RESEARCH PAPER

Bioaccumulation Of Heavy Metals In Marine Products From Guayas And El Oro – Ecuador.

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ABSTRACT

This article presents a comparative analysis of data reported between 2009 and 2018 on the concentration of heavy metals in marine organisms from the coastal provinces of El Oro and Guayas, Ecuador. Through the critical review of previous scientific studies, maximum bioaccumulation values were consolidated in key species such as Anadara tuberculosa, which presented 870 mg/kg of mercury (limit: 0.5 mg/kg), Anadara similis with 37.21 mg/kg of cadmium (limit: 1 mg/kg), and Anadara grandis with 14.13 mg/kg of lead (limit: 0.3 mg/kg). These results reflect an extremely toxic dietary exposure that exceeds international limits by up to 1,740 times.

The methodology consisted of the collection, analysis and correlation of metal values in estuarine tissues, water and sediments, contrasted with the limits of organizations such as FAO, WHO and Codex. The findings show chronic pollution, persistent over time and spatially distributed in areas of high human consumption. The absence of specific regulations that sanction responsible sources such as illegal mining and the lack of urban wastewater treatment aggravates the problem and prolongs its health impact.

As part of the quantitative approach, descriptive statistical methods were applied to assess the frequency, distribution, and spread of diseases related to heavy metal exposure. Measures of central tendency and variability (mean, median, mode, range, standard deviation and coefficient of variation) were calculated, with the support of Microsoft Excel as a processing tool. The analysis of these data, in particular the morbidity records in mining areas of the country between 2009 and 2019, strengthened the understanding of the problem and was the starting point that inspired the elaboration of this article as a concrete contribution to the scientific debate on public health and food contamination.

The conclusions warn of a real risk of neurological, renal and hematological effects in coastal populations. This study shows the urgency of establishing a national regulation that regulates the quality of marine products and demands environmental responsibility from polluting sectors. Within this article you will find not only the most critical levels of exposure reported in the country, but also a methodological approach that transforms scattered data into a well-founded epidemiological alert, a major threat to public health that requires coordinated, multidisciplinary and evidence-based responses..

Keywords: Zaruma, artisanal mining, heavy metals, public health, health risk, Ecuado.

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INTRODUCTION

The bioaccumulation of heavy metals in marine products is an environmental and social issue of great importance. This process occurs when aquatic beings, such as fish, crustaceans and mollusks, absorb heavy metals from the environment, keep them in tissues and cannot effectively eliminate them. (Jorge Luis Gaibor Carpio, 2024) These metals, such as mercury (HG), lead (Pb), cadmium (CD) and arsenic (AS), enter the marine ecosystem through different anthropogenic sources, such as industrial discharge, mining, agricultural production, urban wastewater and fossil fuel processing. (Liliana & Alvarado, 2006) According to (Alanoca, 2016) once these metals and other pollutants are present in the marine environment, they can be incorporated into aquatic life as well as in its food chain, reaching high concentrations of pollutants and metals, especially in large species.

In their research topic (Medina Genesis & Mora Karina, 2017), the problem is quite serious given that the consumption of marine species represents a considerable percentage as a source of human food. Prolonged ingestion of these contaminated foods can cause cumulative toxic effects on the human body.

For (Ramos José, 2002), it has been proven that exposure to high concentrations of mercury can cause different diseases associated with

alterations in the central nervous system, cognitive problems, developmental disorders in both children and babies. Exposure to cadmium can induce kidney dysfunction, osteoporosis, and cardiovascular disorders. These effects are really worrying, especially in vulnerable populations such as children, pregnant women and people with compromised immune systems.

(Gutiérrez Yilbert, 2020) provides that the impacts that aquatic pollution has on the economic and social area. Fishing communities can be affected by the pollution present in their products, resulting in economic losses and affecting the health of the users who consume them. For this and several other reasons, a rigorous study must be carried out on the mechanisms of accumulation of metals in marine organisms to avoid the toxicity that these pollutants produce and how to avoid their exposure to people. Regular monitoring should also be carried out in places where fishing and sale of marine products should be carried out to increase health in the exit of merchandise and mitigate the spread of contaminated products.

The European Commission (2001) states that it is essential to raise awareness among consumers about the risks involved in the consumption of contaminated marine products. This can be achieved by promoting sustainable fishing practices and adopting strategies to reduce pollution in land and coastal areas.

