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Assessment of heavy metal levels in spring water of Dansolihon, Cagayan de Oro City

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ABSTRACT

Heavy metal contamination in drinking water becomes a public health issue, especially in communities situated near abandoned mining areas. This study examined the concentrations of selected heavy metals in spring water sources used for household purposes in Dansolihon, Cagayan de Oro City, and evaluated their compliance with regulatory standards. The main objective was to determine the concentration of Cu, Cr, Pb, Co, Mn, Ni, and Cd, and compare these levels with the limits set by the Philippine National Standards for Drinking Water (PNSDW), United States Environmental Protection Agency (USEPA), and World Health Organization (WHO). A descriptive-comparative research design was used. Water samples were collected from three sampling stations, and standard methods were utilized in the analysis of heavy metals. Results showed that lead had the greatest variation in mean concentration among the sampling stations, which were found to have higher levels at Sitio Iba and Sitio Bonhok, while other metals showed relatively consistent concentrations in all sites, and some are also below the limit of quantitation. The majority of the metals complied with drinking water standards. But lead was greater than the recommended concentration of 0.01 mg/L in two sampling stations closest to an abandoned mining site. Lead concentrations decreased with increasing distance from the mining area. The findings suggest possible residual impacts of legacy mining on spring water and emphasize the importance of site-specific monitoring. It also emphasizes the need for remedial action to be taken in the community.

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INTRODUCTION

Access to clean and safe water is essential for sustaining human health and well-being, as it supports basic needs such as hydration, hygiene, and sanitation (WHO, n.d.). In rural communities like Dansolihon, Cagayan de Oro City, spring water is often the primary source of water for various domestic purposes, including drinking, cooking, bathing, and cleaning. The dependence on spring water sources makes it especially vital to keep these waters uncontaminated and safe for consumption. Unfortunately, rural spring water sources face growing threats of pollution due to human activities. Agricultural practices, including the use of fertilizers and pesticides, can lead to the runoff of harmful chemicals into nearby water bodies, potentially polluting spring water with toxic substances (Zhou *et al.*, 2025). Furthermore, small-scale mining operations, which are common in many rural areas, often release heavy metals into the environment (Haghighizadeh *et al.*, 2024). These metals can seep into the groundwater and spring water sources, polluting them and creating serious health risks for communities that depend on these water sources for everyday use. Another growing concern in many rural areas that further worsen the problem is deforestation. The removal of vegetation disrupts the natural filtration systems that help purify water, making it easier for contaminants to reach water sources (Dosskey *et al.*, 2010). This combination of human activities, such as agriculture, mining activities, and deforestation, creates a complex set of risks that threaten the safety and cleanliness of spring water in Dansolihon and similar rural communities.

Heavy metals such as lead (Pb), cadmium (Cd), nickel (Ni), arsenic (As), manganese (Mn), cobalt (Co), copper (Cu), and chromium (Cr) are significant environmental and public health concern due to their inherent toxicity, persistence, and bioaccumulation in ecosystems (Tchounwou *et al.*, 2012). These metals are not easily broken down or removed from the environment (Briffa *et al.*, 2020), meaning they tend to accumulate over time in soil (Angon *et al.*, 2024), water (Oladimeji *et al.*, 2024), and living organisms (Singh *et al.*, 2011). As a result, even relatively low concentrations of these substances can have long-lasting and potentially devastating effects on both human health and the broader ecological systems. When these heavy metals enter drinking water sources, they pose a direct threat to human health. Lead can damage the brain, especially in young children, affecting cognitive development (WHO, 2024). Cadmium harms the kidneys (Yan and Allen, 2021), while arsenic is a carcinogen linked to various cancers (National Cancer Institute, 2022).

Excessive manganese exposure can cause neurological problems, resembling Parkinson's disease (Kwakye *et al.*, 2015). While copper and cobalt are essential in small amounts, high concentrations can cause digestive and heart issues (Taylor *et al.*, 2020; Mitra *et al.*, 2022).

Hexavalent chromium is highly toxic, potentially damaging the liver, kidneys, and respiratory system (Sharma *et al.*, 2022).

