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# Estimated Health Risk of Cadmium and Chromium in Elderly Blood Cockle Consumers, Lantebung

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This study assessed the non-carcinogenic health risks of Cadmium (Cd) and Chromium (Cr) exposure through blood cockle (*Anadara granosa*) consumption among elderly residents in Lantebung, Makassar Strait. Blood cockle samples were collected from six purposively selected points, and Cd and Cr concentrations were analyzed. Health risks were estimated using intake calculations and the Risk Quotient (RQ). Cd and Cr concentrations were generally below national and international food safety limits. However, some elderly individuals, particularly frequent consumers, exceeded the non-carcinogenic risk threshold (RQ > 1). The highest risks were associated with specific sampling points, reflecting localized contamination. Risk factors included high consumption rates, long exposure duration, and lower body weight. These findings suggest that compliance with contaminant limits alone may not ensure safety for vulnerable populations. Regular environmental monitoring, risk communication for high-risk groups, and strengthened pollution control measures are recommended. Public health interventions, including periodic health screening and guidance on safe seafood consumption, are needed to reduce long-term health impacts.

**Keywords:** Cadmium, Chromium, Blood Cockle, Non-Carcinogenic Risk, Elderly

## INTRODUCTION

Environmental pollution in coastal areas caused by human activities has become a global concern, particularly regarding heavy metal contamination in marine ecosystems, with substantial evidence showing that both natural and anthropogenic sources contribute to the release of toxic metals such as cadmium and chromium, which subsequently bioaccumulate along the food chain and pose adverse health impacts to exposed populations (Angon et al., 2024; Laoye et al., 2025). The Lantebung area in Makassar, located in a coastal zone and part of a mangrove conservation region, is not exempt from environmental pressures resulting from surrounding domestic, agricultural, and industrial activities. These wastes carry heavy metals such as Cadmium (Cd) and Chromium (Cr) into the waters, which have the potential to accumulate in marine organisms such as shellfish consumed by local communities. Long-term consumption of shellfish contaminated with heavy metals may pose health risks, especially for vulnerable groups such as the elderly, who generally have lower immune resistance and declining metabolic function, and dietary seafood intake has been identified as a major exposure pathway contributing to non-carcinogenic health risks in coastal populations (Immaculate Jeyasanta & Patterson, 2025; Mahurpawar, 2015; US EPA, 2004; WHO, 2010, 2016b).

Shellfish are widely recognized as effective bioindicators for heavy metal pollution in coastal ecosystems due to their strong bioaccumulation capacity and limited ability to regulate metal uptake, resulting in higher metal concentrations in their tissues compared to surrounding waters. Previous studies have shown that heavy metal concentrations in shellfish may exceed safety limits and pose potential health risks through dietary exposure (Begum et al., 2023; FAO/WHO, 2011; Lee et al., 2022; Nguyen et al., 2025; Rainbow, 2024; Yuan et al., 2019). In Indonesia, research on health risks associated with heavy metal exposure through shellfish consumption remains limited, particularly studies focusing on elderly populations. Yet, understanding the magnitude of potential risks is critical for formulating prevention strategies and protecting the health of coastal communities.

Research focusing on elderly groups is also highly relevant given that older adults tend to have increased sensitivity to heavy metal toxicity, which may lead to chronic health problems such as kidney disorders, neurological damage, and cognitive impairment (Järup & Åkesson, 2009; Kwon et al., 2023; US EPA, 2004; WHO, 2010). In the context of public health, non-carcinogenic health risk assessments can provide essential data for government authorities and stakeholders to develop more effective environmental and health management policies, especially in coastal regions that heavily rely on marine resources (Begum et al., 2023; Mohiuddin et al., 2022; US EPA, 2004; WHO, 2010).

A study by Gafur and Abbas (2022) conducted in the Tallo River Estuary, Makassar, reported that blood cockles (*Anadara granosa*) collected from the area contained Cadmium and Chromium at levels exceeding the safe consumption limits set by WHO/FAO. These findings indicate that communities in the coastal areas of Makassar City, including the Lantebung region which shares similar environmental characteristics, have a high potential for heavy metal exposure through shellfish consumption. Furthermore, the study estimated safe consumption limits but did not elaborate on non-carcinogenic health risks specifically for vulnerable groups such as the elderly. Therefore, follow-up research focusing on non-carcinogenic risk estimation among the elderly population in this area is urgently needed to support health protection efforts and mitigate risks associated with heavy metal exposure from local food sources (Gafur & Abbas, 2022).

Therefore, the main contribution of this study lies in the assessment of non-carcinogenic health risks that specifically focuses on the elderly population as a vulnerable group, which has not been widely addressed in previous studies conducted in Makassar or other coastal areas of Indonesia. Unlike earlier studies that generally only reported heavy metal concentrations or determined safe consumption limits in a general population, this research directly links the level of heavy metal exposure from shellfish consumption to the health risk implications for the elderly. This approach provides added value both scientifically and practically, as the findings can serve as a basis for developing seafood safety policies, planning targeted public health interventions, and formulating more focused risk mitigation strategies for high-risk groups in the coastal area of Lantebung.

## METHOD

### Ethical statement

Blood cockle (*Anadara granosa*) samples were collected without causing habitat degradation, and the species is not listed as protected under IUCN or Indonesian regulations, ensuring that sample collection complied with ethical standards and local regulations. Participation of elderly respondents followed established research ethics principles, including clear information disclosure, written informed consent, and full confidentiality of personal data. This study received ethical approval from the Research Ethics Committee of Universitas Muslim Indonesia under approval number 624/A.1/KEP-UMI/VIII/2025.

