



Research Article

Assessing the Target Hazard Risks of Cadmium Pollutant due to Consumption of Aquatic Biota and Food Snack Among School Children in Tallo Coastal Area of Makassar

¹Anwar Mallongi, ²Veni Hadju, ¹Ruslan La Ane, ¹Agus Bintara Birawida, ³A.L. Rantetampang, ⁴Moehammad Iqbal Sultan, ⁵M. Nadjib Bustan, ¹Hasnawati Amqan, ¹Noer Bahri Noor and ⁶Apollo

¹Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Indonesia

²Nutrition Science Study Program, Faculty of Public Health, Hasanuddin University, Indonesia

³Faculty of Public Health, Cenderawasih University, Papua, Indonesia

⁴Department of Communication Science, Hasanuddin University, Indonesia

⁵Faculty of Public Health, Makassar State University, Indonesia

⁶State Polytechnic Ujung Pandang, Makassar, Indonesia

Abstract

Background and Objective: Cadmium is used extensively in various industrial processes in the city of Makassar, South Sulawesi, as a result its potential lead to hazard pollutions both to the environment and to the human being. This study aimed to assess the potential target hazard risks of cadmium due to consumption of aquatic biota and food snack among school children in Makassar Coastal areas.

Materials and Methods: This study applied an analytic observational study used a cross sectional approach design and target hazard risk assessment approach. Investigation of Cd in aquatic system for surface water, sediment, shells and crab and in terrestrial for surface soil and school snack were commenced for Cd level concentrations. Then, Target Hazard Quotient (THQ) was calculated to find out whether the Cd contaminated food consumed by school children in school have exceeded the allowable standard or still safe to be consumed. The materials used are hot plate, glassware commonly used in laboratory and spectrophotometer absorption graphite furnace (Hitachi Z-5000 polarized Zeeman atomic absorption spectrometry). **Results:** This study revealed that Cd concentration in aquatic system for surface water, sediment, shell and crab were 0.016 mL L⁻¹, 0.026, 0.012 and 0.023 mg g⁻¹, respectively. Furthermore, Cd concentration in terrestrial system for surface soil, school snack and ambient air were 0.0411 mL m⁻³, 0.016 and 0.006 mg g⁻¹, respectively. All values resulted from the laboratory test were exceeded the acceptable level stated both by World Health Organization and Health Ministry of Republic of Indonesia with 0.01 mL L⁻¹ for water, 0.001 mg g⁻¹ for aquatic biota and school snacks, except for sediment with 70 mg g⁻¹ that still below the standard, respectively. The risk quotient value for THQ due to consume shell and crab were 0.0046 and 0.0011, respectively whereas THQ value for consuming cake in the school was 0.0025. Those values indicated that no risks exist since it still <1 or consumption of those aquatic biota and snacks still save.

Conclusion: To sum up, the concentration of Cd both in aquatic and terrestrial system have been exceeded the allowable level for environmental standard, although the THQ values still below than 1, that means still safe for all those food to be consumed.

Key words: Cadmium, aquatic system, terrestrial system, target hazard quotient

Received:

Accepted:

Published:

Citation: Anwar Mallongi, Veni Hadju, Ruslan La Ane, Agus Bintara Birawida, A.L. Rantetampang, Moehammad Iqbal Sultan, M. Nadjib Bustan, Hasnawati Amqan, Noer Bahri Noor and Apollo, 2017. Assessing the target hazard risks of cadmium pollutant due to consumption of aquatic biota and food snack among school children in Tallo Coastal area of Makassar. Res. J. Toxins, CC: CC-CC.