This study assessed the levels of heavy metals in spring water sources used by the community in Dansolihon, Cagayan de Oro City, and determined the extent of contamination relative to established national and international standards. Specifically, it measured concentrations of heavy metals such as copper (Cu), chromium (Cr), lead (Pb), cobalt (Co), manganese (Mn), nickel (Ni), and cadmium (Cd), and compared these levels to the permissible limits set by the Philippine National Standards for Drinking Water (PNSDW), the World Health Organization (WHO), and the United States Environmental Protection Agency (USEPA). By doing so, the study aimed to determine the current water quality and assess whether it is safe for continuous household use, as well as identify potential environmental threats. The findings of this study provide critical baseline data for local authorities, environmental agencies, and health departments. Such data support evidence-based interventions, guide current and future water resource management strategies, and contribute to protecting public health and preserving the integrity of natural water systems.

MATERIALS AND METHODS

The study area

The research was conducted in Dansolihon, a barangay located in Cagayan de Oro City on the island of Mindanao, Philippines. Geographically, Dansolihon is positioned at approximately 8.3067° latitude and 124.5485° longitude, with an elevation of about 268.5 meters or 880.9 feet above mean sea level. Dansolihon is adjacent to several barangays, including Langaon and Danatag from Baungon, Bukidnon; San Isidro from Talakag, Bukidnon; Rogongon from Iligan City; and Tumpagon, Tagpangi, Pigsag-an, Besigan, Tinagpoloan, and Mambuaya from Cagayan de Oro City. The barangay has a land area of 42.44 square kilometers. According to the 2024 census, the barangay has a population of 6,801 people, which represents 0.85% of the total population of Cagayan de Oro (Philippine Statistics Authority, 2024).

Sampling design and sample collection

The target population for this research was the spring water samples from Sitio Iba, Sitio Bonhok, and Sitio Sawmil of Dansolihon, Cagayan de Oro City. These three sitios were purposively chosen based on their consistent use by residents for household water consumption and their accessibility and safety for sampling. These sitios were exposed to varying environmental and anthropogenic conditions, such as vegetation cover and proximity to potential sources of contamination like agricultural activity or abandoned mining areas.

Considering the significant limitations of the research in terms of cost and time, a targeted or purposive sampling was used. The selected sampling locations were sampled three times, with a time interval of about 2 weeks between samplings. While the results could not be generalized to a larger population, the data could provide insightful information that can guide urgent actions needed and provide foundational information for future research.

A non-composite grab sampling technique was used in this study for the collection of spring water samples, where a single sample was collected from a specific location and time without mixing it with other samples from multiple locations or time intervals (EMB-EEID, 2022). This type of sampling was used because it requires less time and resources and provides information about the specific conditions at the exact point and time of sampling, which is useful for identifying localized contamination or variations in spring water characteristics.

As sample containers, unopened bottles of distilled water sold commercially were used. The distilled water from a sealed bottle was discarded, and water samples were directly collected from the source, capped immediately, and labeled. All samples were immediately placed in a polystyrene foam box with ice and kept therein while in transit to the laboratory. Water samples for heavy metals that could not be analyzed within 24 hours from the time of sampling were preserved by adjusting the pH to 2.0 using concentrated nitric acid (USEPA, 2007).

Heavy metal analysis using atomic absorption spectroscopy

In this study, seven different metals, including copper, chromium, lead, cobalt, manganese, nickel, and cadmium, were examined. To determine the concentrations of these metals in the spring water sample, flame atomic absorption spectroscopy was employed using a Perkin Elmer Analyst 200, which is designed to measure the absorption of light by atoms in a sample that has been vaporized in a flame.

Sample preparation method

The 300 mL water sample was concentrated by heating and allowing the water to evaporate until the sample size fell to approximately 5 to 10 mL. This was then followed by a series of digestion procedures. The digestion begins with 90 to 120 minutes of sample digestion with 20 mL of concentrated sulfuric acid. Second was the addition of 2 mL of hydrogen peroxide, and the digestion was completed after 30 minutes. The solution was cooled to room temperature, filtered, and diluted to 100 mL (Besagas *et al.*, 2022).

Determination of absorption via AAS

The solution was run in an atomic absorption spectrophotometer (AAS) to determine the metal concentration. The concentration of metals in the samples was based on the standard calibration curve obtained by running three standard solutions of known metal concentrations in the AAS.

Comparison of data for the different locations and with standards

The data collected in this study were analyzed using a combination of descriptive statistics and comparative evaluations. The means and standard deviations were used to summarize the concentrations and variabilities of the selected heavy metals such as copper (Cu), chromium (Cr), lead (Pb), cobalt (Co), manganese (Mn), nickel (Ni), and cadmium (Cd) in the spring water samples from the three sampling stations in Dansolihon, Cagayan de Oro City. To evaluate water safety, the measured concentrations were compared with the permissible limits established by the Philippine National Standards for Drinking Water (PNSDW), the World Health Organization (WHO), and the United States Environmental Protection Agency (USEPA). This comparative analysis aimed to identify which heavy metals exceeded regulatory thresholds and posed potential health risks.