The report according to (Jorge Luis Gaibor Carpio, 2024) indicates that heavy metal pollution in coastal areas of Ecuador is not an isolated or recent phenomenon, but a persistent problem that directly affects both estuarine ecosystems and the human communities that depend on them. Provinces such as El Oro and Guayas concentrate the most critical levels, as a result of industrial discharges, mining activities, intensive agriculture and uncontrolled urban dumping. The inspiration for this article came after the dissemination of recent reports in the province of Guayas, in which high levels of heavy metal contamination in locally marketed marine products were revealed, which set off alerts about its possible immediate impact on public health. Faced with this situation, the present study set out to review and comparatively analyze three scientific studies carried out between 2009 and 2019, focused on the presence of mercury (Hg), cadmium (Cd) and lead (Pb) in sediments, waters and bioaccumulatory organisms such as Anadara tuberculosa, similis and Cerithidea valida.

These findings not only confirm a tangible risk to public health and coastal biodiversity, but also reinforce the urgent need to establish environmental monitoring systems To promote environmental education strategies in affected communities. This article, beyond presenting data, seeks to make visible a silenced threat and motivate concrete actions in defense of life and the coastal environment of southern Ecuador.

2. METHODOLOGY

Study design

The present research adopted a documentary and descriptive approach, based on the review, analysis and interpretation of previously published bibliographic sources. No experiments or collection of samples were carried out in the field, but rather academic studies, technical reports, scientific articles and updated journalistic reports that address the presence of heavy metals in aquatic species and their implications for human health.

This type of study makes it possible to collect information from various geographical contexts such as the Ecuadorian Amazon and polluted coastal areas, in order to identify common patterns and understand the magnitude of the problem from a comprehensive perspective (Z. Xu et al., 2019).

Inclusion and exclusion criteria

Indexed scientific papers, university theses, peer-reviewed academic journal articles, and publications from specialized organizations, such as universities, environmental research centers, and technically supported media were included. Verified digital sources reporting recent findings on heavy metal contamination in fish and shellfish were also used.

Materials without bibliographic support, opinion documents without scientific basis, and publications prior to 2010 were excluded, except for those that provided fundamental background on bioaccumulation and toxicology of heavy metals.

Tools and procedures used

For the collection of information, scientific databases such as SciELO and Google Scholar were used, as well as institutional repositories of universities (such as the Dspace of the University of Cuenca). Mendeley software was used

to manage bibliographic references and organize citations in a standardized format.
The chosen documents were classified according to the type of origin, the nation of origin, the metals analyzed and the species impacted. Subsequently, a content analysis was performed to extract and synthesize the relevant findings related to bioaccumulation, effects toxicological factors, vulnerable species and risks to human health.
To organize and analyze this information, a Microsoft Excel database was built, where basic statistical tools were applied, such as the calculation of absolute and relative frequencies, means, standard deviation, and bar graphs were developed that allowed the distribution of the pollutant to be visualized. This analysis facilitated the identification of common patterns and trends, providing solidity to the comparative approach of the study from a descriptive and qualitative perspective.

Methods of analysis
It seeks to apply a qualitative and comparative approach to analyze the data collected. Inferential statistics were not used, since the data were not generated directly. Even so, the results were organized by frequency of appearance of metals in the studies, most affected geographical regions and species with the highest pollutant load. This allowed conclusions to be drawn based on patterns observed throughout the various sources reviewed.
The analysis will allow us to evaluate how the different metals affect aquatic organisms, what their impact is on human health and what environmental or anthropic factors influence their presence. It also made it possible to contrast recent findings from different countries, which enriches the global approach to the problem.

Heavy metal contamination
From a descriptive approach, heavy metals such as mercury (Hg), lead (Pb), cadmium (Cd) and arsenic (As) are persistent elements that tend to accumulate in the environment, especially in bodies of water. According to Senior (2016), these pollutants mainly come from anthropic activities such as mining, the chemical industry, the use of fertilizers, and the discharge of wastewater. As they are non-biodegradable elements, their presence and accumulation in aquatic environments constitutes an environmental problem on a global scale, which was evidenced in the documents analyzed from the gold and guaya regions.
Bioaccumulation and biomagnification in aquatic species

3. RESULTS
The documentary methodology allowed us to identify a recurring pattern in the studies according to Bustamante Salazar & Romero Menoscal (2023), which refers to the progressive accumulation of metals in the tissues of living organisms over time. Likewise, biomagnification, the increasing concentration of contaminants as one moves up the food chain, is key to explaining how these metals affect human consumers. This concept was relevant in the categorization and comparative analysis of vulnerable species in different geographical contexts.

