Lead contamination and its potential risks due to seafood consumption from Sentani Lake, Papua, Indonesia 2013

A.L. Rantetampang*, Anwar Mallongi**

*Faculty of Public Health, Cenderawasih University, Papua, Indonesia.
**Department of Environmental Health,Faculty of Public Health, Hasanuddin University, Makassar, Indonesia.

***Abstract*-**This research aimed to investigate lead (Pb) contamination in aquatic habitat and assess the potential health risks of seafood consumption from Sentani Lake, Papua. Water column, sediment, bivalve, pelagic and benthic fishes samples were collected in one time collection. Furthermore, estimated weekly intake (EWI) and potential health risks were determined using target hazard quotient (THQ) equation. Results revealed the concentration of Pb in water column, sediment, bivalve, pelagic and benthic fishes were ranged from 0.13 to 1.87 mg L^{-1}, 1.24 to 3.84 mg kg^{-1} dw, 0.43 to 2.76 mg kg^{-1}ww, 0.27 to 2.78 mg kg^{-1}ww and 1.39 to 3.55mg kg^{-1}ww, respectively. The magnitude of EWI values of Pb in bivalve, pelagic and benthic fishes showed that consumption per week for body weight of 60 kg for the local people were found to be in the range of 0.49 to 3.16 mg/kg bw and 1.13 to 10.71 mg/kg bw and 5.84 to 11.93 mg/kg bw, respectively. In addition, the magnitude values of target THQ for water column, bivalve, pelagic and benthic fishes were in the range of 0.005 to 0.035, 0.006 to 0.038, 0.004 to 0.039 and 0.021 to 0.051, respectively. All those levels have not exceeded the limit standard or < 1 for potential health risks which mean safe for consumption.

***Index Terms*-** Benthic fishes, Bivalve, Estimated weekly intake, Sediment,Target hazardquotient, Pelagic fishes and Water column.

I. INTRODUCTION

Heavy metals like chromium, copper, zinc, nickel and lead are some of the major components of the industrial wastes, which along with other products from industrial operations are discharged into the aquatic environment. Direct disposal waste into the aquatic contributed a major pollutant level which may generate a threat to human health surround the niece.[1] These substances are toxic to aquatic life [2, 3]. Metals have the tendency to accumulate in various organs of the aquatic organisms, especially fish, which in turn may enter into the human metabolism through consumption causing serious health hazards [4]. Chromium, lead, mercury, zinc, copper and nickel are among the most harmful metallic pollutants. Bioaccumulation of these metals is known to adversely affect liver, muscle, kidney and other tissues of fish, disturb metabolism and hamper development and growth of fish [5-7]. Coastal areas and estuaries 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 [8].

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 [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. 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 [11].

The metals from anthropogenic sources mainly occur in the labile fraction and may be taken up by organisms as the environmental parameters change [12]. The Gulf of Thailand has been a major marine resource for Thai people for a long time. However, recent industrialization and community development have exerted considerable stress on the marine environments and provoked habitat degradation. [13]. This case also may occur anywhere else at the similar circumstances like in Sentani lake. There was no any research have been done before relate the health risks assessment in the study area of concern, this study will be beneficially give a valid data relate the potential health effect of Pb contamination in the site and assist the local and province decision maker to set and monitor the trend of the accumulation pollutant and hazard produced.

II. MATERIAL AND METHODS

2.1 Study Area

This research was commenced in Sentani Lake which is located in the middle of Abepura city, Papua Province, Indonesia. 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 city of the regency. Some fishes even are sold out to the next district around Sentani district itself. Here some interesting daily activities seen at the two mouths of the Sentani Lake like weekend fishing and boating among dwelling along the lake.

2.2 Sample collection for water column and sediment

For Lead analysis, we collected four kinds of samples from the study aquatic tract such as; water column, sediment for the depth of 10 cm, bivalve and fishes. Water samples were collected at twelve varied stations at a depth of 30 cm below the water surface in high density glass bottles. Then, sediment at the top 10cm of the bottom samples were collected at the same stations where water sample collected using the Eickman bottom sampler device [7]. Those samples were kept in polypropylene containers (20g) for Pb analysis and in glass bottles (at least 150 g) for texture analysis. Then, The quotient analysis method served as screen level estimation of risk. The Aquatic Ecological Risk Assessment model was used to analyze exposure and ecological effects and to estimate community level risk and target hazard quotient was used to estimate the health risks [14].

