CATRA RESEARCH INSTITUTE
• ISSN 2720 - 9644 (print)
• ISSN 2721 - 0871 (online)
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INTERNATIONAL JOURNAL OF ENVIRONMENTAL, SUSTAINABILITY AND SOCIAL SCIENCE
Indexed By : GARUDA, Google Scholar, doi Crossref, ROAD, Index Copernicus International, Indonesia OneSearch, ISJD, sinta 4, EBSCO, Clarivate Analytics Web of Science

ASSESSMENT OF HEAVY METALS IN SEAWATER AND SEDIMENT, AND THEIR IMPLICATIONS FOR SEA SALT FARMING IN LA UNION, PHILIPPINES

Volume: 7
Number: 3
Page: 906 - 910

Article History:
Received: 2026-01-30
Revised: 2026-03-27
Accepted: 2026-05-18

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Abstract:
When heavy metals contaminate coastal resources and threaten food safety, marine pollution constitutes a growing challenge to the sustainability of traditional salt farming. Two coastal barangays, Paraoir and Almeida, in Balaoan, La Union, Philippines used in this study to determine the heavy metals in seawater, sediments, and produced salt. Results showed that seawater passed the standards set by the Philippines' Department of Environment and Natural Resources (DENR) for fishery water for the propagation and growth of fish and other aquatic resources, including salt. Higher concentrations of lead (Pb), inorganic arsenic (i-AS), and cadmium (Cd) were found in Paraoir sediments compared with Almeida. Samples of harvested salt proved that mercury (Hg) and Cd were not present, and traces of i-As were recorded within the allowable levels set by the Codex Standards. However, Pb levels in salt samples ranged from 4.03 to 5.45 mg/kg, which did not meet the Codex standards for food-grade salt and suggest potential health concerns if consumed frequently. The presence of Pb in sediments in Paraoir could be related to human activities, which include processing from the cement plant and residues from fishing boats. The study suggests the need for strict implementation of coastal resource management, particularly in pollution control and environmental monitoring. The need to improve the post-harvest practices is essential to ensure the health of consumers while sustaining the traditional salt farming as a livelihood of the communities in the coastal area.

Keywords: Coastal Ecosystems, Food Safety, Heavy Metals, Marine Pollution, Salt Production

INTRODUCTION

The Province of La Union was once a major salt-producing area in the Philippines, serving as an important cultural and livelihood activity in coastal communities. During the 1970-1990, towns such as Balaoan, San Fernando, and Sto. Tomas was identified for traditional salt making using sun-drying of seawater in traditional salt beds. However, starting in 1995, salt farming in the Province steadily declined, leaving only a few producers. The production of salt through solar evaporation is influenced by environmental factors such as the brine water level and water salinity, limited rainfall during the peak season, and suitable climatic conditions.

In the coastal municipality of Balaoan, the recorded seawater salinity ranged from 35 to 37 ppt, a typical characteristic of seawater suitable for salt-making in the area. Though salinity is vital to salt production, other factors determine the sustainability, quality, and safety of the produced salt, including the chemical, biological, and heavy-metal content of seawater and sediments. Critical trace elements that are usually present and accumulate in seawater and sediments include lead, cadmium, arsenic, and mercury, which may contaminate the salt produced during evaporation. Dietary exposure to these metals, even at low levels, may pose risks to public health and food safety,

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prompting many countries to establish monitoring programs and regulatory standards for salt quality (Abdel-Wahab et al., 2022).

Heavy metal contamination in coastal waters varies from place to place, with higher concentrations in areas affected by industrial discharges, commercial activity, and agricultural runoff. In the Philippines, monitoring programs in Manila Bay and other coastal zones have consistently reported elevated levels of metals, including Pb, Cd, Cu, and Zn, in sediments and even in aquatic organisms. It only proves that anthropogenic activities contributed significantly to the contamination patterns, which are raising concerns about salt produced near coastal areas using the sun-drying method. The evaporation of seawater during drying can further concentrate dissolved substances and suspended particles that may carry heavy metals (Prego et al., 1994).

Heavy metals pose a serious risk because they may directly affect the purity, safety, and marketability of salt. Exposure to heavy metals may also pose public health risks and create opportunities for community-based salt farming enterprises. To address these issues and concerns, this study assessed the concentrations of heavy metals in seawater, sediments, and salt produced from coastal areas in Balaoan to ensure salt purity and safety, and to support the livelihoods of salt producers in the area.