Toxicological effects on aquatic fauna
From the qualitative analysis of the selected literature, findings were drawn on the physiological effects that heavy metals generate in aquatic organisms. Martín (2025) document liver tissue damage, reproductive alterations, immunosuppression and malformations in fish exposed to high concentrations of lead and mercury. These effects were systematized in the content analysis matrix used to organize the studies according to metal type, zone, organism and concentration recorded.

Table 1. Concentration of heavy metals in estuarine organisms

Metal	**Province**	**Area**	**Organism**	**Maximum Registered concentration**	**Limit permisible (FAO/Codex)**
Mercury (Hg)	Gold	Abroad Huaylá	Anadara tuberculosa	**870 mg/kg**	0,5 mg/kg
Lead (Pb)	Gold	La Puntilla	Anadara grandis	**14,13 mg/kg**	0,3 mg/kg
Cadmium (Cd)	Gold	La Puntilla	Anadara similis	**37,21 mg/kg**	1 mg/kg
Lead (Pb)	Guayas	Abroad Salted	Cerithidea valid (gastropod)	**0.26 mg/L in Water**	0.01 mg/L
Cadmium (Cd)	Guayas	Abroad Salted	Surface wáter	**0.08 mg/L**	0.005 mg/L

Author: (Eagles-Smith, Ackerman, et al., 2016)
Note: This table presents the maximum values of mercury (Hg), cadmium (Cd) and lead (Pb) detected in tissues of estuarine organisms collected in the provinces of El Oro and Guayas. The data
come from studies carried out between 2009 and 2018, and reflect the bioaccumulation in molluscs such as Anadara tuberculosa, Anadara similis, Anadara grandis y Cerithidea valida. (Villón Navas Briggitte Teresa, 2022)
The highest value corresponds to mercury in El Oro (870 mg/kg in A. tuberculosa), followed by cadmium (37.21 mg/kg in A. similis) and lead (14.13 mg/kg in A. grandis), all of them in concentrations thatfar exceed the limits permissible by international organizations such as the FAO, WHO and Codex Alimentarius. These results show

persistent contamination of anthropogenic origin, with direct impacts on organisms for human consumption.

Table 2. Maximum concentration of heavy metals recorded in organisms and water (2009–2018)

Metal	Province	Area / Station	Organization / Medium	Conc. Maximum	Limit Permissible*
Mercury (Hg)	Gold	Huaylá Estuary	Anadara tuberculosa	870 mg/kg	0.5 mg/kg
Cadmium (Cd)	Gold	La Puntilla	Anadara similis	37.21 mg/kg	1 mg/kg
Lead (Pb)	Gold	La Puntilla	Anadara grandis	14.13 mg/kg	0.3 mg/kg
Cadmium (Cd)	Guayas	Estero Salado	Surface wáter	0.08 mg/L	0.005 mg/L
Lead (Pb)	Guayas	Estero Salado	Surface wáter	0.26 mg/L	0.01 mg/L

Author: (Scientists et al., 2003)
Note: This table includes the highest concentrations of Hg, Cd and Pb recorded in aquatic organisms and environments in both provinces. Similarly, the tissue data include surface water concentrations obtained by Huilcarema (2018) in the Salado estuary, where lead reached 0.26 mg/L, exceeding more than 20 times the threshold established by the WHO (0.01 mg/L).

The comparative analysis shows that metals are present in all the compartments analyzed (tissues, water, sediments) and in all the study areas, which suggests chronic contamination, with spatial variability and risks for public health and aquatic fauna.

Table 3. Main bioindicator species affected by heavy metals

Species	Type	Bioaccumulated metal	Areas with higher levels
Anadara tuberculosa	Mollusk	Hg, Cd	Huaylá Estuary (El Oro)
Anadara similis	Mollusk	Cd, Pb	La Puntilla (El Oro)
Anadara grandis	Mollusk	Pb	El Oro, Guayas
Cerithidea valida	Gastropod	Cd, Pb	Estero Salado (Guayas)
Mytella guayanensis	Mollusk	Cd, Hg	Estero Salado (Guayas)

Author: (Díaz Rizo et al., 2016)
Note: This table highlights the species most commonly used as bioindicators of heavy metal contamination, including mollusks and gastropods such as Anadara tuberculosa, Cerithidea valida, and Mytella guayanensis. All these species are an essential part of the coastal diet and artisanal trade in Guayas and El Oro.