### Materials and Methods

This study was conducted in the Makassar Strait waters and involved elderly individuals who consume blood cockles in the Lantebung area, Bira Subdistrict, Tamalanrea District, Makassar City. The selection of this general area was performed using the Purposive Sampling method based on considerations of environmental pressure from domestic and industrial activities, which specifically pose a high potential for heavy metal contamination. *Anadara granosa* samples were then collected from six sampling points within this location. The determination of these specific sampling points utilized Judgmental Sampling, where the selection of locations was based on professional assessment of the area with the highest potential for contamination. Blood cockle samples were collected from six sampling points distributed along the Makassar Strait waters during the period of August to November 2025 (Figure 1).

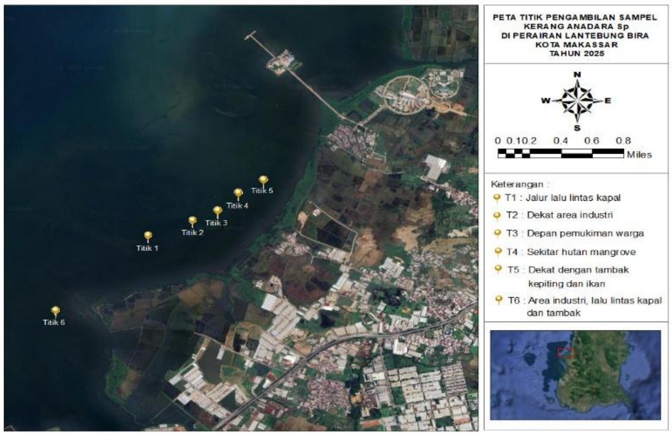


**Figure 1.** Sampling locations of blood cockle (*Anadara sp.*) in the coastal waters of Lantebung Bira, Makassar City, 2025

### Type of Research

This study is an observational research employing an Environmental Health Risk Assessment (EHRA) approach, which includes hazard identification, exposure assessment, dose–response analysis, and risk characterization. These stages were conducted simultaneously to estimate the magnitude of health risks associated with exposure to chromium (Cr) and cadmium (Cd) through the consumption of *Anadara granosa* by the community.

### Place and Time of Research

The study was conducted in the coastal waters of Lantebung Bira, Makassar City, from August to November 2025.

### Population and Sample

The study population consisted of elderly individuals who routinely consumed *Anadara granosa* in the study area. A total of 30 elderly respondents were selected using quota sampling based on predetermined criteria, including age group, frequency of shellfish consumption, and general health status. This sample size was determined by considering time limitations, available resources, and the specific characteristics of the target population. Quota sampling was applied to ensure that key subgroups relevant to exposure patterns were adequately represented. However, it is acknowledged that quota sampling is a non-probability method; therefore, the findings of this study are not intended for statistical generalization to the wider elderly population but rather to support local health risk profiling and preliminary risk assessment.

Samples of *Anadara granosa* were collected from six sampling points using judgmental sampling. The selection of sampling locations was based on several specific criteria, including proximity to potential pollution sources such as domestic wastewater discharge, coastal settlements, small-scale industrial activities, and areas with a high intensity of human activities along the shoreline. Additional considerations included water circulation patterns, accessibility to shellfish harvesting sites, and the representativeness of areas commonly used by local communities for shellfish collection. These criteria were applied to ensure that the sampling points reflected variations in environmental pressure levels and were able to realistically capture spatial variations in contamination. This approach was adopted to enhance the transparency and credibility of the environmental assessment by clearly linking the sampling locations with potential sources of heavy metal inputs.

The samples were analyzed at the Testing Laboratory of the Center for Agricultural Modernization Development, Ministry of Agriculture, South Sulawesi, using an Atomic Absorption Spectrophotometer (AAS) to determine Cr and Cd concentrations. Field data and laboratory results were processed using SPSS and Microsoft Excel and analyzed descriptively to characterize the study variables and support localized environmental health risk assessment.

## Data Collection

Data were collected through two main components: environmental sampling and respondent surveys. Samples of *Anadara granosa* were obtained from six predetermined locations in the coastal waters of Lantebung, Makassar, using judgmental sampling based on professional assessment of areas with potential contamination. Each sample was cleaned, homogenized, and prepared for laboratory analysis following standardized procedures.

In parallel, data on shellfish consumption patterns were obtained from elderly respondents (≥60 years) residing in the Lantebung coastal area. Respondents were selected using quota sampling based on age, frequency of shellfish consumption, and health status. Consumption data were collected using a Food Frequency Questionnaire (FFQ), including information on portion size, frequency, duration of consumption, demographic characteristics, and basic health information. All data collection followed ethical guidelines and was conducted with informed consent.

## Data Analysis and Processing

Laboratory analyses were conducted at the Testing Laboratory of the Center for Agricultural Modernization Development, using an Atomic Absorption Spectrophotometer (AAS) to quantify concentrations of chromium (Cr) and cadmium (Cd) in *Anadara granosa*. The laboratory results were processed to obtain mean, minimum, maximum, and standard deviation values for each metal.

The Intake (I) of each metal was calculated using the formula:

$$I = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:
C = metal concentration (mg/kg),
IR = ingestion rate (kg/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days).

The exposure assessment was conducted using standard parameters, including ingestion rate (IR), exposure frequency (EF), exposure duration (ED), body weight (BW), and reference dose (RfD). All exposure parameters were adopted from internationally recognized guidelines issued by WHO and the US EPA to ensure methodological reliability and comparability with previous studiesThe ingestion rate and exposure frequency were determined based on structured interviews with respondents and adjusted using reference values recommended by US EPA (2004) and WHO (2010, 2016). The exposure duration was defined according to the average duration of shellfish consumption habits among the elderly population, while body weight values were obtained from direct measurements of each respondent and supported by default values recommended in US EPA exposure factor handbooks. Reference doses (RfD) for cadmium (Cd) and chromium (Cr) were adopted from the US EPA Integrated Risk Information System (IRIS) and WHO guidelines to ensure that the toxicity benchmarks used in the risk calculation were scientifically valid and internationally accepted. The non-carcinogenic risk was expressed as the Risk Quotient (RQ), calculated by comparing the estimated daily intake (EDI) with the corresponding RfD values, following the standard risk assessment framework proposed by US EPA. The consistent use of authoritative references for all exposure parameters strengthens the methodological validity and credibility of the health risk assessment conducted in this study.
Non-carcinogenic risk was assessed using the Risk Quotient (RQ):

$$RQ = \frac{I}{RfD}$$

The interpretation of the Risk Quotient (RQ) in this study clearly distinguishes between population-level risk and individual-level risk. The mean RQ values for both cadmium (Cd) and chromium (Cr) were below 1, indicating an acceptable level of non-carcinogenic risk at the population level. However, several individual respondents showed RQ values exceeding the threshold of 1. This finding indicates that potential health risks are not uniformly distributed across the study population but are concentrated among certain individuals with higher exposure levels.

