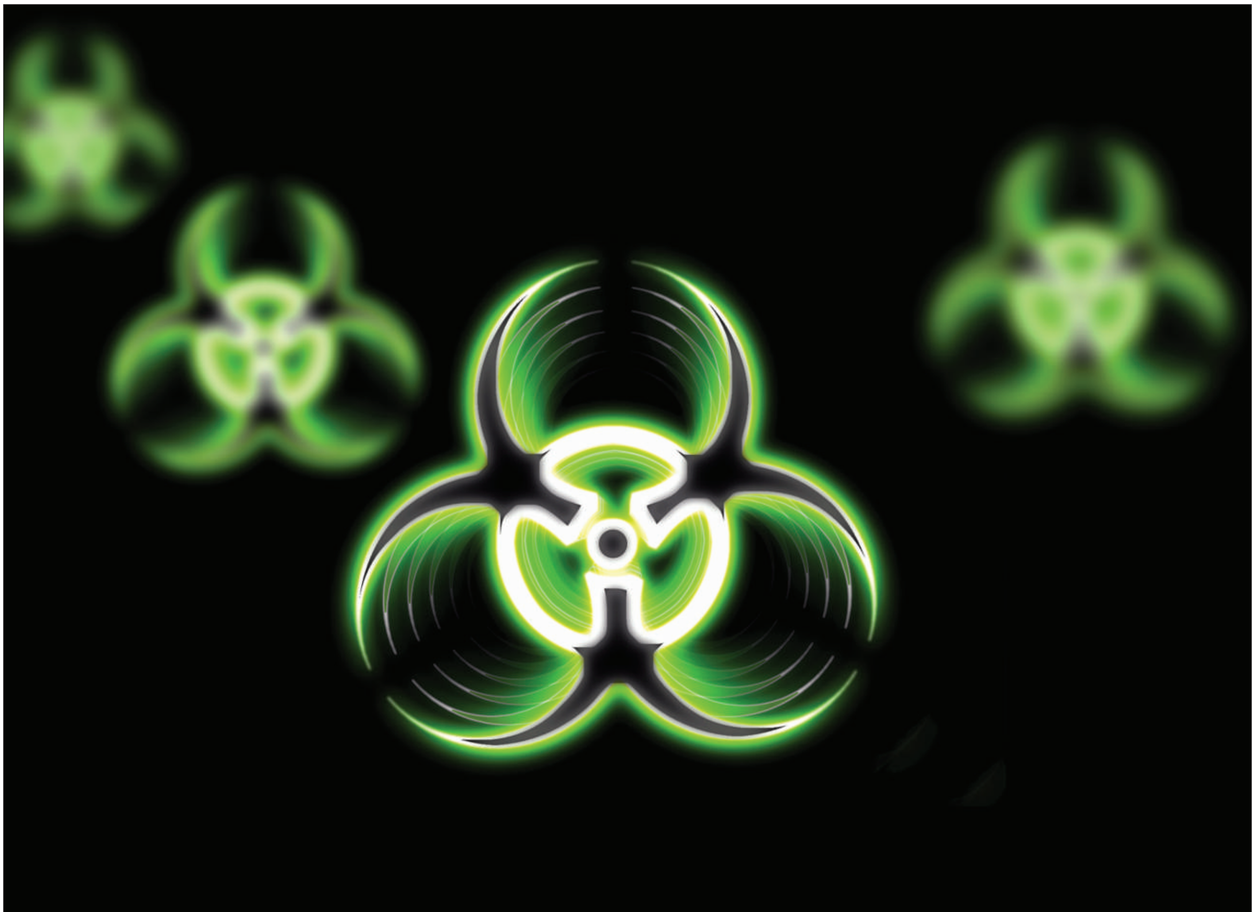

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Research Article
Assessing the Target Hazard Risks of Cadmium Pollutant due to Consumption of Aquatic Biota and Food Snack Among School Children in Tallo Coastal Area of Makassar

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Abstract
Background and Objective: Cadmium is used extensively in various industrial processes in the city of Makassar, South Sulawesi, as a results it 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

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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 environment[1]. 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 particulates[2] 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 animals[3]. 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 role[1]. 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 areas[4]. 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 units[5]. According to the Department of Environmental Management and the cleanliness of Makassar[6], 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 A*nadara 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 analyzed[7].

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:

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

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 high[8-10].

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 EPA[11] region III risk based concentration (Table 1) and it is described by the following equation:

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

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} $\times$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 regulations[12]. 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

		Ecological risks		
Station	Locations	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, Nigeria[15].

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 countries[13].

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 form 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, Nigeria[15].

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 weight[8]. 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 column[15]. 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 Chen[16] 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

		Target Hazard Quotient (THQ)			
Station	Location	Water column	Shell (*Anadara trapezia* 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 Han[17] 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 Mallongi[18] 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 recommended[19]. 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 years[20]. 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 consumption[2]. 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.

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