Corresponding Author: Anwar Mallongi, Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Indonesia

Copyright: © 2017 Anwar Mallongi *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The rapid population, housing and industrial growth in Makassar considerable potential lead to main metal (lead, cadmium, mercury, iron and nickel) substance pollutions in the environment¹. Elevated cadmium (Cd) values are generally indicative of sulphide mineralization. When Cd is associated with Pb and especially Zn, it strongly suggests the presence of Sedex or VHMS mineralization. The concentration of Cd in river particulates² has been estimated as 1 mg kg⁻¹. In industrialized countries there is concern over anthropogenic accumulations of Cd in the environment and it is classified as a potentially harmful element with respect to soil biological activity, plant metabolism and the health of humans and animals³. Percentage level cadmium loadings in sewage sludge are a concern for disposal and limit or prevent sludges being applied to land as fertilizers.

Cadmium is used extensively in industrial processes may potentially lead to harm for human. Cadmium at certain environmental concentrations is a risk factor for many diseases, including cardiovascular and neurodegenerative diseases, in which macrophages play an important role¹. Industrial growth in Makassar considerable potential generate to pollutions in the environment and various diseases to human surround the site. There is increasing evidence that environmental agents mediate susceptibility to infectious disease in all Cd contaminated areas⁴. The number of industries operating in the city of Makassar area are about 4,288 U comprising of 4,099 small industrial units and 199 large industrial units⁵. According to the Department of Environmental Management and the cleanliness of Makassar⁶, a total of 21 industries are the sources of pollutants into Tallo river as water bodies which receiving industrial waste water disposal.

Tallo river crosses the 10 districts in the city of Makassar such as the Panaikang, Lakkang, Tallo, Rappokalling, Daya, Bira, Tamalanrea, Tallo Baru, Antang and Rappojawan districts and long the river there are also industrial activity, namely Makassar Industrial Estate (KIMA). Those data obviously indicated that Tallo coastal area has been polluted by waste released from industries contain cadmium and emission from industrial surround the coastal area. In addition, communities including school children who live surround the Tallo coastal area have been at risk of health problems since the consumption any species of fishes, shells including *Anadara* sp., grabs and also contaminated form soil and daily food they consumed in the school. Then the control efforts of the

factors that could potentially be a threat to the health of the population is necessary and should be done immediately.

Thus, investigation of Cd pollution in the aquatic and terrestrial areas is indispensable to save the environment and it is necessary to assess the target hazard due to Cd aquatic and terrestrial foods consumption obtained from the contaminated site.

MATERIALS AND METHODS

Study area: This study was located at four districts of coastal area of Makassar city in Tamalate, Mariso, Ujung Tanah and Tello districts. Most of the districts have their own specific activities that people routinely conduct for their daily life activities. Industries along all the coastal both home industries and private medium scale industries that have been running for many years. Then other activities such as fishing, boating and swimming frequently in the weekend days. These interesting coastal areas are visited by many people from outside of Makassar for holidays. They buy some foods and take swim or fishing for pleasure. For those reason, this research was conducted along the coastal as seen in the Fig. 1.

Sample collection in aquatic system for water column, sediment, shells and crabs: Samples for water column, sediment, shells and crab were collected from the study aquatic system were collected at 8 stations. Water was collected on 8 stations at a depth of 30 cm below and stored in a high density glass bottles. Then, sediment sample at the top 10 cm of the bottom were collected at the same stations where water sample collected using the Eickman bottom sampler device, after the collection, those samples were kept in polypropylene containers (20 g) for cadmium analysis and in glass bottles (at least 150 g) for texture analysis. All samples then were put in ice box to be delivered to laboratory for analysis.

In addition, shells of *Anadara trapezia* sp. and crab samples were collected at the same aquatic track stations where water and sediment samples were collected. It is about 7-10 shells of *Anadara trapezia* sp. and 5 crab samples with different size in the range of 3-5 cm in length for *Anadara trapezia* and 8-12 cm in size for crab were collected from the stations where available. The tissues were immediately cut off and placed into polyethylene sample bags and kept in an ice box with the temperature of 4°C before being transported to laboratory and put into a freezer (-20°C).