Such elevated individual RQ values may be associated with higher consumption rates of Anadara granosa, lower body weight, longer exposure duration, or a combination of these factors. Therefore, the results should not be overgeneralized to imply that shellfish consumption is entirely safe for all elderly individuals in the study area. Instead, the findings emphasize that potential risks are particularly relevant for specific high-exposure individuals.

Accordingly, this study highlights the importance of targeted risk communication and intervention strategies directed toward vulnerable subgroups rather than applying uniform conclusions at the population level. This approach is consistent with the principle of Environmental Health Risk Assessment (EHRA), which aims to identify and protect high-risk individuals within a population and to support localized and evidence-based risk management policies. The Risk Quotient (RQ) was calculated to estimate potential health risks. The proportion of the population exceeding RQ > 1 was calculated to estimate potential health risks. Descriptive statistics and correlation tests were conducted using SPSS and Microsoft Excel to analyze respondent characteristics and their relationship with risk levels.

## RESULTS AND DISCUSSION

Bira Subdistrict is located on the southwestern coast of Makassar City, specifically in Tamalate District, with geographical coordinates of 5°05'14.00" S and 119°28'52.20" E. This area borders directly with the Flores Sea to the west and is part of a rich coastal ecosystem. The topography is relatively flat, with land contours that support various coastal activities such as fishing, shellfish and crab gathering, as well as seaweed cultivation.

**Table 1.**
Characteristics of Elderly Respondents by Gender and Age Category (n=30)

| Variable | Category | n | % |
|---|---|---|---|
| **Gender** | Male | 9 | 30 |
| | Female | 21 | 70 |
| **Elderly Category** | Young elderly (60–69 years) | 17 | 56.7 |
| | Middle-aged elderly (70–79 years) | 10 | 33.3 |
| | Oldest-old / advanced elderly (≥80 years) | 3 | 10.0 |

As shown in Table 1, the majority of respondents were female (70%). More than half were classified as young elderly (60–69 years, 56.7%), while 10.0% were aged ≥80 years.

### Heavy Metal Concentration Levels in Blood Cockles

The results of the examination of heavy metal concentrations of Cadmium (Cd) and Chromium (Cr) in blood cockles using the AAS (Atomic Absorption Spectrophotometry) method can be seen in the following table:

**Table 2.**
Cadmium (Cd) and Chromium (Cr) Concentrations in Blood Cockles (Anadara granosa) from Lantebung Bira Waters, Makassar City (2025)

| No | Sampling Points | Cadmium (Cd) (mg/kg) | Chromium (Cr) (mg/kg) | Note |
|---|---|---|---|---|
| 1 | T1 | < LOD | 0.465 | *ND* |
| 2 | T2 | 0.350 | < LOD | *ND* |
| 3 | T3 | 0.290 | < LOD | *ND* |
| 4 | T4 | 0.356 | 0.929 | - |
| 5 | T5 | 0.273 | 0.444 | - |
| 6 | T6 | < LOD | 0.454 | *ND* |

*Notes:*
1. *LOD (Limit of Detection):* The lowest concentration of a substance that can be reliably detected by the analytical method.
2. *ND (Not Detected):* Concentration was below the instrument's detection limit.
3. For health risk calculations, *ND* values were treated as 0 mg/kg.

The laboratory analysis of heavy metal concentrations in blood cockles (Anadara granosa) is presented in Table 2. Cadmium (Cd) was detected at four of the six sampling points (T2, T3, T4, and T5). The highest concentration was recorded at T4 (0.356 mg/kg), followed by T2 (0.350 mg/kg), while the lowest detectable concentration was found at T5 (0.273 mg/kg). At sampling points T1 and T6, Cd concentrations were below the limit of detection (ND).

Chromium (Cr) was detected at sampling points T1, T4, T5, and T6. The highest concentration was observed at T4 (0.929 mg/kg). Similar values were recorded at T1 (0.465 mg/kg) and T6 (0.454 mg/kg), while the lowest detectable concentration was found at T5 (0.444 mg/kg). Chromium was not detected at sampling points T2 and T3.

### Dose–Response Analysis

The dose–response relationship describes the association between the total amount of an agent (chemical or biological) administered, received, or absorbed by an organism and the biological changes that occur as a result of exposure (Directorate General of Disease Control and Environmental Health, Ministry of Health, Republic of Indonesia, 2012). The RfD (Reference Dose) value is used as a benchmark to assess potential health risks via the ingestion route. Table 3 presents the agents, RfD values, critical effects, and relevant references.

