Risks Assessment Of Cadmium Through Aquatic Biota Consumption From Sentani Lake In Papua, Indonesia

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Abstract

Aquatic environment is becoming vulnerable because of anthropogenic pollutants as a result of industrialization and urbanization activities. The significant increase of population has a linier growth of chemical substance dispose to the environment. This study aimed to investigate the accumulation of Cd in water column, sediment and aquatic biota and to assess the potential human health risks associate with the seafood consumption from Sentani Lake in Papua. Sampling survey was conducted at twelve stations (eleven stations for contaminated site and one as background site) for one time collection in May, 2013. Site-specific exposure parameters such as body weight and consumption rate of fish and bivalve were investigated in inhabitant of along Sentani Lake and in the city using face-to-face surveys. Results revealed some level of Cd concentration in water column were ranged from (0.55 to 1.70 mg L^{-1}), sediment (1.49 to 2.89 mg kg^{-1} dw), bivalve (1.24 to 1.86 mg kg^{-1} ww) and fishes were in the range of (1.18 to 2.89 and 2.29 to 4.34 mg kg^{-1} ww for pelagic and benthic), respectively. In addition, the background site level of Cd were about 0.12 mg L^{-1}, 0.74 mg kg^{-1} dw, 0.28 mg kg^{-1} ww, 0.35 mg kg^{-1} ww and 0.98 mg kg^{-1} ww, respectively. Lower level of Cd were ranged from 8.7 to 24 µg L^{-1}, 317 to 758 µg kg^{-1} dw and 36 to 141 and 119 to 180 µg kg^{-1} ww, respectively. Elevated Cd level were observed in the receiving stream near community housing and in house industry whereas in upstream sites were considerably lower. It is confirmed that, the magnitude values of target hazard quotient (THQ) at those aquatic habitats were still < 1, with the maximum level were 0.144, 0.175 and 0.181 unit less, respectively. These results suggested that municipal waste discharge into receiving water on the Sentani Lake and industrial activities are the major source of Cd pollution to the Sentani Lake. Bivalve and fishes caught from Sentani Lake were still safe to consume, however it may pose health hazards for continual and long period of consumption.

Keywords: *Cadmium, Water column, Sediment, Aquatic Biota, Sentani Lake, Target Hazard Quotient.*

I. Introduction

Pollution of the aquatic toxic chemical both by organic and inorganic is a major factor posing serious threat to the survival of aquatic organisms including bivalve and fish. [1]. Municipal waste, agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities as well as runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals [2].

The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal and municipal waste [3]. Cadmium (Cd) as one of the metallic pollution in aquatic habitat has dramatically increased with anthropogenic activities and obviously may present significant ecological and human health risks. As a non-essential, Cd is widely distributed in the environment [4]; [5] and is a highly toxic element. Ingestion of Cd can result rapidly in nausea, vomiting, abdominal cramp, diarrhoea and headaches [6].

Long-term ingested Cd may result an accumulation in the renal cortex and may cause proteinuria, glucosuria, and amino acid uria with final renal dysfunction, this problem may occur both in acute and chronic term [7]. The Cd pollutants can be easily transferred to humans through ingestion, inhalation, or dermal routes. [8].

Hence, Cd exposure may pose adverse health effects, including kidney dysfunction, skeletal, and respiratory problems, and possibly also bone effects and fractures [5].

Major sources of Cd exposure include diet, in particular rice, cereals, potatoes, and other root vegetables, and also smoking as cadmium in tobacco smoke is effectively absorbed in lungs [4]. Then, in aquatic biota such as fish, and bivalve due to anthropogenic activities. In the last 25 years the fast growing of population and dwelling significantly increase pollutant along the lake and generate wastes that directly dispose to the lake. This study aimed to investigate the Cadmium concentration levels in water column, sediment, bivalve and fishes organs and assessing the health risks due to bivalve and fishes consumption from Sentani Lake, Papua Indonesia.

2. Materials and Methods

2.1 Study Area

The study was undertaken in Sentani Lake in Sentani Regency, Papua Province Indonesia. With very good natural conditions and location, Sentani Lake is a mouth of three rivers along with the growing fast of industrialization and urbanization surround the site. Sentani Lake is an important drinking water sources and main food protein source such as bivalve, various fishes and other aquatic seafood which are become daily consumption by local people along Sentani Lake and in the regency. Some fishes are sold out in the next district around Sentani district itself.