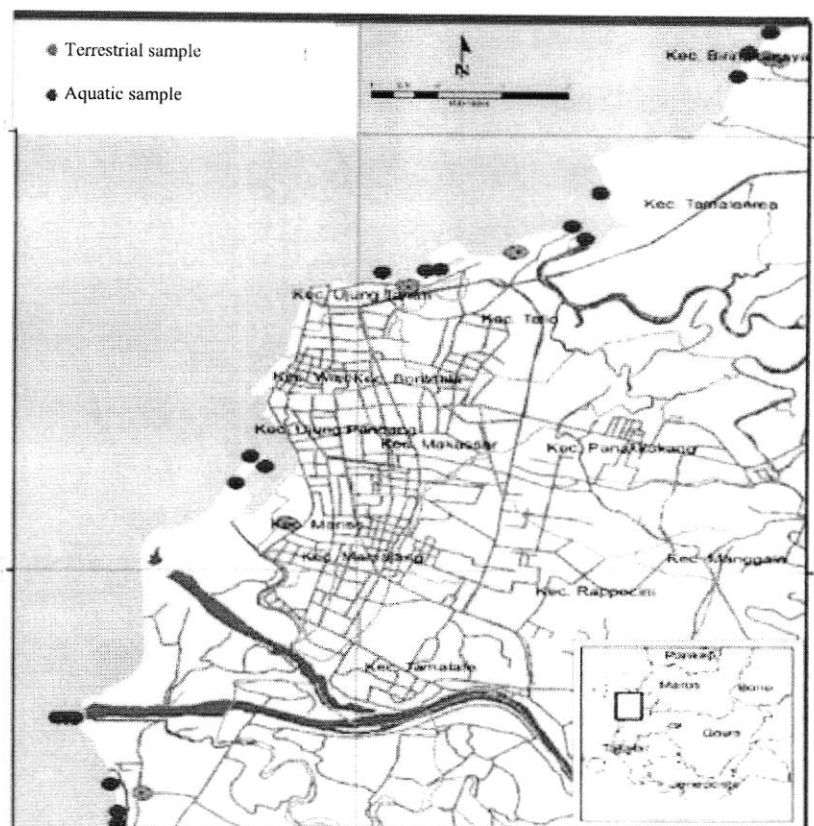


Fig. 1: Map of aquatic and terrestrial samples collection at four districts of Makassar Coastal areas

Soft tissue of shells and crab were removed and cut in section of small pieces at the end the homogenized representing samples were frozen prior being analyzed⁷.

Sample collection of surface soil: Soil samples were taken from four elementary schools, it is divided into three stations. Soil sampling at each site taken three different locations and at each location were taken three points, then at any point, repetitions was done. Soil samples were taken to a depth of 10-20 cm. The soil were cleared from rubbish, gravel, grasses and also roots. Equipment used to take soil samples comprising: A small shovel, navy (screw driver), spoons, filters soil (sieve), measuring the depth of the soil (the crossbar), buckets of places to sift the soil, containers for storing soil samples were filtered and some plastic bags to store, samples collected immediately taken to the Health Laboratory of Makassar city.

Sample collection of school snack: Snacks food samples namely; Apam, Onde-Onde, Goreng Pisang were taken at four schools children with three repetitions in each district adjacent to the air and soil sampling.

Analysis of samples for cadmium level: All collected samples were analyzed at certified Health Laboratory in Makassar, South Sulawesi Province. 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, DORM-2 (fish shells) was obtained from National Research Council Canada. All analyses of parameters were done by three replicates. Their certified values for both of measured values of water (SRM 1643e) Cd parameter with recovery percentage were above of 90%, at the same laboratory, we analyzed.

Statistical analysis: At the first time collected data were transformed to improve its normality and homogeneity of variance. Then, analysis of variance (ANOVA) was performed with SPSS, IBM software (version 22). Concentration-response curves from toxicity tests were analyzed with STATA software (version 8.2).