2.3 Sample Collection for bivalve and fish

Bivalves were collected at the 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 (-20oC). 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 subsamples 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[15, 16].

2.4 Laboratory quality control

All collected samples were analyzed at certified Chemical Laboratory in South Sulawesi Province, Indonesia. Standard reference material (SRM 1643e) for water was used to have an accuracy in procedures of analyses. Here calibrations were done using three replicate samples for water from the U.S. Department of Commerce, National Institute of Standard and Technology (NIST), with three samples of blank. In addition, 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 2, below:

Table 1. Laboratory analytical results of certified reference materials for water 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	0.072±0.010

Both of measured values for the SRM recovery percentage were > 90

2.5 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 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 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 by using the formulation below:

$$EWI = (CPb \times ConsR) / BW \qquad (1)$$

Where; EWI is estimated weekly intakes ; CPb is Pb concentration in water, bivalve and fish; ConsR is the weekly consumption of water, bivalve and fish from Sentani lake, Indonesia (water 14 L per week, then Bivalve 68.6 g/week and fish about 252 g/week, and BW is the human body weight (base on 60 kg adult).

2.6 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 (US EPA, 2000) and it is described by the following equation:

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

Where 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; bivalve: 9.80 g/person/day (FAO, 2005); C is the metal concentration in seafood ($\mu g\ g^{-1}$); RFD is the oral reference dose (Pb = 0.004 $\mu g\ g^{-1}$/day) (US EPA, 1997, 2000); WAB is the average body weight (60 kg), and TA is the averaging exposure time for non-carcinogens (365 days/ year x ED).

III. RESULTS AND DISCUSSION

3.1. Lead Concentration in Water

Various level of lead concentration in the twelve stations is mostly affected by the purpose of the area use with its pollutant point sources. The maximum mean Pb level concentration in bivalve, pelagic and benthic fishes were attained values at (2.76, 2.78 and 3.55) mg kg^{-1} ww, respectively. This may be attributed to the huge amounts of sewage, vehicles and home industrial wastewater discharged into the Lake [17]. The high levels of Pb in water can be attributed to vehicles, industrial, urban and agricultural discharge [1, 18]. 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}. In addition, the monthly variation during 2004, with a maximum lead concentration of 0.225 µg L^{-1}[19].

3.2. Lead Concentration in Bivalve and Fishes

The present results show that Pb concentrations in bivalve, pelagic and benthic fishes organs are closely associated with Pb content of water in Sentani 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 [20]. The sequences of the magnitude of Pb concentration in aquatic habitat from Sentani 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.

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 superficial sediments in Newark Bay may pose a significant threat to aquatic biota [6].

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

Stations	Location	Lead (Pb)				
		Water column (mg L^{-1})	Sediment (15 cm depth) ng kg^{-1}dw)	Biota (mg kg^{-1}ww)		
				Bivalve Anadara rapecia)	*Pelagic fish (pilchard)*	*NBenthic Fish Plectropomus eopardus)*
		n= 3	n=6	n=3	n=3	n=3
St 1	Upstream, about 10 km from S	0.30	2.42	1.39	2.16	3.40
St 2	Upstream, 8 km from S7	0.27	2.65	1.50	2.21	3.55
St 3	Upstream, 6 km from S7	0.24	2.34	1.31	1.67	3.13
St 4	Close to river mouth in the west	1.14	2.74	1.67	1.74	2.56
St 5	At river mouth in the West	1.36	3.15	1.21	1.95	2.55
St 6	At the community Housing	1.87	3.54	2.52	2.57	2.74
St 7	At the river mouth in the North	1.76	3.84	2.76	2.45	2.39
St 8	Close to river mouth in North	1.43	3.54	2.55	2.52	2.84
St 9	Downstream, 6 km from S6	1.32	3.55	2.52	2.55	2.41
St 10	Downstream , 8 km from S6	0.94	2.82	2.20	2.78	1.84
St 11	Downstream , 10 km from S6	0.67	2.74	1.67	1.66	1.63
St 12	Downstream, 15 km from S6	0.13	1.24	0.43	0.27	1.39

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 [6]. 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 [7]. In our study, most of the Pb pollutant released from vehicles, 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 urban waste and heavy industry. [22]

Presented data on lead content in the studied fish species provide no proof of the general pollution of the Sentani Lake. 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 [4, 23]. Other results indicate 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. [24].

