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Assessment of Heavy Metal Accumulation in Mangroves of Kauswagan, Lanao del Norte, Philippines

Jilliane Rae Cabili *, Maria Luisa Orbita

College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, Iligan, Philippines; marialuisa.orbita@g.msuiit.edu.ph (M.L.O.)

* Correspondence: jillianerae.cabili@gmail.com

Abstract

This study investigated heavy metal accumulation in the mangroves of Barangay Tacub, Kauswagan, Lanao del Norte, Philippines, situated within a protected area. Recent developments raise concerns about potential heavy metal pollution impacting the local ecosystem. Despite known threats, no prior studies assessed this in Lanao del Norte's coastal areas. The transect-plot method was used to collect leaf and sediment samples for analysis using atomic absorption spectroscopy (AAS). Environmental parameters like water temperature were measured on-site. Results revealed higher lead (Pb) concentrations in sediments compared to leaves. Cadmium (Cd) was undetectable in both leaves and sediments. Pb concentrations were highest in Transect 3, closest to the estuary. While statistically insignificant, overall, sediments exhibited higher metal concentrations than leaves. These findings suggest potential for Pb accumulation in the Kauswagan mangroves, particularly near the estuary. Further studies with a larger sample size are recommended to confirm these results and assess potential ecological risks. Understanding heavy metal accumulation in this critical ecosystem is crucial for informing future conservation and management strategies.

Keywords: environment; heavy metal; Kauswagan; Lanao del Norte; mangroves

Type: Original Article

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1. Introduction

Mangroves are vital coastal ecosystems found in tropical and subtropical regions [1]. These salt-tolerant trees thrive in intertidal zones, withstanding high salinity, strong winds, and extreme tides. However, their resilience is tested by human activities.

With increasing urbanization and industrialization, coastal areas, including mangroves, face significant environmental stress. One major threat is heavy metal pollution [2]. Industrial activities, processing of metal ores, shipping, and sewage discharge all contribute to elevated heavy metal levels in coastal waters [3]. These pollutants are then trapped in the unique sediments of mangrove forests.

Heavy metals pose a severe threat due to their persistence, toxicity, and bioaccumulation within the food chain. The ability of mangrove muds to accumulate materials discharged into the surrounding marine environment further concentrates these toxins [4].

The proposed study focuses on the mangroves of Barangay Tacub, Kauswagan, Lanao del Norte, Philippines. This area is situated within the Bacolod-Kauswagan Protected Landscape and Seascape, a designated protected area. However, recent developments, including the construction of a power plant, raise concerns about potential heavy metal pollution impacting the local ecosystem.

Despite the known threats of heavy metal pollution on mangroves, no prior studies have assessed this issue in the coastal areas of Lanao del Norte. This research aims to address this knowledge gap by evaluating the accumulation of heavy metals in both the sediments and root tissues of the Kauswagan mangroves. By understanding the levels of accumulated metals, valuable insights into the health of the local coastal environment can be gained.

2. Materials and Methods

The study was conducted on the coast of Barangay Tacub, in the Municipality of Kauswagan, Lanao del Norte. This municipality lies on the mid-central portion of the Northwestern Mindanao coastline with nautical grid coordinates of 8° 9' 35'' N, 124° 5' 51'' E. Barangay Tacub is one of seven coastal barangays within Kauswagan, Lanao del Norte (Figure 1). Situated on a flat coastal plain, the Barangay is approximately 2 km away from the town hall and has nautical grid coordinates of 8°10'57"N 124°6'24"E. It borders Barangay Bagumbayan to the west, Iligan Bay to the north, Barangay Inudaran to the south, and Barangay Libertad to the east. Barangay Tacub has a total land area of 823.1859 ha, covering 13.66% of the municipality's total land area. The Barangay Tacub Coastal Plain is composed of tidal flats, mangroves and nipa palms, and beach ridges and swales, with estimated areas of 161.8694 ha, 172.8689 ha, and 183.8683 ha, respectively.