Environmental hazard quotient: The potential environmental risks using a quantitative screening Hazard Quotient (HQ) were determined. Here the estimation of ecotoxicity (dose) to exposure respond is compared to estimate the potential environmental risks. The cadmium concentrations at background site about 12 km upstream and downstream of the area concern is determined. The ratio of the exposure estimated to the effect concentration considered to represent a safe environmental concentration or screening benchmark is shown in the following formulation:

$$HQ = EEC/\text{screening benchmark} \quad (1)$$

where, EEC is estimated (maximum) environmental contaminant concentration at the site, how much contaminant of Cd in the surface water, sediment or soil (e.g., mg contaminant/kg soil). Screening benchmark is generally a no-adverse effects level concentration (NOAEL), if: HQ < 0.1 no hazard exists, HQ 0.1-1.0 hazard is low, HQ 1.1-10 hazard is moderate and HQ > 10 hazard is high⁸⁻¹⁰.

Target Hazard Quotient (THQ): Non-cancer risk assessments were conducted using the THQ, a ratio of the estimated dose of a contaminant to the dose level below any appreciable risk. If the value of THQ is less than unity, it will be assumed to be safe for risk of non-carcinogenic effects, vice versa. The 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 EPA¹¹ region III risk based concentration (Table 1) and it is described by the following equation:

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

where, EF is exposure frequency (365 days year⁻¹), ED is the exposure duration (70 years), equivalent to the average

lifetime, FIR is the food ingestion rate (crab: 36 g person⁻¹ day⁻¹, shells: 9.80 g person⁻¹ day⁻¹, C is the metal concentration in seafood (µg g⁻¹), RFD is the oral reference dose (Cd = 0.004 µg g⁻¹ day⁻¹)^{12,13}, WAB is the average body weight (60 kg) and TA is the averaging exposure time for non-carcinogens (365 days year⁻¹ × ED).

RESULTS AND DISCUSSION

Results of laboratory analysis for cadmium in the various environment both for aquatic and terrestrial systems are presented in the following Table 1.

Study revealed that the highest Cd concentration in aquatic system for surface water, sediment, shell and crab were 0.210 mL L⁻¹, 5.6516, 0.476 and 1.945 mg g⁻¹, respectively. All these values are exceeded the allowable standard except for sediment that still lower than the standard. Furthermore, the highest Cd concentration in terrestrial system for surface soil and school snack were 6.323 and 0.0085 mg g⁻¹, respectively. These two values also are higher than the standard. Most of the high Cd level were in the station 5 and 6, this location near and in the shopping centre and entertainment facilities. The magnitude of Cd in the aquatic system have been exceeded the allowable standard. The same values in the soil are also over the standard for Cd in soil. In addition, the magnitude of Cd in snack were ranged from 0.0012-0.0085 mg g⁻¹, respectively. All those values have been exceeded the standard allowed by Ministry of Health of Republic of Indonesia and not save to consume regularly.

A study from Mexico measured lead concentrations in fish from three water reservoirs also surpassed the limit of 1 mg kg⁻¹ established by Mexican regulations¹². 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

Table 1: Concentration of cadmium in surface water, sediment, shell, crab, surface soil and school snack in four districts of coastal area in Makassar city, 2016

Station	Location	Surface water (mL L ⁻¹)	Sediment (mg g ⁻¹)	Shell (mg g ⁻¹)	Crab (mg g ⁻¹)	Surface soil (mg g ⁻¹)	School snack (mg g ⁻¹)
1	Upstream, Tamalate (23 km) from Mks city	0.021	0.142	0.253	1.202	3.676	0.0034
2	Upstream, Tamalate (18 km) from Mks city	0.032	2.354	0.420	0.987	3.278	0.0022
3	Upstream, Mariso (15 km) from Mks city	0.024	3.276	0.623	0.276	2.987	0.0056
4	Upstream, border in the West of Mks city	0.102	5.119	0.276	1.254	5.088	0.0085
5	At the West Ujung Tanah, 10 km of Mks city	0.145	4.456	0.543	1.874	6.323	0.0012
6	Near shopping and entertainment center	0.210	5.651	0.476	1.765	6.221	0.0024
7	Close to the river mouth in the North	0.145	2.235	0.376	1.623	3.421	0.0065
8	Close to river mouth to the North	0.117	1.281	0.267	1.945	2.097	0.0023
	Standard	0.010	70.00	0.001	0.001	0.001	0.001

