POTENTIAL TOXICITY OF HEAVY METALS IN RAWADANAU WATERSHED

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ABSTRACT

The study of the potential toxicity of five heavy metals: Cd, Cr, Cu, Fe, and Zn on human health of people living in the Rawadanau Nature Reserve and its vicinity has been accomplished. Among the five studied heavy metals only cadmium and zinc demonstrated significant correlation of water levels and sediment contents of the heavy metals. Statistical analysis demonstrated water and sediment concentrations of either cadmium or zinc could be correlated by $r^2 = 0.8622$ or $r^2 = 0.8545$ respectively. However, based on the suggested threshold value by WHO on the permissible heavy metals ingested by human body, the water levels of cadmium which was found in the range of 0.01 – 0.05 mg L^{-1} posed more deleterious effects to human health than of zinc which was found in the range of 0.02 – 0.18 mg L^{-1}. Considering that the cadmium is a very toxic metal to biota then the exposure levels of people to the heavy metal must be avoided. This will call for stake holders of Rawadanau Nature Reserve to implement good environmental management practices in order for sustaining Rawadanau as a water provider for industries and public of Cilegon and Serang.

***Keywords**: Rawadanau, Water Reservoir, Heavy Metals, Potential Toxicity, Chronic Exposure*

provided with ice packs until further laboratory analyses. The heavy metals levels of water were analyzed following procedures as described in SNI[(3)] while of sediment samples were determined following procedures as described in SW-846[(4)].

RESULTS AND DISCUSSION

The characteristics of water and sediment samples as well as the analyzed heavy metals content are presented in Table 1. The Water Quality Standard Class III[(5)], as shown in the table, is a Governmental Regulation that classifies a particular function of a water body to be suitable for freshwater aquaculture, husbandry, irrigation, or other purposes that require such a water quality. As can be seen in that table, in general, the threshold parameters of water quality are not surpassed except for some heavy metals at some sampling points. Among several of the analyzed heavy metals, chrome and iron were the heavy metals that did not exceed the maximum permissible value at every sampling point. Even, at Cidanau downstream and Cikalumpang rivers the total chrome were below the limit detection of the method of analysis, i.e. less than 0.01 mg/l.

Statistical analysis of the correlation (r^2) between heavy metals levels in water phase and sediment layers are shown in Table 2. The results show that the water levels for cadmium and zinc both have strong correlation to the sediment levels of the two heavy metals. On the contrary, although the concentration of iron in sediment was extremely high, however, it did not explain the iron levels that present in the water phase. These findings suggested that leaching of iron from sediment into water phase did not take place at a sufficient rate.

The presence of heavy metals in either water phase or soil solution mostly has a link to their levels in sediment or soil. Levels of metals in sediment or soil will determine the buffer capacity of the sediment or soil to metals in

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INTRODUCTION

Rawadanau watershed is an ecosystem of which industrial activities and domestic needs on water in Cilegon and Serang districts of Banten Province are relied on. The area of the watershed is approximately 22.620 ha of which 2.500 ha is dedicated for the nature reserve since 1920s[1]. Within the nature reserve a swampy forest consisted of a variety of endemic plants and also a number of animals reveal the biodiversity of the area that serves as a water reservoir.

According to the law of Ministry of Forestry the status of nature reserve makes the area inaccessible for activities like bush walking, fishing, farming etc. However, at the present, as many as 300 illegal occupants (BKSDA officer, personal communication) have entered the nature reserve and conducting agricultural practices inside, which is strictly prohibited. Because of that, the water quality of the water reservoir has changed considerably. For example algal blooming that is caused by nutrient enrichment has occurred. In addition, despite the illegal logging at upper hill of the watershed, the soil erosion as the result of agricultural practices has created sedimentation problems. The use of fertilizers as well as pesticides is suspected to contribute to the decreasing quality of the nature reserve.