METHODS

Sampling Sites and Collection. Field sampling was carried out in April 2025, which is the peak of salt production in Balaoan, La Union. Two salt-producing coastal barangays, Paraoir and Almeida, were selected as sampling sites. Seawater samples were collected at approximately 30 cm below the surface using pre-cleaned polyethylene bottles that had been acid-rinsed and washed with distilled water. Immediately after collection, samples were acidified with nitric acid until the pH reached 2, filtered through a 0.45 µm membrane, and stored at 4°C until analysis. Samples of sediments were collected from the seabed, approximately 5 cm, using plastic shovels previously cleaned, packed in polyethylene bags, air-dried, pulverized, filtered using a 160 µm sieve, and stored at 20 °C prior to laboratory analysis (Elderwish et al., 2019; Öztürk et al., 2009).

Salt Sample Collection. Newly harvested salt samples were obtained directly from local farmers who use the traditional sun-drying technique. Seawater was collected from the coast and left to evaporate naturally over three to four days in high-density polyethylene liners. The salt crystals were then gathered into bamboo baskets and sun-dried for an additional day before being stored for laboratory testing.

Laboratory Analysis. All samples, seawater, sediment, and salt, were submitted to the Department of Science and Technology - Industrial Technology Development Institute (DOST-ITDI) for heavy metal analysis. The analyses focused on inorganic arsenic (i-As), cadmium (Cd), lead (Pb), and mercury (Hg), which are the requirements for both food and agricultural-grade standards for salt.

Statistical Analysis. Experimental data were analyzed to compare results between the two sampling areas. One-way analysis of variance (ANOVA) was used to determine significant differences in mean values. Duncan's Multiple Range Test was performed as a post hoc analysis to determine if there were significant variations. For pairwise comparisons, independent t-tests were applied, with statistical significance determined at the 5% level ($p < 0.05$).

RESULT AND DISCUSSION

Heavy Metal Levels in Seawater and Sediments. The concentrations of inorganic arsenic (i-As), cadmium (Cd), lead (Pb), and mercury (Hg) in seawater and sediments from Paraoir and

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Almeida are shown in Table 1. Seawater samples from both sites complied with the Philippines Department of Environment and Natural Resources (DENR) Class SB standards, confirming their suitability for aquaculture and salt production. However, sediment samples from both locations exceeded effluent limits, with Paraoir showing considerably higher levels of Pb (17.21 mg/kg) and i-As (3.20 mg/kg) compared with Almeida (Pb = 10.43 mg/kg; i-As = 2.35 mg/kg). Cd was only detected in Paraoir sediments (2.36 mg/kg), while Hg was undetected in all samples.

Table 1. Heavy metals measured in water and sediment at two coastal barangays in Balaoan, La Union, Philippines

Sampling Area	Water Samples (mg/L)				Sediment samples (mg/kg)			
	i-As	Cd	Pb	Hg	i-As	Cd	Pb	Hg
Almeida	<0.008	<0.001	<0.005	<0.002	2.35±1.7[a]	ND	10.43±1.2[b]	ND
Paraoir	<0.008	<0.001	<0.005	<0.002	3.20±1.3[a]	2.36±2.1	17.21±1.3[a]	ND
Philippines DENR Standard	0.020	0.005	0.010	0.005	0.02	0.005	0.01	0.005

Means in a column superscripted by different letters are significantly different at 5% level of significance

The greater accumulation of heavy metals in Paraoir may be associated with industrial activities, particularly emissions or waste discharges from a nearby cement plant, in addition to possible contributions from fishing and recreational boat operations. Such findings align with reports that anthropogenic sources, including cement factories, ports, and petroleum-related activities, are key contributors of heavy metals in marine sediments, where they tend to persist due to their non-biodegradable and bioaccumulative nature.

The pollution of marine environments by anthropogenic activities (Abdel-Satar et al., 2021) has raised concerns about health risks associated with aquatic species consumption (Khalil et al., 2017). However, the toxicity of heavy metals depends on multiple factors, including chemical speciation and chelation, dose, exposure route, as well as age, gender, and nutritional status of exposed individuals. Arsenic, Cd, Pb, and Hg are considered highly toxic even at trace levels and rank among the priority metals that are of public health significance (Tchounwou et al., 2012). They can affect the nervous system and accumulate in human adipose tissue and internal organs, potentially increasing the risk for cancer. Lead is one of the most toxic heavy metals that accumulate in the body, and data published in literature indicate that its excessive intake harms different systems and organs, such as the central and peripheral neural system, gastrointestinal tract, muscles, kidneys, and hematopoietic system (Ciobanu et al., 2021).