Table 2: Potential ecological risks assessment for water column, sediment and surface soil from Makassar Coastal area, Sulawesi Selatan, Indonesia, 2016

Station	Locations	Ecological risks		
		Water column	Sediment 10 cm dept	Surface soil
1	Upstream, Tamalate (23 km) from Mks city	0.25	1.67	43.3
2	Upstream, Tamalate (18 km) from Mks city	0.38	27.70	38.6
3	Upstream, Mariso (15 km) from Mks city	0.28	38.60	35.1
4	Upstream, border in the West of Mks city	1.20	60.20	59.9
5	At the West Ujung Tanah, 10 km of Mks city	1.71	52.40	74.4
6	Near shopping and entertainment center	2.47	66.50	73.2
7	Close to the river mouth in the North	1.17	26.30	40.3
8	Close to river mouth to the North	1.38	15.10	24.7

increase in fish size, whereas no significant correlation was found between trace metal levels in the muscle tissue and the length of both species^{13,14}. 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⁻¹. The food processing technique accounted for up to seven times increase in fish lead levels, Abeokuta, Nigeria¹⁵.

Then, 47 samples collected from the villages of Sao 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 ranging 0.01-1.04 and 0.10-5.40 mg kg⁻¹, respectively. In this study, most of the Cd pollutants were released from urban waste which is containing some small industrial waste mixed with the home industry, shops 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. Similar result was found that the levels of most heavy metals in pregnant women and infants were higher in this study than in studies from industrialized western countries¹³.

Presented data of lead content in the collected shell, shrimp and school snack provide proof of the general pollution of the Coastal of Makassar city. Obtained data were measured in relation to shell and crab size. 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. 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⁻¹. The food processing technique accounted for up to seven times increase in fish lead levels, Abeokuta, Nigeria¹⁵.

Study from Yangtze river, China, associate to the 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.

Potential ecological risks: The objective of this formulation earmarked for the estimation of environmental risks to the potential receptors that were performed in both aquatic and terrestrial habitats. The potential environmental risks evaluations were calculated by HQ equation for the estimation of environmental risks to potential receptors in all environmental compartments. In this study, the screening benchmark was based on the standard of the Ministry of the Republic of Indonesia and other relevant standards. For sediment, the screening benchmark accepted by Canadian environmental standard was used with the maximum limit of 174 µg kg⁻¹ dry weight⁸. The potential environmental risk evaluations in those compartments are presented in the following Table 2.

The results revealed that high elevated Cd for water column in Tallo coastal was accumulated in most of the St 4-6 and exceeded the screening benchmark value. This finding is in line with a study from Fifi *et al.*¹⁴ found that high metal concentrations, Cd may pose more threat in soils and groundwater. It was indicated that the Cd distribution in this area was initiated by the disposal of waste from the industries process that directly released Cd containing wastewater into the receiving iver. Likewise, Cd emitted vehicle emission as well as the fall out of atmospheric dry deposition were contributed. In addition, Cd accumulation in the sediment tended to be correlated to the Cd in water column¹⁵. At the river mouth, the Cd accumulation was obviously high with respect of the long period of Cd exposure of the sediment.

The results showed that the potential environmental risks in water column, sediment and surface soil were ranged 0.25-2.47, 1.67-66.5 and 24.7-74.4, respectively. All stations indicated high elevated of Cd concentrations in sediment and surface soil were at risks (HQ>1) where as in water only in upstream were still <1, indicated still save. This level lead to toxicological effects on sediment that might be biological significance. This fact was also found by Lai and Chen¹⁶ who stated that the accumulation of Cd increased when the soil Cd

Table 3: Target Hazard Question (THQ) for water column, sediment, shells and school snack from Makassar Coastal area, Sulawesi Selatan, Indonesia, 2016

