flowing two major rivers. In this region there are artisanal gold mining activities were managed by the people. Currently, gold mining activities not only by the local people but also outsiders. Processing of gold ore was originally done by forming amalgam, which is an attempt to bind the gold ore with metal mercury. Then, the forms of amalgam burned to evaporate or release mercury that separate gold from grain rock or sand particles. Processing of gold and mercury vapor is generated in the form of sewage sludge and particles still contain mercury. This waste was then discharged through the rivers Ilangata and Buladu which empties into the northern coast of North Gorontalo regency

Coastal areas have has higher mercury concentrations than the open ocean. Increasing the depth will further increase the concentration of organic mercury element. Mercury concentrations associated with sediment in the river and estuary. The Buyat bay average mercury concentration in the body shells range from 0,5019 to 2,1529 ppm, and in the sediments ranged from 0,1150 to 1,2341 ppm [14].

Sediment in the river streams and coastal areas still containing Hg2+ ions, then the helps of bacteria will turn into dimethyl mercury $(CH_3)2Hg$ and methyl mercury ion (CH_3Hg+). Volatile dimethyl mercury into the air and by physical factors in the air can be fused with rain water and back into the ground water, rivers and flows to the coastal. Methyl mercury is readily soluble in water and bound water in the tissues of organisms either through the process of bioaccumulation and biomagnification through the food chain. Methyl mercury can be accumulated through a series of plankton, small fish, large fish, and bird predators resulting in enlargement of concentration (biomagnification) up to hundred times to the peak level of tropic organisms. Methyl mercury of fish absorbed through the gills and the food chain. The largest number concentration found in carnivorous fish. Concentrations of mercury were harmful to aquatic biota as a result of methylation from remobilization and other processes that occur in water [15].

When organisms that consume methyl mercury deficiency of enzyme to reduce the mercury content, then methyl mercury will accumulate in the fat tissues of organisms concerned. When the organism is then eaten by a predator, then the fat is absorbed in the intestine and accumulate in the fat tissues of predators. Every level of the food chain there were energy losses, therefore predators must consume more prey in the sense of taking lipophilic substances or fats from their prey. Reference [9] shows that bioaccumulation and bioconcentration of methyl mercury in adipose tissue in tropic levels, as follows: zooplankton, small nekton, other invertebrates, fish, predatory birds and larger animals that eat these fish also consumes the higher mercury. This process explains by reference [5] that is why predatory fish such as shark or other predator birds have higher concentrations of mercury, for example, in fish tissue contains mercury around 0,01 ppm while the shark contains mercury greater than 1 ppm.

CONCLUSION AND SUGGESTION

Species of *Butorides striatus, Tringa melanoleuca, Actitis hypoleucos* and *Pluvialis squatarola* have been exposed to mercury. These species as predators in the coastal ecosystems. They would be biomagnfication in the tropic level (food chain). The position on the tropic level this allows the bird species accumulate higher metal mercury.

Exposure of mercury in the birds which use the coastal habitats of North Gorontalo shows the food chain species of waterbirds that are exposed of metal mercury anyway. Therefore, the local governments are expected to immediately stop the artisanal mining activities to prevent the influence of mercury on human life.

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