**Table 3.**
RfD Values, Critical Effects, and References for the Ingestion Route

| Agent | Dose–Response (RfD) | Critical Effects and References |
|---|---|---|
| $Cr^{6+}$ (Hexavalent Chromium) | $3 \times 10^{-3}$ mg/kg/day | Chronic drinking water bioassay in rats (McKenzie et al., 1958); drinking water exposure study in Jinzhou population (Zhang & Li, 1987) |
| Cd (Cadmium) | $5 \times 10^{-4}$ mg/kg/day | Proteinuria due to chronic exposure in humans (US EPA, 1985) |

The Reference Dose (RfD) values presented in Table 3 provide benchmarks for evaluating potential health risks from oral exposure to hexavalent chromium ($Cr^{6+}$) and cadmium (Cd). $Cr^{6+}$ has an RfD of $3 \times 10^{-3}$ mg/kg/day, derived from chronic drinking water studies in rats and epidemiological studies in the Jinzhou population. Exposure below this value is generally considered low risk, while intake above it may increase the likelihood of chronic adverse effects. Cadmium exhibits a lower RfD of $5 \times 10^{-4}$ mg/kg/day, reflecting its higher toxicity. Chronic human exposure to cadmium has been associated with proteinuria and renal damage. Intakes exceeding this RfD indicate a significant potential for long-term health effects.

**Environmental Health Risk Assessment**
**Heavy Metal: Cadmium**

**Table 4.**
Exposure Analysis Values for Cadmium (Cd) Among Elderly Consumers of Blood Cockles in the Lantebung Bira Waters, Makassar City

| Sampling Points | Respondent | Environmental Health Risk Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C (mg/kg) | R (g/day) | $D_t$ (years) | $f_E$ (days/year) | $W_b$ (kg) | $T_{avg}$ (days) | *Intake (mg/kg/day)* | RQ |
| 1 | 1 | 0 | 250 | 60 | 300 | 47.3 | 10950 | 0 | 0.0000 |
| | 2 | 0 | 250 | 30 | 24 | 82.3 | 10950 | 0 | 0.0000 |
| | 3 | 0 | 250 | 70 | 24 | 42.8 | 10950 | 0 | 0.0000 |
| | 4 | 0 | 250 | 30 | 24 | 42.3 | 10950 | 0 | 0.0000 |
| | 5 | 0 | 250 | 70 | 96 | 53.4 | 10950 | 0 | 0.0000 |
| 2 | 6 | 0.35 | 150 | 80 | 24 | 36.7 | 10950 | 0.000250831 | 0.5017 |
| | 7 | 0.35 | 150 | 70 | 96 | 40.3 | 10950 | 0.000799483 | 1.5990 |
| | 8 | 0.35 | 150 | 70 | 96 | 35.5 | 10950 | 0.000907582 | 1.8152 |
| | 9 | 0.35 | 250 | 65 | 24 | 56.2 | 10950 | 0.000221811 | 0.4436 |
| | 10 | 0.35 | 50 | 60 | 48 | 56.5 | 10950 | 0.000081464 | 0.1629 |
| 3 | 11 | 0.29 | 150 | 60 | 24 | 66.4 | 10950 | 0.000086153 | 0.1723 |
| | 12 | 0.29 | 150 | 66 | 24 | 65.8 | 10950 | 0.000095632 | 0.1913 |
| | 13 | 0.29 | 150 | 60 | 24 | 62.9 | 10950 | 0.000090947 | 0.1819 |
| | 14 | 0.29 | 150 | 65 | 24 | 55.2 | 10950 | 0.000112269 | 0.2245 |
| | 15 | 0.29 | 150 | 70 | 24 | 63.3 | 10950 | 0.000105434 | 0.2109 |
| 4 | 16 | 0.35 | 50 | 76 | 24 | 47.4 | 10950 | 0.000061499 | 0.1230 |
| | 17 | 0.35 | 150 | 69 | 24 | 39.8 | 10950 | 0.000199491 | 0.3990 |
| | 18 | 0.35 | 150 | 70 | 24 | 49.5 | 10950 | 0.000162723 | 0.3254 |
| | 19 | 0.35 | 150 | 72 | 24 | 42.6 | 10950 | 0.000194482 | 0.3890 |

| Sampling Points | Respondent | Environmental Health Risk Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C (mg/kg) | R (g/day) | $D_t$ (years) | $f_E$ (days/year) | $W_b$ (kg) | $T_{avg}$ (days) | *Intake (mg/kg/day)* | RQ |
| | 20 | 0.35 | 50 | 80 | 24 | 56 | 10950 | 0.000054794 | 0.1096 |
| 5 | 21 | 0.27 | 150 | 80 | 24 | 42.6 | 10950 | 0.000166699 | 0.3334 |
| | 22 | 0.27 | 250 | 60 | 24 | 51.7 | 10950 | 0.000171697 | 0.3434 |
| | 23 | 0.27 | 150 | 76 | 300 | 36.53 | 10950 | 0.002308480 | 4.6170 |
| | 24 | 0.27 | 150 | 60 | 24 | 58.9 | 10950 | 0.000090425 | 0.1808 |
| | 25 | 0.27 | 150 | 70 | 24 | 41.4 | 10950 | 0.000150089 | 0.3002 |
| 6 | 26 | 0 | 50 | 62 | 48 | 54.9 | 10950 | 0 | 0.0000 |
| | 27 | 0 | 250 | 65 | 96 | 41.6 | 10950 | 0 | 0.0000 |
| | 28 | 0 | 250 | 68 | 24 | 58.6 | 10950 | 0 | 0.0000 |
| | 29 | 0 | 150 | 63 | 96 | 48 | 10950 | 0 | 0.0000 |
| | 30 | 0 | 150 | 43 | 96 | 47.9 | 10950 | 0 | 0.0000 |

The individual exposure analysis for Cadmium (Cd) in Table 4 reveals significant variations in health risk levels across different sampling points. At Sampling Points 1 and 6, the Risk Quotient (RQ) is 0.0000, as Cd concentrations in the blood cockle samples were below detectable limits, indicating no current health risk in these specific areas.

However, at Sampling Points 2, 3, 4, and 5, calculated Intake values range from to mg/kg/day. A critical finding is that three respondents (Respondents 7, 8, and 23) exhibit RQ values greater than 1, signaling potential non-carcinogenic health risks. The highest risk was identified in Respondent 23 (Sampling Point 5), with an RQ of 4.6170. This extreme value is primarily driven by a very high Exposure Frequency (fE) of 300 days per year combined with a low Body Weight (Wb) of 36.53 kg.