Elevated risk for the American robin and short-tailed shrew was due to their small foraging ranges and habit of eating earthworms, which bioaccumulations Pb. Elevated risk for the eastern cottontail was due to vegetation accumulating Pb to levels that were considerably higher than conventional bioaccumulation models would indicate [25]. 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 superficial sediments in Newark Bay may pose a significant threat to aquatic biota[26]. Lead concentrations in the vertical direction varied between 8.4 ng/k at a depth of 0.2 m and 3.3 ng/l at 5 m. The vertical studies were inconclusive and appeared to be influenced by resuspension of bottom sediments [27].

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. [28]. Study in Bohai, North China, Data of the next year verifies the uncertainty analysis result that with a confidence of more than 75% the risk quotients for Hg and Pb exceed the critical value. The sources, background concentration and biota assessment of heavy metals of Bohai Sea were discussed too.[29] 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.[30].

3.3. Estimated weekly intake (EWI) and targethazard quotient(THQ) from consuming seafood.

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 [31].

Table 3. Estimated weekly intake (EWI) for water column, bivalve and fishes consumption from Sentani Lake, Papua Indonesia 2013.

Stations	Location	EWI			
		Water column	*Bivalve (Anadara Trapecia)*	*Pelagic fish (pilchard)*	*Benthic Fish (Plectropomus Leopardus)*
St 1	Upstream, about 10 km from	0.07	1.59	9.07	14.28
St 2	Upstream, 8 km from S7	0.06	1.72	9.28	14.91
St 3	Upstream, 6 km from S7	0.06	1.50	7.01	13.15
St 4	Close to river mouth in west	0.27	1.91	7.31	10.75
St 5	At river mouth in the West	0.32	1.38	8.19	10.71
St 6	At the community Housing	0.44	2.88	10.79	11.51
St 7	At the river mouth in North	0.41	3.16	10.29	10.04
St 8	close to river mouth in North	0.33	2.92	10.58	11.93
St 9	Downstream, 6 km from S6	0.31	2.88	10.71	10.12
St 10	Downstream , 8 km from S6	0.22	2.52	11.68	7.73
St 11	Downstream ,10 km from S6	0.16	1.91	6.97	6.85
St 12	Downstream, 15 km from S6	0.03	0.49	1.13	5.84

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 this analyses, the weekly intake of Pb depends on the Pb concentration in food and the daily food consumption.

Table 3 shows the estimated weekly intakes (EWIs) for Pb caused by the consume of seafood. An important aspect in assessing risk to human health from potentially harmful chemicals in food is the knowledge of the dietary intake of such substances, that must remain within determined safety margins. For Pb, the World Health Organization has established as ‘‘safe” intake level a Provisional Tolerable Weekly Intake (PTWI) of 25 g kg^{-1} bw , World Health Organization, 2003. In our case, Pb weekly intakes through the consumption of fish (Pb: 0.04–4.96 g kg^{-1} bw), bivalve (Pb: 0.05– 0.19 g kg^{-1} bw) that were lesser than tolerable weekly intake limits.

A similar scenario is encountered with the target hazard quotients (THQs). As shown in Table 4 there were no THQ values for all Pb over 1 through the consumption of either bivalve or fishes, indicating health risk was absent. Analogously, the THQs of Pb (0.002–0.18) from consumption of fish being less than 1, suggested that health risk was insignificant. 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 [10].

Table 4. Hazard quotient (HQ) and **t**arget hazard question (THQ) for water column, sediment, bivalve and fishes from Sentani Lake, Papua Indonesia 2013.