Statistical analysis

This study employed descriptive statistical analysis to interpret the data collected from spring water samples in Dansolihon, Cagayan de Oro City. Descriptive statistics, including mean and standard deviation, were used to interpret the concentrations of selected heavy metals across the three sampling stations and sampling periods.

RESULTS AND DISCUSSION

Spring water samples from Sitio Iba, Sitio Bonhok, and Sitio Sawmill were analyzed for specific heavy metals (Cu, Cr, Pb, Co, Mn, Ni, and Cd) to evaluate metal contamination levels and their distribution patterns across the study area. Spring water sources require careful monitoring for heavy metals due to their environmental persistence and potential to cause ecological and health hazards even in small amounts. Assessing metal concentrations at various sampling locations helps reveal site-specific geological factors, possible human-related contamination, and the suitability of spring water for domestic use.

The results revealed that the concentration of most metals in all sampling stations was generally low, indicating relatively good water quality in terms of heavy metal contamination. However, it can also be observed that lead and manganese have relatively highest concentrations in the seven metals being studied, both with a mean concentration of 0.015. These mean concentrations of lead and manganese in Dansolihon spring water are considerably lower than those in other areas, such as the Angat River Network in Bulacan (Estrella *et al.*, 2015), and Cagayan de Oro City's major water supply system using the raw water from the Bubunawan River, as reported by Besagas *et al.*, 2022. Despite these favorable comparisons, the presence of these metals necessitates regular monitoring to prevent future escalation from small-scale mining or waste disposal. Statistical significance among sampling stations was assessed using one-way ANOVA, and the corresponding p-values were reported directly in the data table for clarity and comparison. The *p*-values presented indicate the results of the statistical tests conducted to determine whether heavy metal concentrations significantly differed among the three sampling stations. All computed p-values exceeded the 0.05 level of significance, indicating that the observed variations in metal concentrations among the sampling sites were not statistically significant.

The low levels of heavy metals found in the spring water samples and the lack of statistically significant variations among sampling stations suggest that natural geochemical conditions rather than localized anthropogenic contamination currently have a greater influence on the spring water sources in Sitio Iba, Sitio Bonhok, and Sitio Sawmill. The uniformly low levels of other metals and the consistent <LOQ values for nickel

and chromium suggest a relatively steady and uniform water quality throughout the study area. Although these findings do not point to an immediate environmental or public health concern, the detection of trace amounts of some metals highlights the importance of continued monitoring since heavy metals are persistent and may build up over time if human land activities increase. As a result, these data establish a vital reference point for future monitoring, which highlights the need for preventive protection of spring water to maintain its quality. Table 1 shows the concentrations of selected heavy metals in spring water samples collected from Sitio Iba, Sitio Bonhok, and Sitio Sawmill in Dansolihon, Cagayan de Oro City.

Table 1. Concentrations of heavy metals in spring water samples

Heavy metals	Sampling stations (Mean ± SD, mg/L			*p*-value*
	Sitio Iba	Sitio Bonhok	Sitio Sawmill	
Cu	0.012 ± 0.001	0.014 ± 0.002	0.014 ± 0.002	.70
Cr	<LOQ ± N/A	<LOQ ± N/A	<LOQ ± N/A	-
Pb	0.015 ± 0.004	0.012 ± 0.003	0.010 ± 0.004	.38
Co	0.004 ± 0.002	0.005 ± 0.002	0.005 ± 0.003	1.00
Mn	0.004 ± 0.002	0.011 ± 0.012	0.015 ± 0.008	.31
Ni	<LOQ ± N/A	<LOQ ± N/A	<LOQ ± N/A	-
Cd	0.003 ± 0.001	0.003 ± 0.002	0.002 ± 0.001	.68