These elevated RQ values suggest that long-term consumption of contaminated cockles may lead to chronic health issues, such as renal dysfunction or bone mineral density loss, particularly in the elderly population whose physiological resilience is diminished. These results emphasize the need for site-specific consumption advisories and stricter environmental monitoring in the Lantebung Bira coastal area to mitigate heavy metal bioaccumulation.

**Heavy Metal: Chromium**

**Table 5.**
Exposure Analysis Values for Chromium (Cr) Among Elderly Consumers of Blood Cockles in the Lantebung Bira Waters, Makassar City

| Sampling Points | Respondent | Environmental Health Risk Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C (mg/kg) | R (g/day) | $D_t$ (years) | $f_E$ (days/year) | $W_b$ (kg) | $T_{avg}$ (days) | *Intake (mg/kg/day)* | RQ |
| 1 | 1 | 0.465 | 250 | 60 | 300 | 47.3 | 10950 | 0.003996641 | 1.3322 |
| | 2 | 0.465 | 250 | 30 | 24 | 82.3 | 10950 | 0.000091879 | 0.0306 |
| | 3 | 0.465 | 250 | 70 | 24 | 42.8 | 10950 | 0.000412239 | 0.1374 |
| | 4 | 0.465 | 250 | 30 | 24 | 42.3 | 10950 | 0.000178762 | 0.0596 |
| | 5 | 0.465 | 250 | 70 | 96 | 53.4 | 10950 | 0.001321636 | 0.4405 |
| 2 | 6 | 0 | 150 | 80 | 24 | 36.7 | 10950 | 0 | 0 |
| | 7 | 0 | 150 | 70 | 96 | 40.3 | 10950 | 0 | 0 |
| | 8 | 0 | 150 | 70 | 96 | 35.5 | 10950 | 0 | 0 |
| | 9 | 0 | 250 | 65 | 24 | 56.2 | 10950 | 0 | 0 |

| Sampling Points | Respondent | Environmental Health Risk Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C (mg/kg) | R (g/day) | $D_t$ (years) | $f_E$ (days/year) | $W_b$ (kg) | $T_{avg}$ (days) | *Intake (mg/kg/day)* | RQ |
| | 10 | 0 | 50 | 60 | 48 | 56.5 | 10950 | 0 | 0 |
| 3 | 11 | 0 | 150 | 60 | 24 | 66.4 | 10950 | 0 | 0 |
| | 12 | 0 | 150 | 66 | 24 | 65.8 | 10950 | 0 | 0 |
| | 13 | 0 | 150 | 60 | 24 | 62.9 | 10950 | 0 | 0 |
| | 14 | 0 | 150 | 65 | 24 | 55.2 | 10950 | 0 | 0 |
| | 15 | 0 | 150 | 70 | 24 | 63.3 | 10950 | 0 | 0 |
| 4 | 16 | 0.929 | 50 | 76 | 24 | 47.4 | 10950 | 0.000161655 | 0.0539 |
| | 17 | 0.929 | 150 | 69 | 24 | 39.8 | 10950 | 0.000524375 | 0.1748 |
| | 18 | 0.929 | 150 | 70 | 24 | 49.5 | 10950 | 0.000427729 | 0.1426 |
| | 19 | 0.929 | 150 | 72 | 24 | 42.6 | 10950 | 0.000511210 | 0.1704 |
| | 20 | 0.929 | 50 | 80 | 24 | 56 | 10950 | 0.000144031 | 0.0480 |
| 5 | 21 | 0.444 | 150 | 80 | 24 | 42.6 | 10950 | 0.000271657 | 0.0906 |
| | 22 | 0.444 | 250 | 60 | 24 | 51.7 | 10950 | 0.000279802 | 0.0933 |
| | 23 | 0.444 | 150 | 76 | 300 | 36.53 | 10950 | 0.003761967 | 1.2540 |
| | 24 | 0.444 | 150 | 60 | 24 | 58.9 | 10950 | 0.000147359 | 0.0491 |
| | 25 | 0.444 | 150 | 70 | 24 | 41.4 | 10950 | 0.000244590 | 0.0815 |
| 6 | 26 | 0.454 | 50 | 62 | 48 | 54.9 | 10950 | 0.000111386 | 0.0371 |
| | 27 | 0.454 | 250 | 65 | 96 | 41.6 | 10950 | 0.001541096 | 0.5137 |
| | 28 | 0.454 | 250 | 68 | 24 | 58.6 | 10950 | 0.000286128 | 0.0954 |
| | 29 | 0.454 | 150 | 63 | 96 | 48 | 10950 | 0.000776712 | 0.2589 |
| | 30 | 0.454 | 150 | 43 | 96 | 47.9 | 10950 | 0.000531244 | 0.1771 |

The individual exposure analysis in Table 5 illustrates the distribution of Chromium (Cr) risk across 30 respondents in six sampling points. The results show that Intake values vary significantly, ranging from 0 to 0.003996 mg/kg/day, which directly influences the Risk Quotient (RQ).

While the majority of respondents have an RQ ≤ 1, two specific individuals (Respondent 1 at Sampling Point 1 and Respondent 23 at Sampling Point 5) exhibit RQ values exceeding the safety threshold, with scores of 1.3322 and 1.2540, respectively. These elevated risks are primarily driven by a combination of high intake rates (R = 150–250 g/day) and high exposure frequencies (fE = 300 days/year).

In contrast, sampling points 2 and 3 show an RQ of 0 due to the non-detectable concentration of Chromium in the samples. For the high-risk individuals, long-term consumption of blood cockles may lead to non-carcinogenic health complications, as the elderly population typically possesses diminished physiological detoxification mechanisms.