The selection of these species is due to their high bioaccumulation capacity, their wide estuarine distribution and their commercial value. The presence of metals such as Hg, Cd and Pb in dangerous concentrations in their tissues represents not only an environmental alert, but also a food and community health problem.

Table 4. Comparison based on three scientific studies on heavy metal contamination in El Oro and Guayas

Study / Source	Province	Area / Station	Metals Analyzed	Organizations / Medium	Value Maximum Reported	Regulations Overcome	Impacts Detected
Tamayo (2021)	Gold	Huaylá Estuary , La Puntilla	Hg, Cd, Pb, Ace, Zn, Cu, Cr, Ni	Anadara tuberculosis, A. similis, A. grandis	Hg: 870 mg/kg	Codex, WHO, FAO	High risk for human consumption , bioaccumulation, loss of Biodiversity
	Guayas	Estero Salado, Santay Island	Hg, Cd, Pb, As	Cerithidea valida, Mytella guayanensis	Cd: 1.3 7 ppm (fabric)	INEN 1108, Codex	Dispersed contamination, presence in water and organisms, Commercial species affected
Pernía et al. (2019)	Guayas, El Oro	Estero Salado,	Hg, Cd, Pb, hydrocarbons, coliforms	Water, sediments, Bivalves	Cd: 7,3 9 mg/kg	Canadian standards	Malformations in crabs, reduction of oxygen, alteration

		Churute, Huaylá		(Ucides, Anadara)		and Ecuadorian	of bacteria sedimentary
Huilcarema (2018)	Guayas	Estero Salado, Puente Portete	As, Cd, Pb, Hg	Surface water, sediment, Organisms	Pb: 0,26 mg/L (water)	WHO limit (0.01 mg/L Pb)	Chronic risk from exposure oral, child hazard, and Pregnant women

Note: This table consolidates the key data from the three studies reviewed (Tamayo, Pernía and Huilcarema), considering: geographical area, type of metal, contaminated environment, maximum value reported and its comparison with current regulations. It allows a comparative view between provinces and between sources of pollution (water vs. sediment vs. biological tissue).

The data confirm that El Oro concentrates the most extreme values, while Guayas presents a wider and more varied contamination in different compartments. Most of the records exceed national (MAATE) and international limits, which shows poor environmental management and a lack of continuous monitoring.

balanced view, with sediment and organism data, reinforcing evidence of multisectoral contamination. The table allows the identification of the sites and studies with the greatest environmental impact, which can serve as a basis for prioritizing remediation actions or new sampling campaigns in critical sectors.

Table 5. Maximum values of Hg, Cd and Pb per study Author: (Quispe et al., 2019)

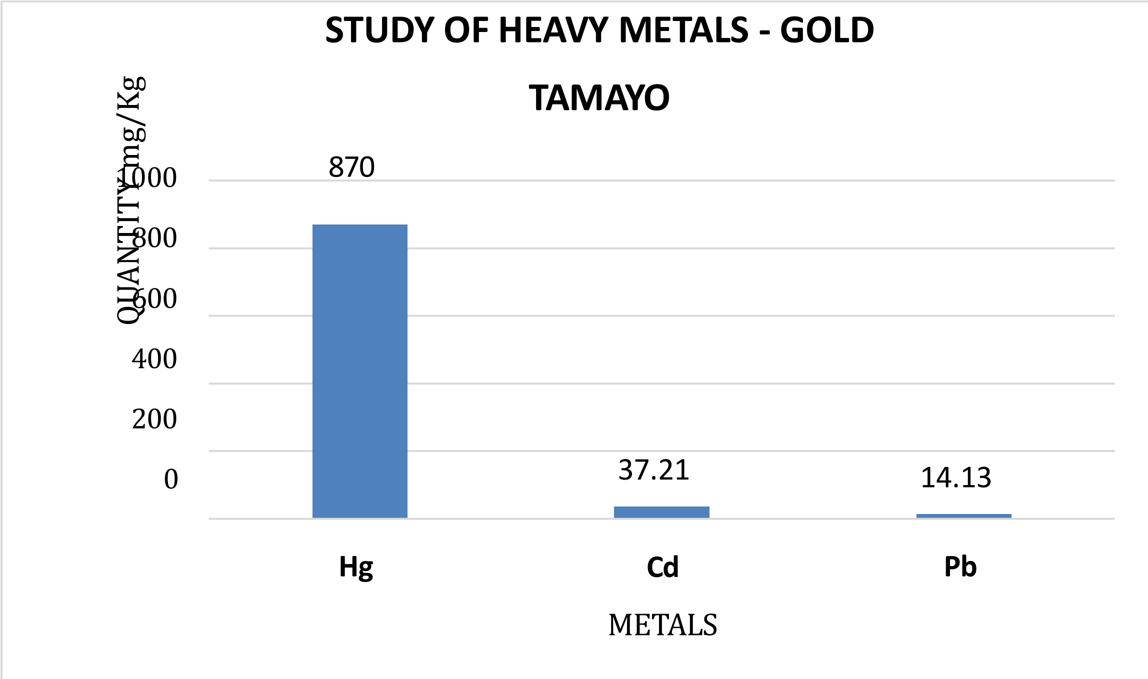
Province	Metal	Maximum Recorded Value	Unity	Area / Fountain
Gold	Hg	870 mg/kg	mg/kg (tissue)	Huaylá Estuary (Anadara tuberculosa)
Gold	CD	37.21 mg/kg	mg/kg (tissue)	La Puntilla (Anadara similis)
Gold	Pb	14.13 mg/kg	mg/kg (tissue)	La Puntilla (Anadara grandis)
Guayas	CD	1.37 ppm	ppm (fabric)	Estero Salado (Cerithidea valida)
Guayas	Pb	Does not specify maximum value	-	Mentioned in sediments and tissues