Stations	Location	THQ			
		Water	*Bivalve Anadara Trapecia*	*Pelagic fish(pilchard*	*Benthic (Plectropomus Leopardus)*
St 1	Upstream, about 10 km from S	0.006	0.021	0.032	0.051
St 2	Upstream, 8 km from S7	0.005	0.023	0.033	0.053
St 3	Upstream, 6 km from S7	0.006	0.020	0.025	0.047
St 4	Close to river mouth in the west	0.023	0.025	0.026	0.038
St 5	At river mouth in the West	0.035	0.018	0.029	0.038
St 6	At the community Housing	0.033	0.038	0.039	0.041
St 7	At the river mouth in the North	0.020	0.041	0.037	0.036
St 8	Close to river mouth in North	0.017	0.038	0.038	0.043
St 9	Downstream, 6 km from S6	0.005	0.038	0.038	0.036
St 10	Downstream , 8 km from S6	0.007	0.033	0.042	0.028
St 11	Downstream , 10 km from S6	0.005	0.025	0.025	0.024
St 12	Downstream, 15 km from S6	0.006	0.006	0.004	0.021

Table 4 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 [10]. 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. 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.[18]

IV. CONCLUSION

Lead in varied parameters determined in water column, sediment, bivalve and fishes from Sentani Lake, Abepura, Papua Province Indonesia. The considerable variation in levels of lead among the different species, highlights the important role of ecological and physiological factors in concentrating Pb pollutants. From the human health point of view, Pb of THQ values (<1). This estimated THQ values seem to indicate that consumption of these fish and bivalve does not implicate an appreciable human health risk. Nevertheless, it must be remembered either that the limit value set by WHO or estimated intake does not take into account exposure from other food sources. 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 a final conclusion, we suggest that more specific recommendations regarding human consumption (kind of species and frequency and size of meals) are done according to the data concerning levels of environmental pollutants in the most consumed fish and seafood species.

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REFERENCES

1. Rantetampang, A.L. and A. Mallongi, *Risks Assessment Of Cadmium Through Aquatic Biota Consumption From Sentani Lake In Papua, Indonesia International Journal of Engineering Research & Technology (IJERT), 2013. 2(6): p. 2493-2500.* 2013.
2. Bindler, R., et al., , *A whole-basin study of sediment accumulation using stable lead isotopes and flyash particles in an acidified lake, Sweden. Limnol Oceanogr, 2001. 46: p. 178-188.* 2001.
3. García-Alix, A., et al. , *Anthropogenic impact and lead pollution throughout the Holocene in Southern Iberia. Science of The Total Environment, 2013. 449(0): p. 451-460.* 2013.
4. Yang, Y., et al., , *Comprehensive assessment of heavy metal contamination in sediment of the Pearl River Estuary and adjacent shelf. Marine Pollution Bulletin, 2012. 64(9): p. 1947-1955.* 2012.
5. Rossmann, R. and J.A. Barres, *Contamination of green bay water with lead and cadmium by a 37-m long, 2-m draft research vessel. Science of The Total Environment, 1992. 125(0): p. 405-415.* 1992.
6. Bonnevie, N.L., D.G. Gunster, and R.J. Wenning, *Lead contamination in surficial sediments from Newark bay, New Jersey. Environment International, 1992. 18(5): p. 497-508.* 1992.
7. Santos, L.F.P., et al. , *Assessment of cadmium and lead in commercially important seafood from São Francisco do Conde, Bahia, Brazil. Food Control, 2013. 33(1): p. 193-199.* 2013.
8. Company, R., et al., *Source and impact of lead contamination on δ-aminolevulinic acid dehydratase activity in several marine bivalve species along the Gulf of Cadiz.* Aquatic Toxicology, 2011. **101**(1): p. 146-154.
9. Bindler, R., et al., *A whole-basin study of sediment accumulation using stable lead isotopes and flyash particles in an acidified lake, Sweden. Limnol Oceanogr 2001;46:178 –188.* 2001.
10. USEPA., *Risk-based concentration table: Philadelphia PA; Washington, DC, USA. 2000.* 2000.
11. García-Alix, A., et al., *Anthropogenic impact and lead pollution throughout the Holocene in Southern Iberia.* Science of The Total Environment, 2013. **449**(0): p. 451-460.
12. Yang, Y., et al., *Comprehensive assessment of heavy metal contamination in sediment of the Pearl River Estuary and adjacent shelf.* Marine Pollution Bulletin, 2012. **64**(9): p. 1947-1955.
13. Cheevaporn, V. and P. Menasveta, *Water pollution and habitat degradation in the Gulf of Thailand.* Marine Pollution Bulletin, 2003. **47**(1–6): p. 43-51.
14. Chen, C.S., *Ecological risk assessment for aquatic species exposed to contaminants in Keelung River, Taiwan.* Chemosphere, 2005. **61**(8): p. 1142-1158.
15. Wang, J., S. Chen, and T. Xia, *Environmental risk assessment of heavy metals in Bohai Sea, North China. Procedia Environmental Sciences, 2010. 2(0): p. 1632-1642.* 2010.
16. Bennett, J.R., et al., *Ecological risk assessment of lead contamination at rifle and pistol ranges using techniques to account for site characteristics. Science of The Total Environment, 2007. 374(1): p. 91- 101.* 2007.
17. Abdel-Moati, M.A. and A.A. El-Sammak, *Man-made impact on the geochemistry of the Nile Delta Lakes. A study of metals concentrations in sediments. Water, Air and Soil Pollution, 1997. 97: p. 413-429.* 1997.
18. Yi, Y., Z. Yang, and S. Zhang, *Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River basin. Environmental Pollution, 2011. 159(10): p. 2575-2585.* 2011.
19. Korai, A.L., et al., *Lead Concentrations in Fresh Water, Muscle, Gill and Liver of Catla Catla (Hamilton) from*