Comparable studies in other countries have also reported excessive Pb levels in salt products, which raises public health concerns since Pb is one of the most toxic metals, capable of accumulating in human tissues and impairing neurological, renal, and hematopoietic functions. Even at trace concentrations, heavy metals pose risks to human health, emphasizing the importance of strict monitoring of salt intended for food use (Abbas et al., 2024).

Heavy Metal Levels in Salt Samples. Heavy metals detected in salt produced at the two coastal barangays in Balaoan, La Union, are shown in Table 2. From the four concerned heavy metals in salt, only two were detected. Results of the laboratory analysis revealed that Inorganic arsenic (i-As) and Lead (Pb) are present in the produced salt, while Mercury (Hg) and Cadmium (Cd) were not detected. Mean concentration of i-As in salt ranges from 0.075 - 0.07 μg/g, which passes the Codex maximum limit of i-As (0.05 μg/g) for food-grade salt. On the other hand, the mean

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concentration of Pb ranges from 4.030 – 5.45mg/kg, which did not pass the Codex maximum limit of Pb (0.05 μg/g) for food-grade salt.

Table 2. Heavy metal analysis of salt produced at two coastal barangays in Balaoan, La Union, Philippines

Parameter	Almeida	Paraoir	Codex maximum limit (μg/g)
Inorganic Arsenic (i-As), (μg/g)	0.075±0.42	0.075±0.58	0.5
Mercury (Hg), (μg/g)	Not detected	Not detected	0.05
Lead (Pb), (mg/kg)	4.03±0.68	5.45±0.32	1.0
Cadmium (Cd), (μg/g)	Not detected	Not detected	0.2

No significant difference in all parameters among treatments at $P < 0.05$

Based on the results of the study, a high level of lead (Pb) in coastal sediment is related to the presence of lead in produced salt, which is not recommended for human consumption or use in fish and food processing. According to Codex legislation, the maximum tolerated amounts of heavy metals in salt are 0.5 μg/g of As, 2 μg/g of Pb, 0.5 μg/g of Cd, and 0.1 μg/g of Hg (Codex Standard-150, 2006). The maximum permitted level of lead in food-grade salt is 2.0 μg/g according to RA 8172 of the Philippines, which is one of the requirements of salt to be iodized and used for human consumption. In the study of Heshmati (2014), the Pb content of newly harvested salt samples was 1.22 μg/g, respectively, which is higher than the permitted level for human consumption. In another report in Iran, Pb concentration in harvested salt was 2.728 μg/g (Cheraghali et al., 2010).

The results demonstrate that while seawater quality in Balaoan remains favorable for salt-making, sediment contamination poses a significant risk by introducing heavy metals into the final product. The presence of Pb above acceptable limits in harvested salt highlights the need for urgent mitigation strategies. These may include stricter regulation of industrial discharges, improved management of boat-related petroleum waste, and the introduction of pre-filtration methods in salt farming to reduce sediment entry into evaporation ponds. The findings also underscore the value of continuous monitoring of coastal pollution and the adoption of preventive measures to safeguard both consumer health and the sustainability of the local salt industry. Supporting salt farmers with cleaner production technologies and pollution control measures will be crucial to ensure that salt production remains a viable livelihood while protecting public health (Bryan and Langston, 1992).

CONCLUSION

Seawater in Paraoir and Almeida, Balaoan, La Union, satisfies the national standards for aquaculture and salt production. On the other hand, contamination of lead (Pb), inorganic arsenic (i-As), and cadmium (Cd) in sediment, particularly in Paraoir, poses a significant environmental concern. The high concentration of Pb obtained in the produced salt exceeds the Codex standards, highlighting a potential risk to consumer health. The industrial and coastal operations near the area may influence the quality of the produced salt despite the suitability of the seawater conditions. It is suggested that strict implementation of environmental protection and control in pollution must be done, especially regarding the potential sources of heavy metals. To minimize the contamination and ensure food safety, there should be improvements in post-harvest handling, processing, and promoting best practices among local salt producers.

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