Note: This table summarizes the extreme concentration values for each metal by study and zone. It highlights that Tamayo (2021) reports the highest levels in mollusc tissues, especially in El Oro, while Huilcarema (2018) provides evidence of direct water contamination in Guayas. For their part, Pernía et al. (2019) offer a

Table 6. Table of maximum values of heavy metals by study and province

I am a student	Province	Metal	Maximum Value
Tamayo (2021)	Gold	Hg	870.00 mg/kg
Tamayo (2021)	Gold	CD	37.21 mg/kg
Tamayo (2021)	Gold	Pb	14.13 mg/kg
Tamayo (2021)	Guayas	CD	1.37 ppm
Pernía (2019)	Gold	Hg	7.61 mg/kg
Pernía (2019)	Gold	CD	7.39 mg/kg
Pernía (2019)	Gold	Pb	1.67 mg/kg
Pernía (2019)	Guayas	Hg	2.65 mg/kg
Pernía (2019)	Guayas	CD	1.58 mg/kg
Pernía (2019)	Guayas	Pb	0.98 mg/kg
Huilcarema (2018)	Guayas	Hg	0.05 mg/L
Huilcarema (2018)	Guayas	CD	0.08 mg/L
Huilcarema (2018)	Guayas	Pb	0.26 mg/L

Note: This final summary consolidates the maximum data of the three studies by province and metal, which allows us to clearly observe that El Oro concentrates the most critical records for the three metals analyzed. The most affected sites (Estero Huaylá and La Puntilla) and the most vulnerable species are identified. (Bernal Espinoza et al., 2025) This pattern suggests a more localized but intense source of pollution in El Oro, while Guayas presents a more diffuse but equally significant exposure. This information makes it possible to base recommendations for focused environmental monitoring and public policies differentiated by area. Graph 1.Comparison between Hg (mercury), Cd (cadmium), Pb (lead) in Tamayo-El Oro



Note: The graph corresponding to the study by Tamayo (2021) in the province of El Oro shows an extremely high concentration of mercury (870 mg/kg) in mollusc tissues, exceeding the limit recommended by international organizations by more than 1700 times. This figure contrasts significantly with the levels of cadmium (37.21 mg/kg) and lead (14.13 mg/kg), which although they also exceed the permissible values, are well below mercury. The difference suggests a localized and sustained source of Hg contamination, possibly associated with mining activities in the Huaylá estuary area.