Station	Location	Target Hazard Quotient (THQ)			
		Water column	Shell (<i>Anadara trapezia</i> sp.)	Crab	School snack
1	Upstream, Tamalate (23 km) from Mks city	0.004	0.023	0.028	0.043
2	Upstream, Tamalate (18 km) from Mks city	0.003	0.019	0.025	0.038
3	Upstream, Mariso (15 km) from Mks city	0.003	0.019	0.027	0.051
4	Upstream, border in the West of Mks city	0.019	0.021	0.019	0.056
5	At the West Ujung Tanah, 10 km of Mks city	0.042	0.019	0.030	0.065
6	Near shopping and entertainment center	0.029	0.034	0.059	0.078
7	Close to the river mouth in the North	0.021	0.045	0.042	0.049
8	Close to river mouth to the North	0.014	0.041	0.033	0.045

concentration was raised but was kept at a constant level during different growth stages.

Potential Target Hazard Quotient (THQ): The magnitudes of value of THQ in Table 3 shows for water column, shell, crab and school snack consumption were ranged 0.003-0.042, 0.019-0.045, 0.019-0.059 and 0.038-0.078, respectively.

The THQ value was peak observed in St. 5 and St. 6 where various shops, open market and community dwelling are located. In general, consumption of shell and crab is an important source of exposure to lead for humans due to the exposure period as well as the food school snack that routinely consumed by students. In a study also conducted by Choi and Han¹⁷ the associations between cadmium exposure period and osteoporosis by considering the effect of obesity in aged males communities are suggested to consume those contaminated aquatic habitat not regularly and in small amount.

Study conducted by Mallongi *et al.*⁷, Hasmi and Mallongi¹⁸ reported that tuna fish were sufficiently high in metal to warrant health concern for high-risk groups those who consumed fish from contaminated area with very high consumption rates. The consumption of these contaminated fish will exceed the risk-based concentration of zero recommended¹⁹. 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. Among the organs in which the environmental pollutant cadmium causes toxicity, the kidney has gained the most attention in recent years²⁰. Those facts obviously described the different of potential risks for people who consumed food contaminated by cadmium and those who consumed uncontaminated Cd food. Fortunately, the results

obtained from target health risks assessment revealed that people who consumed those foodstuffs cultivated in study area were not at risk. However, there might be potential health risks with respect of the continual long period of Hg contaminated foodstuffs consumption². Finally, it is suggested that a regular monitoring and surveillance evaluation on the existing policy relate to the households and shops waste disposal should be strictly and stated under law and regulation that are in place in accordance with actual water quality condition in Makassar Coastal area.

CONCLUSION

Cadmium concentration both in aquatic and terrestrial systems have been exceeded the allowable level for environmental standard and for cadmium in food standard. Although the magnitude of THQ values were still lower than 1, that means still safe for all those food to be consumed, it may produce hazard for long period of consumption due to the accumulation and biomagnifications process in the living aquatic habitats.

ACKNOWLEDGEMENTS

Authors highly appreciate and would like to thank the head of Tallo district who have given a very kind cooperation during the research commencement. Hence, we thank to laboratory members of chemical laboratory, Health Laboratories Makassar, Indonesia for their assistance during sample collection and analysis. Appreciation also goes to the Hasanuddin University, Makassar Papua for partly financial support within this study.

REFERENCES

1. Olszowski, T., I. Baranowska-Bosiacka, I. Gutowska, K. Piotrowska and K. Mierzejewska *et al.*, 2015. The effects of cadmium at low environmental concentrations on THP-1 macrophage apoptosis. *Int. J. Mol. Sci.*, 16: 21410-21427.