A part from that, the swampy forest that obtains water inlet from 17 tributaries (5 of them delivering water continuously and the rest are intermittently) and delivering out the water through single channel called Cidanau River receives additional pollutants load from domestics that are transported to the water reservoir via some of the tributaries. Definitely, such the conditions induce a threat to the sustainability of industries in Cilegon because of the increasing cost to clean up the contaminated water in order to satisfy the requirements for industrial processes. Also, chemicals present in the water such as heavy metals might induce hazard to humans.

Heavy metals are, by definition of chemistry, a class of metals that having specific gravity of at least 5 fold greater than water. Some of them are essential elements to living organisms and the others are toxic. Essential heavy metals, however, at elevated concentration in human body or, in general, living organism, may cause adverse effects.

The purpose of this study was to assess to what extent the levels of heavy metals that present in the water and sediment of the Rawadanau ecosystem is potentially imposing human hazard. In this study five heavy metals: cadmium (Cd), copper (Cu), chrome (Cr), iron (Fe), and zinc (Zn) were assessed.

METHODOLOGY

Water and sediment samples were obtained at several sampling points as shown in Table 1. The location of sampling points were determined following methods as described in reference 2. Each water sample was collected by immersing a polyethylene bottle of volume 500 ml at depth below 30 cm at position where no water turbulence existed. Immediately after collecting the water a concentrated nitric acid was added to maintain the pH solution < 2.

Then at the same sampling point sediment was taken by using Ekman grab sampler of size 20 x 20 cm^2 and then poured into polyethylene bottle of size 1000 ml. Both water and sediment samples were kept on a cool box

Table 1. Sampling points, characteristics, and laboratory test results of water and sediment samples

processed to produce fertilizers frequently contain cadmium that might be present in the range <10 – 500 mg kg^{-1} as impurity minerals[7]. As the result phosphate fertilizers might be contaminated with such a metal. Runoff of precipitation and irrigation, then, washed out a portion of the metal from field to the swampy forest of Rawadanau. Some remain in soils and the other might be unintentionally included in harvested agricultural products. Such this thing happened on several varieties of rice harvested from several agricultural fields in West Java that demonstrated containing cadmium at levels in the range 0.05 – 0.33 mg kg^{-1}[8]. Cadmium in rice, then, may enter into a food chain and finally reach into human body and by chronic exposure the metal might bioaccumulate to such a level that can cause the emergence of toxicity symptoms.

In addition, several people who are living in the Rawadanau vicinity are also conducting activities like fishing and net-casting in the swampy forest. However, similar to plants that are able to absorb cadmium fish is also capable of accumulating toxic metals. Data gathered from another research demonstrated that Indonesian people might be exposed to toxic cadmium via fish consumptions at levels in the range 8 – 40 μg/day/person[9].

$$\text{Provisional value (PTWI)} = \frac{\text{Rxtx } C_{HM}}{}$$

Although the levels of cadmium in rice or fish are below the PTWI suggested by WHO, however, considering cadmium is easily to accumulate in human body then prolong exposure to the metal will increase the risk to be poisoned by the metal. The disease similar to *itai itai* occurred in Toyama Prefecture Japan may endanger if drinking water is from Rawadanau. The disease was caused by the inhabitants repeatedly consuming rice harvested from fields that were irrigated with cadmium contaminated water[10].

$$PTWI_{Cd} = \frac{21 \text{ day} \times 7 \text{ days} \times 0.05 \text{ mg/l}}{60 \text{ kg}}$$

$$= 0.012 \text{ mg/kg}$$

Cadmium that present in drinking water or

water phase. The capability of sediment or soil to buffer heavy metals in water is controlled by several processes such as adsorption and desorption, precipitation and dissolution, complex formation, or combination of all these mechanisms.

Considering that concentrations of cadmium and zinc were buffered by sediment where the water of which they present was in contact with then it is necessary to evaluate to what extent such a buffer capacity of sediment in Rawadanau Nature Reserve might impose to human threat.