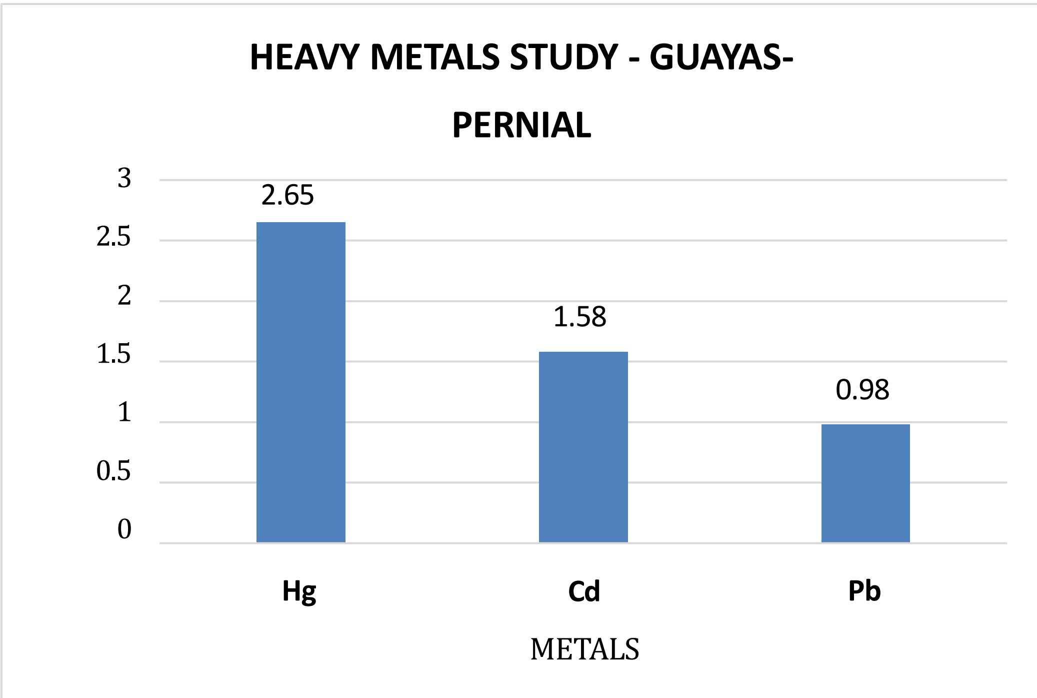
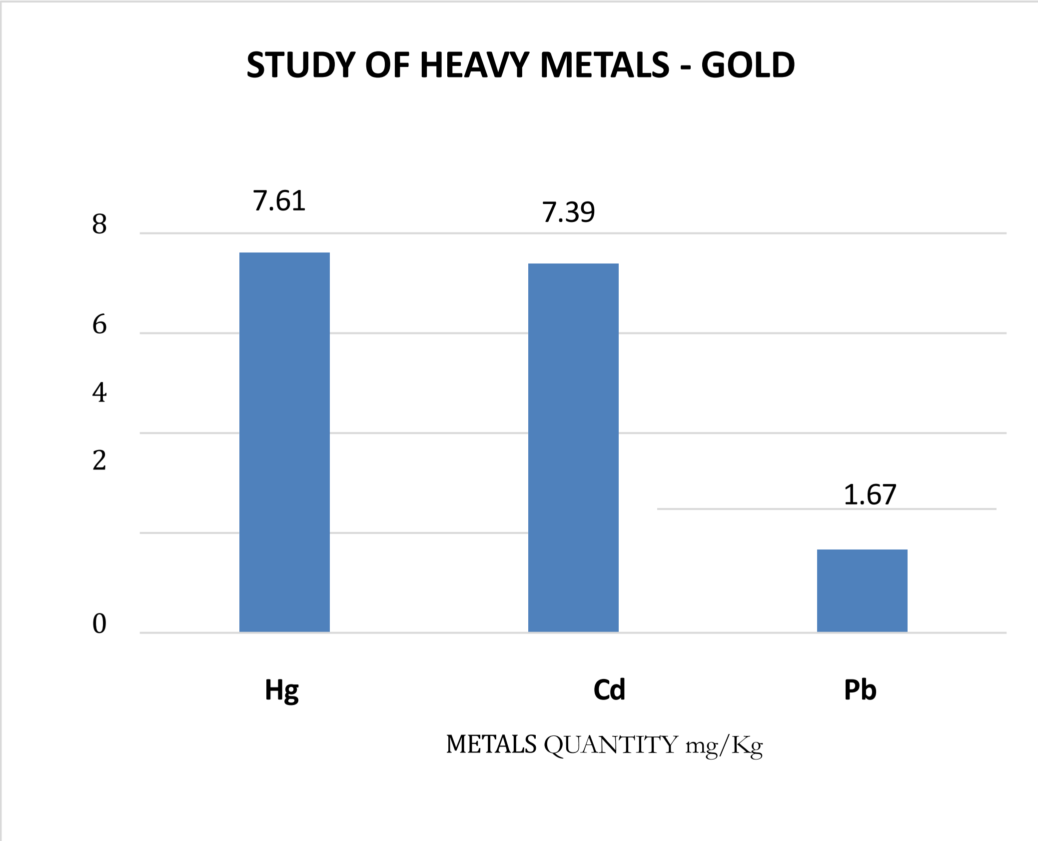