2. McLennan, S.M. and R.W. Murray, 1999. Geochemistry of Sediments. In: Encyclopedia of Geochemistry, Marshall, C.P. and R.W. Fairbridge (Eds.). Springer, New York, ISBN-13: 978-0412755002, pp: 182-192.
3. ATSDR., 2010. Cadmium, relevance to public health. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service, USA.
4. Rager, J.E., A. Yosim and R.C. Fry, 2014. Prenatal exposure to arsenic and cadmium impacts infectious disease-related genes within the glucocorticoid receptor signal transduction pathway. *Int. J. Mol. Sci.*, 15: 22374-22391.
5. Environmental Impact Department of Sulawesi, 2004. Environmental impact report of management agency of South Sulawesi in 2004. Environmental Impact Department of Sulawesi, Indonesia.
6. Department of Environmental Management and The Cleanliness of Makassar, 2008. Database environmental status of Makassar 2006. Department of Environmental Management and Cleanliness of Makassar, Makassar.
7. Mallongi, A., P. Parkpian, P. Pataranawat and S. Chinwetkitvanich, 2015. Mercury distribution and its potential environmental and health risks in aquatic habitat at artisanal buladu gold mine in Gorontalo Province, Indonesia. *Pak. J. Nutr.*, 14: 1010-1025.
8. Environment Canada, 1995. Interim sediment quality guideline. Soil and Sediment Quality Section, Guidelines Division, Ecosystem Conservation Directorate Evaluation and Interpretation Branch, Ottawa, Ontario, Canada.
9. US EPA., 1997. Ecological risk assessment guidance for superfund (ERAGS) Step 2: Screening level exposure estimate and risk calculation. United States Environmental Protection Agency, Washington, DC.
10. Rayment, G.E. and G.A. Barry, 2000. Indicator tissues for heavy metal monitoring-additional attributes. *Mar. Pollut. Bull.*, 41: 353-358.
11. USEPA., 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. Third Edition, Report No. EPA/600/4-91/002, July 1994, United States Environmental Protection Agency, Cincinnati, Ohio.
12. Nevarez, M., L.O. Leal and M. Moreno, 2015. Estimation of seasonal risk caused by the intake of lead, mercury and cadmium through freshwater fish consumption from urban water reservoirs in arid areas of Northern Mexico. *Int. J. Environ. Res. Public Health*, 12: 1803-1816.
13. Kim, Y.M., J.Y. Chung, H.S. An, S.Y. Park and B.G. Kim *et al.*, 2015. Biomonitoring of lead, cadmium, total mercury and methylmercury levels in maternal blood and in umbilical cord blood at birth in South Korea. *Int. J. Environ. Res. Public Health*, 12: 13482-13493.
14. Fifi, U., T. Winiarski and E. Emmanuel, 2013. Assessing the mobility of lead, copper and cadmium in a calcareous soil of Port-au-Prince, Haiti. *Int. J. Environ. Res. Public Health*, 10: 5830-5843.
15. Acquavita, A., S. Covelli, A. Emili, D. Berto and J. Faganeli *et al.*, 2012. Mercury in the sediments of the Marano and Grado Lagoon (Northern Adriatic Sea): Sources, distribution and speciation. *Estuarine Coastal Shelf Sci.*, 113: 20-31.
16. Lai, H.Y. and B.C. Chen, 2013. The dynamic growth exhibition and accumulation of cadmium of pak choi (*Brassica campestris* L. ssp. *chinensis*) grown in contaminated soils. *Int. J. Environ. Res. Public Health*, 10: 5284-5298.
17. Choi, W.J. and S.H. Han, 2015. Blood cadmium is associated with osteoporosis in obese males but not in non-obese males: The Korea national health and nutrition examination survey 2008-2011. *Int. J. Environ. Res. Public Health*, 12: 12144-12157.
18. Hasmi and A. Mallongi, 2016. Health risk analysis of lead exposure from fish consumption among communities along Youtefa Gulf, Jayapura. *Pak. J. Nutr.*, 15: 929-935.
19. US EPA., 1996. Risk-based concentration table, January-June 1996. United States Environmental Protection Agency, Philadelphia, PA.
20. Yang, H. and Y. Shu, 2015. Cadmium transporters in the kidney and cadmium-induced nephrotoxicity. *Int. J. Mol. Sci.*, 16: 1484-1494