*significant at 0.05 level

The average concentrations of selected heavy metals in the spring water samples were compared with the established drinking water standards set by the Philippine National Standards for Drinking Water (PNSDW), the United States Environmental Protection Agency (USEPA), and the World Health Organization (WHO). This comparison is used to assess if the measured metal concentrations could present potential risks to consumers or fall within acceptable safety thresholds. The results indicate that the concentrations of copper, cobalt, manganese, and cadmium are within the permissible limits of all applicable standards, while chromium and nickel are below the analytical limit of quantitation. Lead concentrations varied from 0.007 to 0.015 mg/L across the sampling sites. While Sitio Sawmill remained within the permissible limit, the mean Pb concentrations in Sitio Iba (0.015 mg/L) and Sitio Bonhok (0.013 mg/L) were higher than the drinking water guideline value of 0.01 mg/L established by PNSDW, USEPA, and WHO. Lead concentrations exhibited a distinct spatial trend across the sampling stations, with the relatively highest level found at Sitio Iba, which is closest to the abandoned mining site, followed by Sitio Bonhok, and the lowest concentration observed at Sitio Sawmill, the farthest station. This decreasing pattern with distance suggests that residual contamination from the abandoned mining area may be influencing lead levels in nearby spring water sources.

Comparable spatial variations have been observed in other environmental studies of legacy contamination, where Pb concentrations tend to be higher in proximity to historical contamination sources and decrease with distance along environmental variations (Reid *et al.*, 2026). The observed exceedance of guideline values at sites closer to the mining area further emphasizes the importance of site-specific monitoring and targeted management of drinking water sources in communities affected by legacy contamination. Since there is no known safe exposure limit for lead (USEPA, n.d.), the exceedance found at two sites shows non-compliance and raises a possible public health issue that calls for continued monitoring of lead concentrations and the promotion of appropriate water treatment or alternative water sources for household use in affected sitios. The comparison of the average concentrations of selected heavy metals in the spring water samples and the established drinking water standards is shown in Table 2.

Table 2. Comparison of heavy metal concentrations with drinking water standards

Heavy metal	Site	Mean conc. (mg/L)	Standard limits (mg/L)			Compliance status
			PNSDW[1]	USEPA[2]	WHO[3]	
Cu	Sitio Iba	0.012	1.0	1.3	2	Compliant
	Sitio Bonhok	0.014				
	Sitio Sawmill	0.014				
Cr	Sitio Iba	<LOQ	0.05	0.1	0.05	Compliant
	Sitio Bonhok	<LOQ				
	Sitio Sawmill	<LOQ				
Pb	Sitio Iba	0.015	0.01	0.01	0.01	Non-compliant
	Sitio Bonhok	0.013				
	Sitio Sawmill	0.007				
Co	Sitio Iba	0.012	-	-	-	-
	Sitio Bonhok	0.011				
	Sitio Sawmill	0.011				
Mn	Sitio Iba	0.004	0.4	0.05	0.08	Compliant
	Sitio Bonhok	0.011				
	Sitio Sawmill	0.023				
Ni	Sitio Iba	<LOQ	0.07	Not regulated by USEPA	0.07	Compliant
	Sitio Bonhok	<LOQ				
	Sitio Sawmill	<LOQ				
Cd	Sitio Iba	0.003	0.003	0.005	0.003	Compliant
	Sitio Bonhok	0.003				
	Sitio Sawmill	0.002				

CONCLUSION

This research investigated heavy metal levels in spring water across Sitio Iba, Sitio Bonhok, and Sitio Sawmill in Dansolihon, Cagayan de Oro City, and evaluated their compliance with drinking water standards established by the PNSDW, WHO, and USEPA to ascertain the water's safety for domestic consumption and to identify potential environmental factors influencing metal distribution. Results showed that most analyzed heavy metals were within permissible limits across all sampling stations. However, lead (Pb) concentrations exceeded the guideline value of 0.01 mg/L at Sitio Iba and Sitio Bonhok, while Sitio Sawmill remained within the allowable limit. A clear spatial pattern was observed, with Pb concentrations decreasing with increasing distance from the abandoned mining site. This distance-dependent trend suggests that residual contamination from historical mining activities may still be influencing nearby spring water sources. The detection of lead levels exceeding safety guidelines near the abandoned mine is alarming, as no amount of lead exposure is considered safe and poses significant health risks, especially to children and pregnant women. These findings highlight the necessity of conducting site-specific assessments rather than relying on overall averages, as localized exceedances may otherwise be overlooked. Ultimately, this study provides evidence that spring water sources in areas with a history of mining, although often perceived as clean, may still be vulnerable to legacy contamination. This study also contributes baseline information on lead contamination in rural spring water systems and highlights the need for continued monitoring and for protecting drinking water quality in communities located near abandoned mining sites.

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