Figure 2. Comparison between Hg (mercury), Cd (cadmium), Pb (lead) in Pernía-Guayas

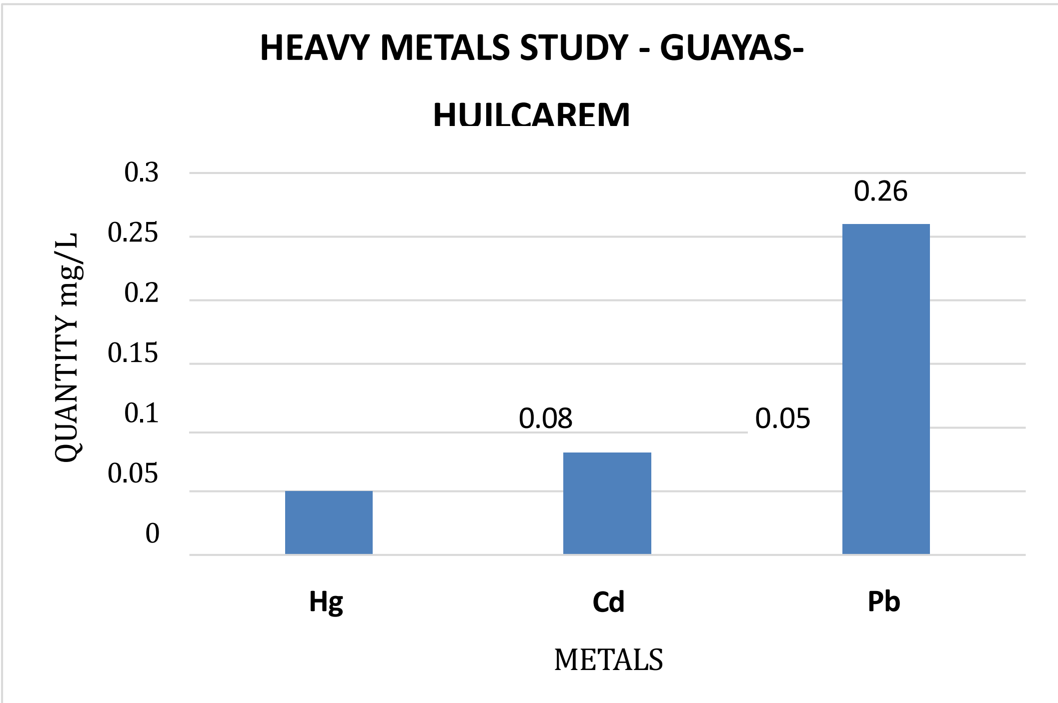
Note: The graph derived from the study by Pernía et al. (2019) in Guayas shows a more balanced pattern of contamination, where mercury (2.65 mg/kg), cadmium (1.58 mg/kg) and lead (0.98 mg/kg) are all above the regulatory limits, but without an extreme disproportion between them. This suggests a more dispersed and multi-organic source of pollution, possibly associated with industrial discharges, urban waste and aquaculture activity present in the Estero Salado.

Figure 3. Comparison between Hg (mercury), Cd (cadmium), Pb (lead) in Pernía-El Oro



Note: In El Oro, the study by Pernía et al. (2019) reveals high concentrations of mercury (7.61 mg/kg) and cadmium (7.39 mg/kg) in sediments and tissues, while lead is detected at lower levels (1.67 mg/kg). This behavior reaffirms the contamination profile previousl identified by Tamayo, although with lower values. The coincidence in the trend suggests that the contamination processes remain active, but also that there is variability depending on the site and the medium analyzed (sediment vs. tissue).

Figure 4. Comparison between Hg (mercury), Cd (cadmium), Pb (lead) in Huilcarem-Guayas



Note: In the graph derived from the study by Huilcarema (2018), it is observed that lead in surface water of the Salado estuary reaches a concentration of 0.26 mg/L, a value 26 times higher than the limit recommended by the WHO (0.01 mg/L). It is followed by cadmium with 0.08 mg/L and mercury with 0.05 mg/L. Although the absolute figures are lower than in tissues or sediments, their impact is significant as it is water, as it facilitates the direct entry of metals into the aquatic food chain and humans. Pollution
The aquatic environment in Guayas poses an immediate risk to public health and estuarine ecosystems
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DISCUSSION