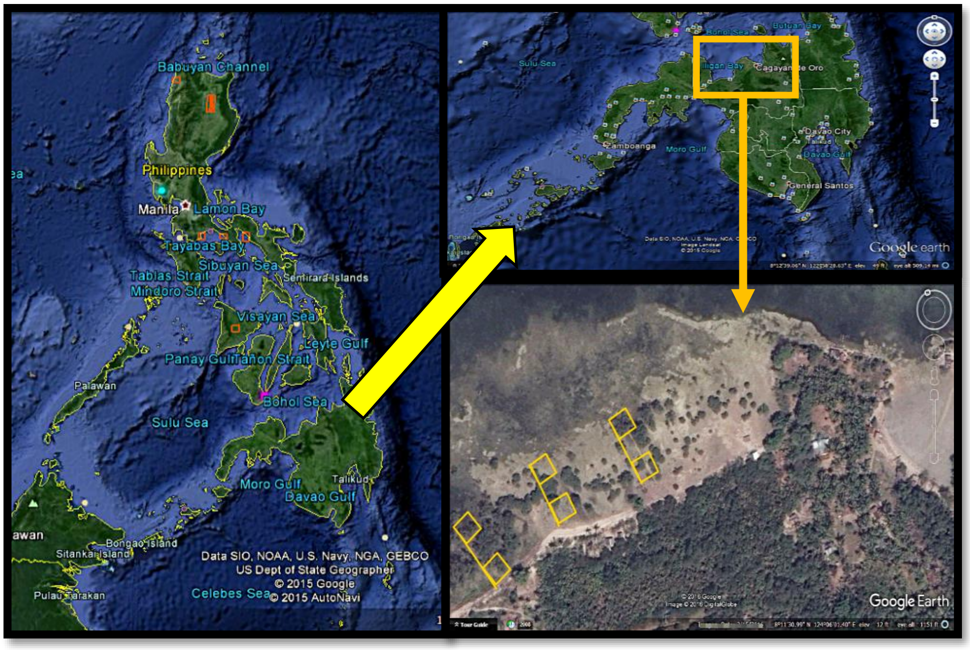

Figure 1: Map showing the Municipality of Kauswagan, with the sampling area in Tacub showing the location of the three transects.

The transect-plot method was used to collect mangrove leaves and sediment. Three transect lines, each 50 m long, were established seaward at intervals of 50 m apart. Within each transect, two 10-m by 10-m plots were constructed at 20-m intervals, resulting in a total of six plots. Twenty leaves were collected from *Sonneratia* trees located within the plots. Leaves were selected from trees that were one meter tall, with a girth at breast height greater than 2.5 cm, and with a similar degree of leaf predation. The collected leaves were washed with distilled water, oven-dried at 60°C for 17 h, and then homogenized [5].

For sediment collection, 200-g samples were collected from the upper 5 cm of the sediment using a clean, acid-washed plastic scoop. Samples were randomly collected from a 5-cm x 5-cm area within each plot. A total of 400 g of sediment was collected from each transect. The samples were stored in clean, acid-washed plastic containers and transported to Mindanao State University-Iligan Institute of Technology (MSU-IIT) for heavy metal content analysis.

In the laboratory, individual sediment samples were wet-sieved through a 1-mm bronze mesh with distilled water. The sieved material was then collected in a clean, labelled, acid-washed glass jar. Samples were oven-dried at 100°C for 17 h to remove any remaining water content. Once dried, the samples were homogenized and stored in a dry, acid-washed plastic bag for metal analysis.

Leaf and sediment samples were transported to MSU-IIT laboratory for heavy metal analysis using atomic absorption spectroscopy (AAS). For leaf tissue, only lead (Pb) and cadmium (Cd) were analyzed, as these metals can be used as bioindicators of heavy metal exposure [6]. Metal concentrations were determined in ppm (mg/L) for each sample, and an average was calculated from the three replicates. The mean and standard error of the determined metal concentrations within the samples were calculated. Differences in metal concentrations between sediments and leaves from different plots were tested using a one-way ANOVA.

Environmental parameters such as water temperature were measured in situ using a standard mercury thermometer. pH was measured using a pH meter, and salinity was measured with a handheld refractometer. Total dissolved solids, total suspended solids, biological oxygen demand - five day (BOD5), nitrates, phosphates, and dissolved oxygen were measured in MSU-IIT laboratory.