2.2 Methods

2.2.1 Sample Collection for water column and sediment and its procedures

We collected four kind of samples of this study; water column, sediment, bivalve and fishes. Water samples were collected at twelve various stations at a depth of 30 cm below the water surface in high density glass bottles. Then, sediment at the top 15 cm of the bottom samples were collected from the same stations where water sample collected using the Eickman bottom sampler device. [9]. Those samples were kept in polypropylene containers (20g) for Cd analysis and in glass bottles (at least 150 g) for texture analysis.

2.2.2 Sample Collection for bivalve and fish and its procedures

Likewise, bivalves were collected at those aquatic track stations where water and sediment samples collected. Approximately 15-20 bivalves with the size in the range of 4-6 cm in length for *Anadara trapecia* were collected. The tissues were immediately cut off and placed into polyethylene sample bags and kept in an ice box with the temperature of 4ºC before being transported to laboratory and put into a freezer (-20^{o}C). Soft tissue of bivalve were removed and cut in section of small pieces at the end the homogenized representing samples were frozen prior being analyzed.

Biota (pelagic and benthic) fishes were collected with hook-and-line to complement dock sampling efforts. At the same stations of each of these two species of fish chosen were collected (a total of 24 fish). They were placed in labeled polypropylene Falcon tubes, stored in ice and immediately transported to the laboratory. To assess the risk of population exposure, the whole fishes were used but by taking into account the conditions of consumption. Since these two species are widely distributed and consumed.

At each site, three random sub-samples of water column, sediment and aquatic biota were collected to ensure sample representativeness on the site. All samples were kept cool on the study field. During their transportation to the laboratory, precautions (cold storage on ice, complete filling containers, use of plastic materials for storage, avoidance of undue agitation) were taken to minimize any kind of disturbances [10] [11] [12].

2.2.3 Laboratory Quality Control

All samples were analyzed at the certified Laboratory. Determination of Cd was carried out using the inductively coupled plasma mass spectrometry (Perkin Elmer-Elan 9000). To have an accuracy in procedures of analyses, calibrations were done using three replicate samples of standard reference material (SRM 1646a estuarine sediment) from the U.S. Department of Commerce, National Institute of Standard and Technology (NIST) Gaithersburg, MD 20899 and three samples of blank. DROM-2 (fish muscles) was obtained from National Research Council Canada. All analyses of parameters were done by three replicates. Their certified and measured values are shown in Table. 1 below:

Table 1. Laboratory analytical results of certified and measured values for water and fish standard reference materials

Parameter	Water (SRM 1643e)		Fish (DORM-2)	
Cadmium (Cd)	Certified values $\mu g\ L^{-1}$	Measured Values $\mu g\ L^{-1}$	Certified values $mg\ kg^{-1}$	Measured Values $mg\ kg^{-1}$
	19.63±0.21	20.09±0.37	0.065±0.007	0.068±0.009

2.2.4 Target Hazard Quotient (THQ)

Health risk assessment method was developed to assess the health hazards caused by the pollution emergency. Therefore, water intake and water use actions from the 50 km long reach downward the accident place should be forbidden during the accident. [13].

Health risk assessments with respect to the ingestion of fish and bivalve are used target hazard quotient. This method was available in US EPA Region III Risk based Concentration table [14] and it is described by the following equation:

$$THQ = \frac{EF \times ED \times FIR \times C}{RFD \times BW \times TA} \times 10^{-3}$$

Where; THQ is the target hazard quotient, EF is exposure frequency (365 days/year); ED is the exposure duration (60 years), equivalent to the average lifetime; FIR is the food ingestion rate (fish: 40g/person/day and Bivalve (*Anadara trapecia*): 20g/person/day). Consumption of food containing cadmium has been identified as a health risk. The U.S. Environmental Protection Agency and the National Academy of Sciences recommend keeping this corresponds to a reference dose (RfD) of Cd in food do not greater than 1×10^{-3} mg/kg/day [15]; [14]. BW is body weight (60 kg) and TA is the averaging exposure time for non-carcinogens (365 days/year x ED)

3. Results and Discussion

The level of Cd concentrations in water column, sediment and marine organisms during one sampling period is presented in Table 2.

3.1. Cadmium Concentration in Water

The difference Cd concentration among the stations is mostly affected by the location purpose use with its pollutant point sources. Cd levels concentration attained their maximum values at stations 4,7 and 6 (1.33, 1.46 and 1.70) mg L^{-1}, respectively. Where as in stations 1, 2 and 3 (0.25, 0.23 and 0.22) mg L^{-1} were less polluted site. This may be attributed to the increased cover of the aquatic and higher plants which absorb metals from water and sediments.

The maximum mean values of the measured Cd were recorded at station 6 with 1.70 mg L^{-1} near community house and home industry. These levels are higher than the permissible limits (Table 2) recommended by USEPA (1986). This may be attributed to the huge amounts of raw sewage, agricultural and home industrial wastewater discharged into the Lake [16]. The high levels of Cd in water can be attributed to industrial and agricultural discharge (Mason, 2002). In an urban waste water study conducted in the United Kingdom by Rule et al. Cd was observed in the waste water generated from industrial, commercial, private sectors as well as from municipal waste with the highest average cadmium concentration detected in the waste water of new (<5 years old) private housing (0.375 µg/L).

3.2 Cadmium Concentration in sediment

The results obtained for the sediment analysis are shown in table (1). The Cd concentrations in bottom sediment varied quite widely and exhibit fluctuations between stations. Cd exhibited a similar pattern of concentration as its abundance in water. Cd attained its highest value in Station 7 with (2.49 mg kg^{-1} dw) followed by station 10 with (2.49 mg kg^{-1} dw), where as the background level was (0.74 mg kg^{-1} dw), respectively. The magnitude level of Cd concentration in sediments of Sentani Lake could be attributed to the industrial, municipal and agricultural wastes discharge as well as from spill of leaded petrol from fishing boats which are distributed in the Sentani Lake.

3.3. Cadmium Concentration in Fish and Bivalve

The present results show that Cd concentrations in pelagic fish organs of *Plectropomus Leopardus* are closely associated with Cd content of water and sediment in the Sentani Lake. This situation may be generated to the abundance of Cd in water and sediment by the similar pattern. A remarkable relationship between Cd concentrations in aquatic organisms and sediment were observed by Ibrahim and El-Naggar in Damietta Branch of the River Nile [17].

The sequences of the magnitude of Cd concentration in aquatic habitat from Sentani Lake were Benthic (*Plectropomus Leopardus*) > Pelagic fihs (*Pilchard*) > baivalve (*Anadara Trapecia*), *with the maximum values were* (4.34 > 2.89 > 2.40) mg/kg ww), respectively. Phillips also reported a higher amount of cadmium in mollusks higher than those Cd in water. None of the species analyzed in this study were found to contain level of cadmium concentration above the proposed permitted concentration.

A high concentration of cadmium causes several health problems to humans. Cadmium and its compound along with mercury and some other dangerous metals are included in the blacklist for human health hazard. Ingestion of cadmium produces shock acute renal failure when the amount exceeds 350 mg.

Table 2. Cadmium concentration in water column, sediment and and accumulation in bivalve and fish from Sentani Lake, Papua Indonesia 2013.

Stations	Location	Cadmium (Cd)				
		Water column (mg L^{-1})	Sediment 15 cm depth) (mg kg^{-1}dw)	Biota (mg kg^{-1}ww)		
				Bivalve (Anadara Trapecia)	*Pelagic fish (pilchard)*	*Benthic Fish (Plectropomus Leopardus)*
		n= 3	n=6	n=3	n=3	n=3
St 1	Upstream, about 10 km from S	0.25	1.49	1.28	2.36	3.45
St 2	Upstream, 8 km from S7	0.23	1.55	1.52	2.48	4.21
St 3	Upstream, 6 km from S7	0.22	1.79	1.62	2.11	4.34
St 4	Close to river mouth in the west	1.33	1.98	1.50	2.35	2.38
St 5	At river mouth in the West	1.18	2.34	1.24	2.25	2.74
St 6	Community Housing /home industry	1.70	1.89	1.78	2.63	2.25
St 7	At the river mouth in the North	1.46	2.49	1.62	2.43	2.49
St 8	Close to river mouth in the North	1.27	2.39	2.40	2.80	3.29
St 9	Downstream, 6 km from S6	1.11	1.75	2.37	2.89	3.60
St 10	Downstream , 8 km from S6	0.55	2.49	2.25	2.83	2.29
St 11	Downstream , 10 km from S6	0.71	2.24	1.86	1.18	2.64
St 12	Background site	0.12	0.74	0.28	0.35	0.98

In this study, it is obviously that Cd has the highest concentration (4.34 mg kg^{-1}ww) in benthic and pelagic fishes that had comparatively higher than those Cd level in bivalve. Cd concentration may be regulated in fish due to the essential nature of this metal for metabolic process. In addition this obviously due to the size of the fish. The bigger the fish the higher Cd concentration in the fish. Study in China about the main nutrients and contaminants were measured and the risk–benefit was evaluated based on recommended nutrient intakes and risk level criteria set by relevant authorities. The comprehensive effects of nutrients and contaminants in marine oily fish were also evaluated using the data of two related human dietary intervention trials performed in dyslipidemic Chinese men and women in 2008 and 2010. It was found that Cd were much lower than their corresponding maximum limits. [18]. Study in the municipality of São Francisco do Conde, located in Todos os Santos Bay, Brazil, there is a high risk of environmental cadmium and lead contamination produced by industrial sources. In this work, a determination of cadmium and lead contamination in fish (Centropomus undecimalis and Mugil brasiliensis), mussels (Mytella guyanensis) and shrimp (Penaeus brasiliensis) is reported higher than the permitted concentration. [19]

Table 3. Risks assessment of Cadmium accumulation in water and sediment and the target hazard quotient (THQ) due to biota consumption from Sentani Lake, Papua

Stations	Location	Cadmium				
		HQ		THQ		
		Water column (mg L^{-1})	Sediment 15 cm depth) (mg kg^{-1}dw)	Biota (mg kg^{-1}ww)		
				Bivalve (Anadara Trapecia)	*Pelagic fish (pilchard)*	*Benthic Fish (Plectropomus Leopardus)*
St 1	Upstream, about 10 km from S	0.25	1.49	0.043	0.098	0.144
St 2	Upstream, 8 km from S7	0.23	1.55	0.051	0.103	0.175
St 3	Upstream, 6 km from S7	0.22	1.79	0.054	0.088	0.181
St 4	Close to river mouth in the west	1.33	1.98	0.050	0.098	0.099
St 5	At river mouth in the West	1.18	2.34	0.041	0.094	0.114
St 6	Community Housing /home industry	1.70	1.89	0.059	0.110	0.094
St 7	At the river mouth in the North	1.46	2.49	0.054	0.101	0.104
St 8	Close to river mouth in the North	1.27	2.39	0.080	0.117	0.137
St 9	Downstream, 6 km from S6	1.11	1.75	0.079	0.120	0.150
St 10	Downstream , 8 km from S6	0.55	2.49	0.075	0.118	0.095
St 11	Downstream , 10 km from S6	0.71	2.24	0.062	0.049	0.110
St 12	Background site	0.12	0.74	0.009	0.015	0.041
	Standard	> 1 ; State a risk				

3.4 Target Hazard Quotient (THQ)

Target hazard quotient (THQ) calculation results show various level of Cd in bivalve *Anadara Trapecia* caught from Sentani Lake that is displayed in table 3. The values of THQ for bivalve consumption were ranged from 0.041 to 0.080 where as the background value was 0.009, respectively. Since bivalve is one of the favorite sea foods of community in Sentani Regency and surrounding area, we assume that bivalve consumed by some high-risk groups of people. Likewise, the highest Cd

values (*Pilchard and Plectropomus*) were 0.120 and 0.175 for pelagic and benthic fishes, respectively. Although these values are still <1, the potential risks might be posed due to the continual bioaccumulation and long term consumption. Similar experience was found in municipality of Montecristo, Colombia the Cd mean level for all fish samples (0.407 +/- 0.360 microg/g fresh wt) did not exceed the recommended limit ingestion level, risk assessment based on the hazard index suggested that a fish intake of 0.12 kg per day could increase the potential health effects related to Cd exposure in the local human population [20].

4. Conclusion

The effects of cadmium on health in terms of risk identification are well known; some concentrations of Cadmium was still lower than WHO recommendation which imply potential health risks in the area of concern. As a result, it can be assumed that the seafood from this region is safe for human consumption. However, it can be a hazard for a long period of consumption. Therefore, it is imperative to handle the problem of the pollution in Sentani Lake to reduce health risk. The use of chemical fertilizers and pesticides in the plantations in the surroundings of the Lake, the discharge of garbage and solid waste of any kind into the lake, and the spillage of petroleum products in the lake must be prohibited.

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