**Exposure Analysis**

The exposure parameters in Table 6 characterize the interaction between the elderly population and their environment through blood cockle consumption. The data show that elderly individuals in Lantebung have a high Intake Rate (R) with a mean of 162 g/day, exceeding the common average for general populations. The Exposure Frequency (fE) shows significant variability (24 to 300 days/year), indicating that while some consume shellfish occasionally, others do so almost daily. The Exposure Duration (Dt) (median 65 years) reflects a lifelong habit of living in a coastal area and consuming local marine products. Combined with a relatively low average Body Weight (BW) of 52.7 kg, these factors increase the physiological vulnerability of this group, as a lower body mass results in a higher concentration of contaminants per kilogram of body weight. The Averaging Time (Tavg) of 10,950 days serves as a standardized denominator to assess the daily dose over a significant portion of the elderly's lifespan.

**Table 6.**
Exposure Parameters of Elderly Blood Cockle Consumers in Lantebung Bira

| No | Exposure Parameter | Mean | Median | Min | Max |
|---|---|---|---|---|---|
| 1 | Intake Rate (R) | 162 | 150 | 50 | 250 |
| 2 | Exposure Frequency (fE) | 86 | 48 | 24 | 300 |
| 3 | Exposure Duration (Dt) | 63 | 65 | 30 | 80 |
| 4 | Body Weight (BW) | 52.7 | 49.5 | 36.5 | 82.3 |
| 5 | Averaging Time (Tavg) | 30 x 365 = 10950* | | | |

*Note:* Tavg for non-carcinogenic effects is calculated as Dt×365 days. For this study, a standardized Tavg of 10,950 days (based on a 30-year default period) was applied for long-term non-carcinogenic risk calculations.

**Table 7.**
Non-Carcinogenic Intake of Cadmium (Cd) and Chromium (Cr) among Elderly Blood Cockle Consumers in Lantebung Bira, Makassar City, 2025

| No | Statistical Parameter | Intake of Cadmium (Cd) (mg/kg/day) | | Intake of Chromium (Cr) (mg/kg/day) | |
|---|---|---|---|---|---|
| | | Real-Time | Lifetime | Real-Time | Lifetime |
| 1 | Mean | 0.0002104 | 8.83086E-05 | 0.00052407 | 0.000243045 |
| 2 | Median | 0.06858E-05 | 4.43276E-05 | 0.000170209 | 9.68753E-05 |
| 3 | Minimum | 0 | 0 | 0 | 0 |
| 4 | Maximum | 0.00230848 | 0.000911242 | 0.003996641 | 0.00199832 |

The non-carcinogenic intake of Cadmium (Cd) and Chromium (Cr) among elderly blood cockle consumers in Lantebung Bira, Makassar City (2025), is expressed in mg/kg/day. The results indicate that the average (mean) intake levels for both metals remain relatively low under both real-time scenarios (based on current actual exposure duration) and lifetime scenarios (projected over a standardized 30-year exposure duration). However, the median values are notably lower than the mean, suggesting a right-skewed distribution where a small proportion of the elderly population experiences significantly higher intake levels. A minimum value of zero indicates that some individuals had no cockle consumption during the study period. Conversely, the high maximum intake values, particularly for Chromium (Cr), highlight a specific subgroup at higher potential risk, especially when frequent consumption is sustained over a long period.

**Table 8.**
Non-Carcinogenic Risk Quotient (RQ) Characteristics of Cadmium (Cd) and Chromium (Cr) among Elderly Blood Cockle Consumers in Lantebung Bira, Makassar City, 2025

| No | Statistical Parameter | RQ Cadmium (Cd) | | RQ Chromium (Cr) | |
|---|---|---|---|---|---|
| | | Real-Time | Lifetime | Real-Time | Lifetime |
| 1 | Mean | 0.420799019 | 0.176617295 | 0.174689989 | 0.081014951 |
| 2 | Median | 0.181371622 | 0.088655212 | 0.056736277 | 0.032291755 |
| 3 | Minimum | 0 | 0 | 0 | 0 |
| 4 | Maximum | 4.616959602 | 1.822484053 | 1.332213502 | 0.666106751 |

The non-carcinogenic Risk Quotient (RQ) a unitless index representing the ratio of intake to the reference dose was used to characterize the health risks for the elderly population in Lantebung Bira (2025). The mean RQ values for both Cadmium (Cd) and Chromium (Cr) were below 1 under both real-time scenarios (based on actual exposure duration) and lifetime scenarios (based on projected 70-year life expectancy), indicating that, on average, the non-carcinogenic health risks remain within acceptable limits (RQ ≤ 1). However, the maximum RQ values for both metals exceeded the threshold of 1, specifically reaching 4.616 for Cadmium and 1.332 for Chromium in the real-time scenario. These findings suggest that a specific subgroup of elderly individuals faces significant potential health risks from blood cockle consumption. This condition highlights the necessity for targeted interventions for these vulnerable groups, focusing on dietary habits and coastal environmental management to mitigate heavy metal bioaccumulation.

**Risk Management**

Based on the Technical Guidelines for Environmental Health Risk Assessment (EHRA) issued by the Ministry of Health of the Republic of Indonesia (2012), risk management is a follow-up action implemented when risk characterization results indicate an unacceptable level of risk, namely when exposure exceeds safe thresholds and may lead to adverse health effects. Accordingly, risk management of Cadmium (Cd) and Chromium (Cr) exposure among elderly blood cockle consumers is directed toward exposure control through technological, socio-economic, and institutional approaches. Technological measures include proper processing of shellfish prior to consumption, routine monitoring of Cd and Cr concentrations, and control of pollution sources. Socio-economic approaches involve education on safe consumption practices and dietary diversification, while institutional approaches focus on strengthening food safety regulations and routine surveillance of marine biota quality.