Keenjhar Lake. J. Anal. Environ. Chem, 2008. 9(1): p. 11-19. 2008.

20. Ibrahim, N.A. and G.O. El-Naggar, *Assessment of heavy metals levels in water, sediment and fish at cage fish culture at Damietta Branch of the river Nile. . J. Egypt. Acad. Environ. Develop, 2006. 7(1): p. 93-111.* 2006.
21. Adekunle, I.M. and M.F. Akinyemi, *Lead levels of certain consumer products in Nigeria: a case study of smoked fish foods from Abeokuta. Food and Chemical Toxicology, 2004. 42(9): p. 163-14684.* 2004.
22. Ayrault, S., et al., *Lead contamination of the Seine River, France: Geochemical implications of a historical perspective. Chemosphere, 2012. 87(8): p. 902-910.* 2012.
23. Kljaković Gašpić, Z., et al., *Cadmium and lead in selected tissues of two commercially important fish species from the Adriatic Sea.* Water Research, 2002. **36**(20): p. 5023-5028.
24. Adekunle, I.M. and M.F. Akinyemi, *Lead levels of certain consumer products in Nigeria: a case study of smoked fish foods from Abeokuta.* Food and Chemical Toxicology, 2004. **42**(9): p. 1463-1468.
25. Bennett, J.R., et al., *Ecological risk assessment of lead contamination at rifle and pistol ranges using techniques to account for site characteristics.* Science of The Total Environment, 2007. **374**(1): p. 91-101.
26. Bonnevie, N.L., D.G. Gunster, and R.J. Wenning, *Lead contamination in surficial sediments from Newark bay, New Jersey.* Environment International, 1992. **18**(5): p. 497-508.
27. Rossmann, R. and J.A. Barres, *Contamination of green bay water with lead and cadmium by a 37-m long, 2-m draft research vessel.* Science of The Total Environment, 1992. **125**(0): p. 405-415.
28. Santos, L.F.P., et al., *Assessment of cadmium and lead in commercially important seafood from São Francisco do Conde, Bahia, Brazil.* Food Control, 2013. **33**(1): p. 193-199.
29. Wang, J., S. Chen, and T. Xia, *Environmental risk assessment of heavy metals in Bohai Sea, North China.* Procedia Environmental Sciences, 2010. **2**(0): p. 1632-1642.
30. Yi, Y., Z. Yang, and S. Zhang, *Ecological risk assessment of heavy metals in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze River basin.* Environmental Pollution, 2011. **159**(10): p. 2575-2585.
31. FAO. and WHO., *Summary and Conclusions. 61st Meeting, Rome, 10-19 June 2003. Retrived 10 August 2013, from website: http://www.fao.org/english/newsroom/news/2003/19783-en.html. 2003.* 2003.

AUTHORS

First Author – A.L. Rantetampang, PhD Program of Public Health, Faculty of Public Health, Cenderawasih University, Papua, Indonesia; email address. Alrant17@yahoo.co.id
Second Author – Anwar Mallongi, PhD Program of Environmental Health, Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Indonesia. email address. anwar_envi@yahoo.com
Correspondence Author – A.L. Rantetampang, email address. Alrant17@yahoo.co.id