The results that we have analyzed in this study show us an alarming bioaccumulation of heavy metals, especially in the analysis of mercury, cadmium and lead in Asturian marine organisms in the provinces of El Oro and Guayas. The concentrations recorded, such as the 870 mg/kg of mercury in Anadara tuberculosa in the Huaylá estuary (El Oro), exceed the limits in magnitude Heavy metal concentration permits for organizations such as FAO, WHO and Codex Alimentarius. These results confirm the existence of critical and non-point pollution, with direct effects on public health and environmental sustainability.
In the study carried out in El Oro, the values are extremely high, suggesting a point and intense source, possibly associated with informal mining activities, while, in Guayas, the contamination manifests itself in a more diffuse way, affecting both organisms and the surface water of the Estero Salado. This shows us a more diversified anthropogenic pressure, including urban discharges, untreated wastewater and industrial activities.
Comparison with previous studies, such as those carried out by Tamayo (2021), Pernía et al. (2019) and Huilcarema (2018), confirm the hypothesis of the existence of multisectoral and persistent pollution. The trend of heavy metals in tissues, water, and sediments indicates a lack of effective policies and plans for environmental control and toxicological monitoring in vulnerable areas.
On the other hand, the selected species (such as Anadara similis, Mytella guayanensis and Cerithidea valida) are not only environmental bioindicators, but are also part of the diet of coastal populations and a source of employment for fishermen in the surrounding communities, which increases the risk of human exposure. This represents a greater impact on vulnerable populations such as children, pregnant women and people with limited access to health services.
The pollution patterns observed in Ecuador are not an isolated case, but are similar to other cases reported in Latin America, such as in Peru and Brazil, where there has also been an accumulation of heavy metals in consumer species, so it is understood that the problem goes far beyond the local level and requires a coordinated response at the regional level.
Finally, these data obtained should be used as evidence for the development of a comprehensive toxicological control plan, environmental sustainability, education and regulation of pollution sources. Such a plan must propose environmental policies, since, if this evidence is ignored, it could aggravate the problems of public health and environmental well-being in the short and long term.

CONCLUSION

The study on the highest levels of heavy metals in the tissues of estuarine molluscs, such as Anadara tuberculosa and Anadara similis, shows that these species are commonly sold and consumed by local communities and contain levels of mercury, cadmium and lead well above the permissible limits set by the international organizations such as the FAO, WHO and Codex Alimentarius. This situation represents a serious food risk that, if maintained over time, can translate into chronic effects on the health of the population, including neurological, hepatic and renal alterations, as well as problems in child and reproductive development. The discovery of heavy metals not only in fabrics, but also in surface water and sediments, confirms the presence of continuous sources of pollution, probably derived fromindustrial discharges, informal mining and poor management of urban waste. The high accumulation capacity of these elements in filter species turns estuarine ecosystems into reservoirs of toxicity that, through the food chain, end up impacting humans. This type of pollution not only affects marine ecosystems, but extends to the field of public health as a form of invisible but constant exposure.
While the most extreme concentrations were recorded in El Oro, particularly in areas such as the Huaylá Estuary and La Puntilla, the province of Guayas showed a more dispersed but significant distribution in areas such as the Salado Estuary and Santay Island. This difference suggests the existence of a more focused and intense pollution in El Oro, compared to a broader and more diffuse exposure in Guayas. In both cases, the marine bioindicator species analyzed show that the human population is exposed to heavy metals both by direct consumption and by contact with contaminated environments, which increases the risk of underdiagnosed chronic diseases.
The use of molluscs such as Anadara spp and gastropods such as Cerithidea valida not only made it possible to identify the areas with the highest concentration of heavy metals, but also to establish a correlation between environmental pollution and the threat to human health. These species, due to their ability to retain pollutants for long periods, their high representativeness in the local diet and their availability throughout the year, should be integrated in an orderly manner into the country's environmental monitoring plans. Their use as ecological sentinels offers a fast and effective way to anticipate outbreaks or health risks in coastal communities.
The evidence consolidated in this study shows that current environmental management is insufficient in the face of the magnitude of the problem. Long-term exposure to heavy metals in food products can have irreversible impacts on the health of the most vulnerable populations, especially children, pregnant women, and people with chronic diseases. In this context, it is

It is urgent that government entities integrate environmental health and toxicological surveillance approaches into their public policies, strengthening national legislation, improving control over industrial discharges and promoting educational campaigns for the prevention of the consumption of contaminated species. Only an effective articulation between the health, environment, production and education sectors will make it possible to contain the effects of this silent threat on collective health

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