The determination of safe consumption limits indicates that the acceptable exposure thresholds for elderly individuals are 0.000694 mg/kg/day for Cadmium (Cd) and 0.00417 mg/kg/day for Chromium (Cr), assuming a body weight of 63 kg, an exposure frequency of 95 days per year, and an exposure duration of 47 years. Blood cockle consumption exceeding these thresholds requires the implementation of risk management measures to prevent long-term health effects, particularly renal function impairment due to Cadmium exposure and other potential health disturbances associated with Chromium exposure.

This study demonstrates that blood cockles (*Anadara granosa*) collected from the coastal waters of Lantebung Bira contain detectable levels of Cadmium (Cd) and Chromium (Cr), with concentrations varying across sampling points. Although the measured concentrations were generally below the maximum permissible limits established by national and international food safety standards, the Environmental Health Risk Assessment (EHRA) revealed that certain elderly individuals may experience unacceptable non-carcinogenic health risks. These findings highlight that compliance with contaminant concentration limits alone does not necessarily guarantee safety for vulnerable populations, particularly when long-term exposure and consumption behaviors are considered (BPOM RI, 2022; FAO/WHO, 2002).

**Characteristics of Elderly Respondents and Exposure Patterns**

The study involved 30 elderly respondents, a population group widely recognized as being particularly vulnerable to environmental contaminants due to age-related physiological decline. The majority of respondents were female (70%) and classified as young elderly (60–69 years). Previous studies and international risk assessment guidelines indicate that elderly populations have increased susceptibility to heavy metal toxicity as a result of reduced renal function, decreased metabolic detoxification capacity, lower body mass, and cumulative exposure over time (US EPA, 2018; WHO, 2021).

Exposure analysis revealed relatively high shellfish consumption rates, with a mean intake of 162 g/day, combined with a long median exposure duration of 65 years. These exposure characteristics, together with a relatively low average body weight (52.7 kg), substantially increased the estimated daily intake of heavy metals. Similar findings have been reported in Indian coastal regions, where dietary intake of heavy metals from seafood exhibited non-carcinogenic and combined hazard risk indices that suggest routine monitoring is warranted (Immaculate Jeyasanta & Patterson, 2025). Seasonal bioaccumulation of heavy metals among multiple seafood species has also been associated with health risk metrics such as THQ and HI across diverse coastal ecosystems (Tanhan et al., 2022). Furthermore, research from European coastal waters indicates elevated hazard indices for certain contaminants among sensitive population segments, emphasizing the need for targeted risk evaluations (Traven et al., 2023).

This result confirms that consumption behavior and exposure duration are key drivers of health risk in environmental health risk assessments. Even when heavy metal concentrations in seafood remain within regulatory limits, vulnerable populations such as the elderly may still experience elevated health risks due to their specific physiological and behavioral characteristics.

**Heavy Metal Concentrations in Blood Cockles**

The concentrations of Cd and Cr in blood cockles exhibited clear spatial variation, indicating localized contamination at specific sampling points. Based on Table 2, the highest Cadmium (Cd) concentration was detected at Sampling Point T4, with a value of 0.356 mg/kg. Although this concentration remains below the maximum limit established by the European Commission for Cd in bivalve mollusks, it may exceed more conservative reference values adopted in several international health risk assessments. The presence of Cd at sampling points T2, T3, T4, and T5, and its absence at T1 and T6, reflects heterogeneous contamination patterns in the Lantebung Bira coastal waters. Similar concentration ranges and spatial variability have been widely reported in coastal environments worldwide, highlighting the strong bioaccumulation capacity of bivalves in areas affected by metal pollution (Noman et al., 2022; Qin et al., 2021; Tanhan et al., 2022; Wang et al., 2022).

Chromium (Cr) concentrations also showed marked spatial variation. Cr was detected at sampling points T1, T4, T5, and T6, while it was not detected at T2 and T3.

The highest Cr concentration was observed at Sampling Point T4 (0.929 mg/kg), followed by comparable values at T1 (0.465 mg/kg) and T6 (0.454 mg/kg), with the lowest detected concentration at T5 (0.444 mg/kg). The consistently higher concentrations of both Cd and Cr at T4 suggest a stronger influence of localized contamination sources or site-specific environmental conditions, such as sediment composition and hydrodynamic processes, that favor metal accumulation. Similar site-specific enrichment patterns have been reported in coastal and estuarine ecosystems influenced by anthropogenic activities (Wang et al., 2022; Younis et al., 2024).

As filter-feeding organisms, blood cockles readily accumulate dissolved and particulate-bound metals from seawater and sediments. This biological characteristic makes them effective bioindicators of coastal pollution and valuable sentinels for assessing potential dietary exposure risks to local communities, particularly those with high levels of seafood consumption (Noman et al., 2022; Nzekwe et al., 2025; Qin et al., 2021).

**Dose–Response Assessment and Non-Carcinogenic Risk**

Cadmium posed the greatest non-carcinogenic health risk among the metals assessed. Although the mean Risk Quotient (RQ) values for Cd were below the safety threshold (RQ < 1), several individual respondents exhibited RQ values exceeding 1, indicating potential health concerns. Chronic exposure to cadmium primarily affects renal function, particularly the proximal tubules, and may lead to proteinuria and progressive kidney damage following long-term accumulation, as reported in recent risk assessment studies of seafood consumers exposed to heavy metals in coastal areas. For example, seafood species in Haikou (China) exhibited elevated non-carcinogenic risks associated with Cd intake, underscoring the relevance of Cd in dietary exposure risk assessments (Lin et al., 2024).

Chromium exposure showed a similar pattern, with most respondents presenting RQ values below 1, but with isolated cases exceeding the acceptable risk threshold. One important limitation of this study is that chromium speciation was not differentiated between trivalent chromium (Cr(III)) and hexavalent chromium (Cr(VI)). The laboratory analysis measured total chromium concentrations in blood cockles without identifying the specific chemical forms. This distinction is critical because Cr(VI) is substantially more toxic and carcinogenic than Cr(III), while Cr(III) has limited cellular permeability and generally lower toxicity (Kamila et al., 2023).

Therefore, the use of a reference dose (RfD) based on Cr(VI) in this study represents a conservative and protective approach in risk assessment. However, this assumption may lead to an overestimation of potential health risks if a substantial proportion of chromium in the samples was present in the less toxic Cr(III) form. Mechanistic studies of Cr speciation highlight the importance of distinguishing oxidation states in environmental exposures, as Cr(VI) readily enters cells and induces toxic oxidative stress compared to Cr(III) (Rasool et al., 2026)

Nevertheless, in the absence of chromium speciation data, the use of a Cr(VI)-based RfD is justified to ensure adequate protection of vulnerable populations, particularly the elderly, who are more susceptible to adverse health effects. Future studies are strongly recommended to incorporate chromium speciation analysis to allow a more accurate differentiation between Cr(III) and Cr(VI), thereby improving the precision of health risk characterization.

**Risk Characterization and Public Health Implications**

The variability in non-carcinogenic risk observed among elderly consumers underscores that health risks from seafood intake depend strongly on species type, regional contamination patterns, and consumption behavior. Recent global evidence indicates that, although most aquatic foods comply with safety standards, elevated cadmium levels are more frequently observed in molluscs, and risk levels may exceed acceptable thresholds in specific populations and regions (Nzekwe et al., 2025; Pandion et al., 2022; Singhato et al., 2025; Tanhan et al., 2022; Xu et al., 2025). Studies conducted in China, Southeast Asia, and other coastal regions have consistently shown that bivalves tend to accumulate higher concentrations of cadmium (Cd) compared to finfish, resulting in higher non-carcinogenic risk values for frequent shellfish consumers (Noman et al., 2022; Nzekwe et al., 2025; Qin et al., 2021; Xu et al., 2025).

The presence of individual RQ values exceeding 1 for both Cd and Cr indicates that a subset of elderly consumers in the Lantebung Bira coastal area may face unacceptable non-carcinogenic health risks. According to the US EPA risk assessment framework, an RQ greater than 1 signifies that exposure exceeds the reference dose and may increase the likelihood of adverse health effects under long-term exposure conditions (USEPA, 2009). Similar findings have been reported in coastal environments, where heavy metals in seafood and sediments pose potential non-carcinogenic health risks to local populations, particularly for communities with high seafood consumption (Wang et al., 2022; Xu et al., 2025; Younis et al., 2024; Zhao et al., 2021).

These findings are consistent with recent studies in coastal regions of Southeast Asia and other developing countries, where cadmium has frequently been identified as the dominant contributor to non-carcinogenic health risks associated with shellfish consumption (Ku et al., 2022; Singhato et al., 2025; Tanhan et al., 2022; Wang et al., 2022; Younis et al., 2024).

Moreover, recent literature emphasizes that vulnerable populations such as the elderly are at greater risk due to age-related physiological decline, lower body weight, and cumulative exposure over time, which can substantially amplify health risks even when contaminant concentrations remain within regulatory limits (US EPA, 2023; WHO, 2016a; Younis et al., 2024). Therefore, incorporating vulnerable population characteristics into seafood safety evaluations is increasingly recognized as essential in contemporary environmental health risk assessments.

**Implications for Risk Management**

The findings of this study underscore the need for targeted risk management strategies focused on elderly populations in coastal areas, who are particularly vulnerable to the adverse effects of heavy metal exposure. Risk communication programs should prioritize clear guidance on safe consumption limits, especially for shellfish harvested from locations with higher contamination levels. Previous studies have emphasized that effective communication of seafood consumption advisories is crucial for reducing health risks among high-exposure groups (WHO, 2021; US EPA, 2023; Younis et al., 2023).

In addition, regular and systematic monitoring of heavy metal concentrations in marine biota is essential for early detection of contamination trends and for supporting evidence-based public health interventions (Wang et al., 2022; Singhato et al., 2021). Such monitoring should be integrated with pollution source control strategies, including improved waste management and regulation of industrial and domestic discharges into coastal waters.

Community education programs that promote dietary diversification and awareness of potential contamination risks are also necessary to minimize long-term exposure, particularly among elderly individuals who often rely heavily on local seafood resources (Tanhan et al., 2022; Qin et al., 2023). Collectively, these measures are fundamental to ensuring sustainable seafood safety and protecting public health in the Lantebung Bira coastal region.

## CONCLUSIONS

This study demonstrates that blood cockles (*Anadara granosa*) harvested from the coastal waters of Lantebung–Bira contain detectable levels of Cadmium (Cd) and Chromium (Cr), with clear spatial variability among sampling points. Although the concentrations of both metals were generally below national and international maximum permissible limits, the Environmental Health Risk Assessment (EHRA) indicated that some elderly individuals experienced non-carcinogenic risk levels exceeding the acceptable threshold (RQ > 1). Cadmium was identified as the primary contributor to the observed health risk. This condition was mainly influenced by high consumption rates of blood cockles, long exposure duration, and relatively low body weight among elderly respondents. In contrast, Chromium contributed less significantly to the overall risk profile.

These findings highlight that food safety evaluations based solely on contaminant concentration thresholds may underestimate actual health risks, particularly in vulnerable populations such as the elderly. Therefore, incorporating exposure characteristics, including dietary habits, duration of exposure, and individual physiological factors, is essential for a more comprehensive and realistic environmental health risk assessment.

## SUGGESTION

It is recommended that risk-based seafood consumption guidelines be developed for elderly populations in coastal areas, particularly in Lantebung Bira, to minimize potential health risks from heavy metal exposure. Continuous monitoring of Cadmium and Chromium levels in coastal waters and marine biota should be strengthened, alongside stricter control of pollution sources. Health education programs focusing on safe consumption practices and dietary diversification for the elderly are also essential. Future studies are encouraged to involve larger sample sizes, include additional contaminants, and apply biomonitoring approaches to provide a more comprehensive assessment of long-term health risks associated with seafood consumption.

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