Table 2. Statistical analysis of correlation between water phase and sediment heavy metal content pd"0.05

Heavy metal	r
Cd	0.9623*
Cr	-
Cu	-
Pb	0.3639*
Zn	0.8545*

* = significant ns = non significant

According to World Health Organization (WHO)[6] potential toxicity of a substance to an organism is determined by two parameters, i.e. its hazard value and the exposure level. Multiplication of these two parameters will determine the risk level of the substance to the aforementioned organisms. The WHO[6] has determined that the threshold value for cadmium considered to be safe for humans is quantified as Provisional Tolerable Weekly Intake (PTWI) that is not more than 0.0083 mg/kg body weight. On the other hand the threshold value for zinc is quantified as Provisional Tolerable Maximum Daily intake (PTMDI) that is not more than 1.0 mg/kg body weight.

In order to assess the risk level for cadmium it is assumed that human consumes water 2 liters per day and has mean body weight of 60 kg. By using these assumptions then the potential toxicity of cadmium can be calculated as follows:

$$\frac{R \times t \times C_{HM}}{W_b}$$

Where,
R = consumption rate
t = duration of exposure
C_{HM} = heavy metal concentration)
W_b = body weight

By a similar calculation the obtained PTMDI for Zn is 0.006 mg/kg. Thus, comparing results of these calculations with the threshold value suggested by WHO it is clear that cadmium has and zinc has not exceeded their corresponding threshold value. In another word, such water levels of cadmium imposing more adverse effects than zinc to human health who consumes the water.

The presence of cadmium in Rawadanau is not surprising because of at least 35% of the watershed area was utilized for rice field and other crops[1]. Agricultural management necessitates applying pesticides and fertilizers continuously in order to maintain good harvested products. The use of phosphate fertilizers for crops is suspected to provide significant contribution to the cadmium levels found in the area. Phosphate rocks that are

foods may enter digestive track of humans via foodweb mechanisms and might end up in kidney and liver for years. The potential of cadmium being absorbed by human body multiplies if in human diet is also insufficient of iron or other nutrients[11]. It has also been observed cadmium that presents in metabolism systems capable of disturbing the calcium homeostatis[12] and may cause the bone weakness.

Cadmium is not an essential metal and is not required in metabolism. A person who by coincidence consumes cadmium at elevated concentrations will severely irritate his stomach, leading to vomiting and diarrhea and even might cause death[11].

CONCLUSION

Form this study it is concluded that cadmium that present in water pose a potential to affect human health of people living in and surrounding Rawadanau Nature Reserve. Such levels of heavy metal might provide chronic human health deterioration if long exposure to the heavy metals are not avoided. Thus preventing chronic exposure of inhabitants from the heavy metal must be carried out by Rawadanau stakeholders.

REFERENCES

(1) International Environment Technology Center-UNEP, BPP Teknologi, Center for Water Policy Research-UNE, SEAMED-BIOTROP. 1999. "Technology Needs for Lake Management in Indonesia: Case Studies: Lakes Rawadanau and Rawa Pening Java", Japan: IETC-UNEP.

(2) Hadi, A. 2005. *Prinsip Pengelolaan Pengambilan Sampel Lingkungan,* Jakarta: Gramedia Pustaka Utama.

(3) Standar Nasional Indonesia. 2004 *Air dan Air Limbah*. Metode: SNI 06-6989-4,-6,-7,-16,-17. Jakarta: Badan Standardisasi Nasional

(4) US Environmental Protection Agency, 2005. *SW-846: Test Methods for Evaluating Solid Wastes: Physical / Chemical Methods, 3rd ed*, USA: USEPA.

(5) Governmental Regulation Number 82 Year 2001 on Water Quality Management and Water Pollution Control.

(6) World Health Organization, 2000, "Hazardous Chemicals in Human and Environmental Health, " Translated by: