Assessing The Target Hazard Quotients (THQs) Of Lead Via Drinking Water And Seafood Consumption From Paniai Lake, Paniai Regency Papua, Indonesia 2013

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ABSTRACT

This research aimed to investigate lead (Pb) contaminations in aquatic habitat and assess the potential health risks of seafood consumption from Paniai Lake, Papua, Indonesia. Water column from lake, drinking well water, shrimp and fishes samples were collected in one time collection in Mei 2013. Furthermore, potential health risks were determined using target hazard quotient (THQ) equation. The results showed that, Pb in water from lake, drinking well water, shrimp, pelagic and benthic fishes were ranged from 0.32 to 2.35 mg L^{-1}, 0.24 to 0.95 mg L^{-1}, 4.22 to 12.57 mg kg^{-1}ww, 3.58 to 11.01 mg kg^{-1}ww and 5.40 to 14.55 mg kg^{-1}ww, respectively. The elevated Pb concentrations were observed in shrimp and benthic fish (at the maximum concentrations of 12.57 mg kg^{-1}ww and 14.55 kg^{-1}ww), respectively. Estimated magnitude of weekly intake (EWI) values of Pb in shrimp, pelagic and benthic fishes showed that consumption per week for body weight of 70 kg for the local people were found to be in the range of 4.8 to 14.4 mg/kg bw, 15.0 to 46.2 mg/kg bw and 22.7 to 61.9µg/kg bw, respectively. Hence, the assessment of target hazard quotient (THQ) values of water from lake, drinking well water, shrimp and fishes were in the range of 0.005 to 0.35, 0.004 to 0.14, 0.063 to 0.189, 0.077 to 0.165 and 0.081 to 0.221, respectively. All those levels have not exceeded the limit standard or < 1 for potential health risks which mean safe for consumption. This study also suggested the magnitude of Pb release to Paniai Lake is governed primarily by the scale of waste disposed. In case of health risks assessment by comparing with PTWIs and THQ, (based on the shrimp and fish consumption for 70 years life span of 70 kg body weight), the results showed that people who consumed shrimp and fish from Paniai Lake were not at risk.

Key Words; Drinking water, shrimp, pelagic and benthic fish, target hazard quotient.

1. INTRODUCTION

Chromium, cadmium, lead, zinc and nickel are some of the major component pollutants heavy metals released from the industrial, vehicles and urban wastes. Along with other various products are intense discharged into the aquatic environment. Then, rapid population growth, urbanization, intensive agricultural and industrial production, all give rise to increased levels of emissions of organic and inorganic pollutants into the environment.[1] Coastal areas and estuaries including lake are particularly sensitive to metal contamination from anthropogenic sources and in the last few decades the study of space–time distribution and variation of metals has been extensively researched.[2] In case of lead (Pb) prior to the advent of lead pollution, atmospheric deposition contributed an insignificant fraction of the lead accumulated in lake sediments relative to the supply from the catchment [3]. Direct disposal waste into the aquatic contributed a major pollutant level which may generate a threat to human health surround the niece.[4]

Present day lead pollution is an environmental hazard of global proportions. A correct determination of natural lead levels is very important in order to evaluate anthropogenic lead contributions.[5] The metals from anthropogenic sources mainly occur in the labile fraction and may be taken up by organisms as the environmental parameters change.[6] Lead is a microelement naturally present in trace amounts in all biological materials in soil, water, plants and animals.[7] It has no physiological function in the organism.[8, 9] The main source of lead contamination are smelting works, application of waste water treatment sludge's to soil, transportation, rain, snow, hail and other, approximately 98% of lead in the atmosphere originates from the human activates.[10] Lead can be taken in by eating food, drinking water or breathing air children and to lesser extent, adults can also be exposed by ingesting soil.

Paniai Lake of Papua Indonesia has been a major marine seafood resource for Paniai people for a long time. However, recent industrialization and community development have exerted considerable stress on the lake environments and provoked habitat degradation. The following pollution problems in the lake such as untreated municipal and industrial waste water are considered to be the most serious problems of the regency due to limited waste water treatment facilities in the area, eutrophication of the lake,[11] and less awareness of community to the lake sustainability.

To the best of our knowledge, no previous studies have investigated how lake characteristics with its all aquatic biota are associated with lead pollutant levels of water, organism for shrimp, fishes and bivalve in all sharp of the lake. Accordingly, we measure the Pb levels of water, shrimp, pelagic and benthic fishes and assess the environment risks and calculate the estimated weekly intake as well as the potential target hazard risks with respect to water, shrimp and fishes consumption.

2. MATERIAL AND METHODS

2.1 Study Area

The study was conducted in Paniai Lake and in the town of the Paniai Regency, West Papua Province Indonesia. Here open market is one of the interesting daily activities seen at the two mouths of the Paniai Lake. In addition, at the plain land site of Paniai lake is also the landing area of some small aircrafts that intense give pollutant to the lake. Then, the growing of small industrialization and urbanization surround the site generates some various disposal wastes into the lake. Paniai Lake now is an important drinking water sources and main food protein source such as fishes, shrimp, various bivalve and other aquatic seafood which are become daily consumption by local people along Paniai Lake and in the town.

2.2 Methods

2.2.1 Sample collection for water column and drinking well water

We collected four kind of samples of this study; water column, drinking well water, shrimp and fishes. Water samples were collected at ten various stations at a depth of 30 cm below the water surface in high density bottles where as drinking well water were collected from well owned and consumed by local people in the town. Shallow well water were collected in the town of Paniai. Shallow well sampling area, Pb in filtered water samples do not exceed concentrations detected.

2.2.2 Sample Collection for Shrimp and Fish

Shrimp and fishes were collected at the same aquatic track where water samples collected. Approximately 10-15 shrimps with the size in the range of 3-7 cm in length 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). 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 20 fishes). 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, drinking well water, shrimps and fishes were collected to ensure sample representativeness on the sites. 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. [4, 7, 8, 12].

2.2.3 Laboratory Quality Control

Samples were analyzed at the certified Chemical Laboratory in South Sulawesi Province, Indonesia. To have an accuracy in procedures of analyses, calibrations were done using three replicate samples of standard reference material (SRM 1643e) for water from the U.S. Department of Commerce, National Institute of Standard and Technology (NIST), with 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 Table1 below:

Table 1. Laboratory analytical results of certified reference materials (sediment and fish)

Parameter	Water (SRM 1643e)		Fish (DORM-2)	
Lead (Pb)	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	20.12±0.38	0.065±0.007	0.069±0.009

3.2.4 Provisional Tolerable Weekly Intake (PTWI)

Health concerns of water and biota consumers in study area need to be assessed in relation to relevant guidelines. The provisional tolerable weekly intake (PTWI) guideline was recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) showed appropriate safe exposure levels, which were used to estimate the amount of contaminants ingested over a lifetime without appreciable risks.[13]

In the case of Pb, The provisional tolerable weekly intake (PTWI) guidelines recommended for Pb in a level of 4 µg/kg bw (FAO, 1996) is used in the this analyses, the weekly intake of Pb depends on the Pb concentration in food and the daily food consumption. In addition, the human body weight can influence the tolerance of pollutants. Estimated weekly intake was calculated:

$$EWI = (C_{Pb} \times Cons_R)/BW \qquad (1)$$

EWI is estimated weekly intakes ; C_{Pb} is Pb concentration in water, shrimps and fish; $Cons_R$ is the weekly consumption of water, shrimps and fish from Paniai Regency, Indonesia (water 14 ml/L per week, then shrimp 68.6 g/week and fish about 252g/week, and BW is the human body weight (base on 60 kg adult).

3.2.5 Target Hazard Quotient (THQ)

The methodology for estimation of target hazard quotient (THQ) although does not provide a quantitative estimate on the probability of an exposed population experiencing a reverse health effect, but it offers an indication of the risk level due to pollutant exposure. This method was available in US EPA Region III Risk based concentration table [14], and it is described by the following equation:

$$THQ = \frac{EF \times ED \times FIR \times C}{BW \times TA} \times 10^{-3} \qquad (2)$$

where THQ is target hazard quotient; EF is exposure frequency (365 days/year); ED is the exposure duration (70 years), equivalent to the average lifetime; FIR is the food ingestion rate (fish: 36 g/person/day; and shrimp: 9.80 g/person/day) (FAO, 2005); C is the metal (Pb) concentration in seafood (lg g_1); RFD is the oral reference dose (Pb = 0.004 lg g_1/day)[15]; BW is the average body weight (60 kg), and TA is the averaging exposure time for non-carcinogens (365 days/ year _ ED).

3. RESULTS AND DISCUSSION

3.1. Lead Concentration in Water

Various level of lead (Pb) concentration in the ten stations is mostly affected by the purpose of the area use with its pollutant point sources. The maximum mean Pb level concentration in shrimp, pelagic and benthic fishes were attained values at stations 5 and 6 (10.81, 11.01 and 14.55) and (12.57, 9.57 and 14.74) mg kg^{-1} ww, respectively. 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 Pb in water can be attributed to industrial, urban and agricultural discharge.[4, 17].

In an urban waste water study conducted in the United Kingdom by Rule et al. Pb was observed in the waste water generated from industrial, commercial, private sectors as well as from municipal waste with the highest average concentration detected in the waste water of new (<5 years old) private housing (0.375 µg/L).

The monthly concentrations of lead in water samples remained below the WHO standard of 50 µg L^{-1} and the total mean concentration of Pb 0.04 µg L^{-1} was considerably lower during the study. Study in Keenjhar revealed the monthly variation of lead in water samples from Keenjhar Lake during 2003 shown a maximum level of lead concentration was about 0.235 µg L-1. Inaddition, the monthly variation during 2004, with a maximum lead concentration of 0.225 µg L-1.[18]

3.2. Lead Concentration in Shrimp and Fishes

The present results show that Pb concentrations in shrimp, pelagic and benthic fishes organs are closely associated with Pb content of water in Paniai Lake. This obviously may be generated to the abundance of Pb into water by the similar pattern. A remarkable relationship between Pb concentrations in aquatic organisms and water as well as sediment were observed by Ibrahim and El-Naggar in Damietta Branch of the River Nile.[19]

The sequences of the magnitude of Pb concentration in aquatic habitat from Paniai Lake were Benthic fishes > Shrimp > Pelagic fishes, *with the maximum values were* (14.74 > 12.57 > 11.01) mg/kg ww), respectively. Phillips also reported a higher amount of lead and cadmium in mollusks higher than those in water. None of the species analyzed in this study were found to contain level of lead concentration above the proposed permitted concentration.

Table 1. Lead concentration and accumulation in water column, drinking well water, shrimp and fishes from Paniai Lake, Papua Indonesia 2013.

Stations	Location	Lead (Pb)				
		Water column Lake (mg L^{-1})	Drinking Well Water (mg L^{-1})	Biota (mg kg^{-1}ww)		
				Shrimp	*Pelagic fish*	*Benthic Fish*
		n= 3	n=3	n=3	n=3	n=3
St 1	Upstream, about 7 km from St.5	0.43	0.24	6.39	5.16	5.40
St 2	Upstream, 5 km from St.5	0.32	0.85	7.60	7.21	8.55
St 3	Upstream, 3 km from St.5	0.37	0.38	5.41	8.67	11.13
St 4	Close to river mouth in the west	1.50	0.74	8.77	10.74	12.56
St 5	At small harbor and market	2.35	0.95	10.81	11.01	14.55
St 6	Close to community Housing	2.18	0.89	12.57	9.57	14.74
St 7	At the river mouth in the North	1.34	0.84	9.74	6.55	9.39
St 8	Close to river mouth in the North	1.16	0.74	8.57	7.32	7.84
St 9	Downstream, 3 km from St.5	0.32	0.55	4.51	7.35	7.41
St 10	Downstream , 5 km from St.5	0.44	2.52	4.22	3.58	6.84

However, it is different with the study in Newark bay, concentrations of lead measured in all reaches of the estuary were found to exceed sediment quality criteria (250 mg/kg) and predicted toxic effects values (110 mg/kg). The highest lead concentrations in the estuary were located adjacent to petroleum refineries, paint and pigment formulating plants, and other industrial areas. These results indicate that lead contamination of surficial sediments in Newark Bay may pose a significant threat to aquatic biota.[7]

Some relevant studies presented data on cadmium and lead content in the studied fish species provide no proof of the general pollution of the Adriatic. Obtained data were tested in relation to fish length. Metal concentrations in liver decreased with the increase in fish size, whereas no significant correlation was found between trace metal levels in the muscle tissue and the length of both species.[20] Hence study in Nigeria indicated contamination of these fish foods by lead with mean values varying from 8.0 ± 0.8 to 12.5 ± 1.6 mg/kg The food processing technique accounted for up to seven times increase in fish lead levels, Abeokuta, Nigeria.[21] Then, Forty-seven samples collected from the villages of São Bento, Muribeca and Pati Island were analyzed for their trace metal levels using electrothermal atomic absorption spectrometry (ETAAS). Cadmium and Lead contents detected in the samples were found to range from

0.01 to 1.04 mg kg−1 and from 0.10 to 5.40 mg kg−1, respectively. [22]

In our study, most of the Pb pollutant released from urban waste which is containing some small industrial waste mixed with the home industry and open market waste. This situation is similar with the research on Oise river that revealed the finding signature is called "urban" rather than "industrial", because it is clearly distinct from the Pb that is found in areas contaminated by heavy industry, i.e. the heavy industries located on the Oise River which used lead from European ores characterized by high 206Pb/207Pb ratios (~1.18–1.19) and possibly a minor amount of North American lead (206Pb/207Pb ratios > 1.20).[23]

3.3 Estimated Weekly Intake of Drinking Water, Shellfishes and Fish Consumption

The standard for the Indonesian people shape was investigated and conducted by the National Statistical and population Bureau, Ministry of Population and Housing, reported that the average body weights of Indonesian men were range from 51.2 kg to 71.0 kg and women from 50.5 kg to 58.6 kg. Then estimate weekly intake for the maximum water, aquatic biota consumption per body weight at 50, 60 and 70 kg were determined (Figure 1). We here measure the body weight of 70 kg.

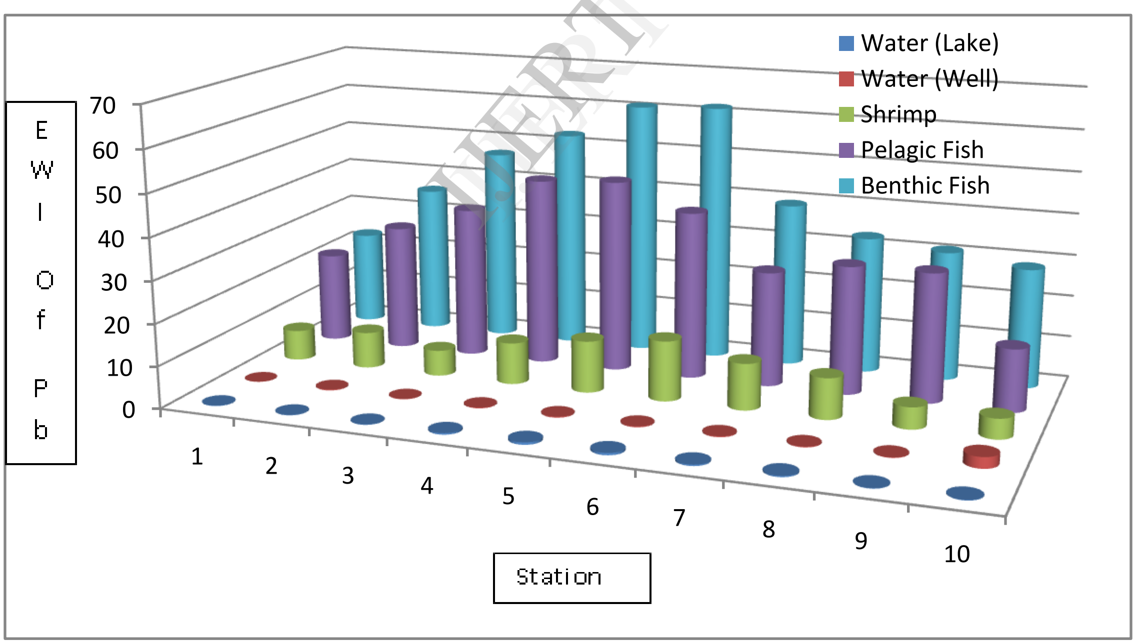

Figure 1. Estimated weekly Intake (EWI) of Water (Lake), Water (Well) Shrimp and Fish Consumption

The estimated values of PTWI concentration of lead in shrimp and fishes showed the magnitude of EWI of shrimp, pelagic and benthic fishes consumption per week for body weight of 70 kg for the local people. The values were found to be in the range of 4.8 to 14.4 µg/kg bw, 15.0 to 46.2 µg/kg bw and 22.7 to 61.9 µg/kg bw, respectively. In our study, the calculated weekly intake was below the established limit either for drinking water from lake and well and shrimp, but not for fish. Of those two different biota fishes, the values were higher than PTWI level in, the highest values was in *Station 6* (> 25 g/kg bw) (World Health Organization, 2003). These values indicated that they are not safe and be at risk.

3.4 Target Hazard Quotient (THQ) of Drinking Water, Shellfishes and Fish Consumption

Fish have been identified as a significant source of human exposure to various compounds Kimbrough (1991). This study also discuss the context of overall health risk assessment. Figure 2 shows, the value of THQ for shrimp, pelagic fish and benthic lead consumption were ranged from 0.063 to 0.168, 0.054 to 0.165 and from 0.081 to 0.221, respectively. The highest THQ value observed in St.5 and St.6 where open market and community dwelling are located. In general, consumption of shrimp and fish is an important source of exposure to lead for humans (Svensson et al. 1995). Lipton and Gillett (1991) reported that tuna were sufficiently high in metal to warrant health concern for high-risk groups with very high consumption rates. The consumption of these contaminated fish will exceed the risk-based concentration of ‘‘zero’’ recommended by the US EPA (1996). People consuming large amounts of contaminated seafood may have elevated concentration of heavy metals in their tissues compared to the general population who do not (Asplund et al. 1994; Dewailly et al. 1994, Han et al, 1998). Relevant finding of Risks assessment study from Yangtze River, China, Health risk analysis of individual heavy metals in fish tissue indicated safe levels for the general population and for fisherman but, in combination, there was a possible risk in terms of total target hazard quotients.[17]

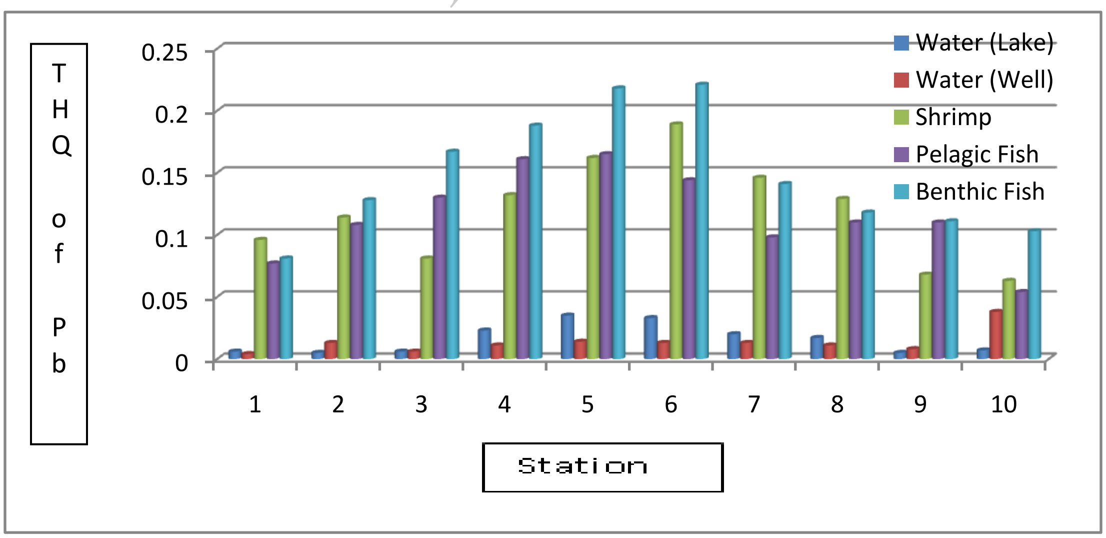

Figure 2. Target hazard quotient (THQ) for Pb through consumption of drinking water, shrimp and fishes

The results display various magnitude of THQ for water both from lake and from well and aquatic biota collected along the Panaiai lake and town. Because shrimp and fish are one of the necessary seafood in Paniai Regency and surround the site, we assume that all of these aquatic seafood consumed by some high-risk groups of people. In general, these estimates, resulting lower than 1 seem to indicate that dietary consumption of these seafood does not implicate an appreciable human health risk. In addition, it also recommend limited consumption of shrimp and fish from lead polluted water because most current health risks associated with seafood safety originate in the environment. It is in fact that absolute residue limits are difficult to derive because of the lack of direct evidence for critical levels in seafood. Risks to humans of consuming shrimp especially have not been clearly proven, although there is some indirect evidence (Han and Hung 1990; Han et al. 1994, Han et al. 1998).

4. CONCLUSION

Lead was determined in drinking water, shrimp and fish from Paniai lake and from the town of Paniai. The considerable variation in levels of Lead contaminant among the different species highlights the important role of ecological and behavioral factors in concentrating pollutants. From the human health point of view, the THQ value was (<1) show a situation of no risk for the consumers. Nevertheless, it must be remembered either that the limit value set by WHO, of estimated intake does not take into account exposure from other foods. Consequently, intake might be significantly underestimated and might be of concern, above all in the cases where the exposure is closer to the tolerable weekly intake as seen on the results above should be carefully calculated.

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