3. Results and Discussion

Results showed that the concentration of Pb in the sediment was higher than in the leaves (Figure 2). However, the concentration of Cd in both leaves and sediments was below the detection limit, which is less than 0.08 ppm and 0.03 ppm, respectively.

The present study aimed to assess the bioaccumulation of heavy metals in *Sonneratia* leaves and surrounding sediments. Mangroves are generally considered to have the ability to accumulate metals and possess a certain tolerance to relatively high levels of heavy metal pollution [7].

Transect 3 showed the highest concentration of Pb in both the sediment and leaves because it is closest to the estuary. The high Pb content in the sediment was likely influenced by the sediment type, where the heavy metal content follows the trend: mud substrate > sandy mud substrate > sandy substrate [8]. Larger sediment particle size facilitates the absorption process of heavy metals by the sediment layer [9].

In general, the concentration of heavy metals in sediment is relatively higher than in leaves. However, the recorded Pb levels in the leaves in this study could be a future concern, as non-essential metals can become toxic even at low concentrations [10].

The heavy metal concentration can be influenced by its location and can be attributed to surface runoff and discharge of domestic

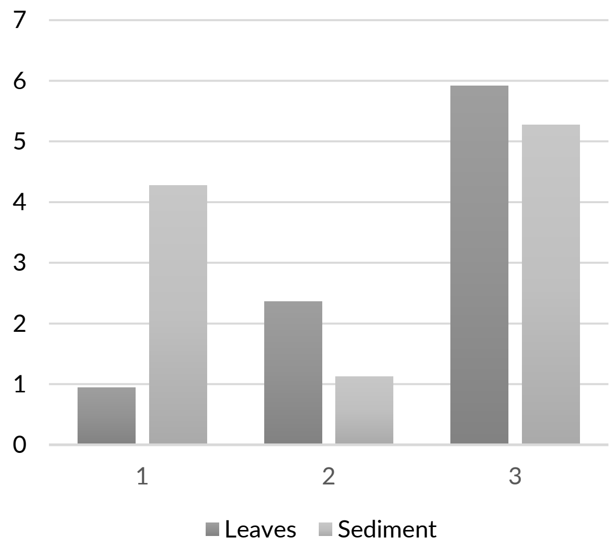

Figure 2: Pb concentration in *Sonneratia* leaves and sediment.

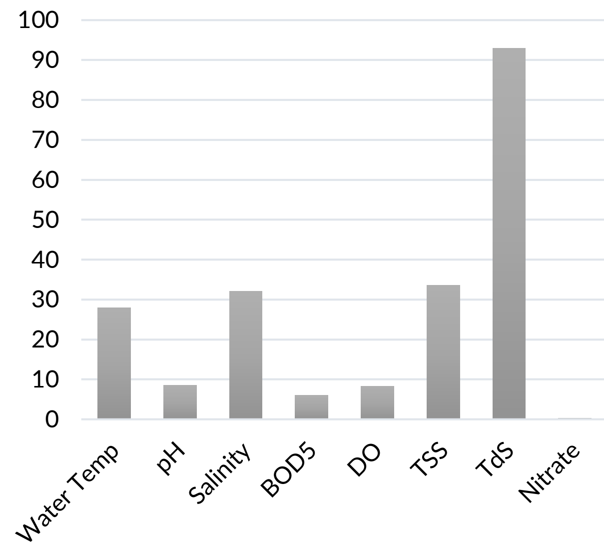

Figure 3: Environmental parameters tested.

Table 1: Mean Pb concentrations between mangrove sediments and leaves.

Sample	Mean	Standard Deviation	Variance	df	f	p-value
Leaves	3.07	2.57	6.58	2	1.65	0.23
Sediment	3.56	2.17	4.69	15		

effluents from the community. This trend follows a very similar pattern of heavy metal concentration (Fe > Zn > Pb > Ni > Cu > Cr > Cd) observed in mangrove sediments in an area under intense development and industrialization in Hong Kong [11]. High concentrations of Pb were also found in sediments in India [12].

The location of the study area is an important consideration since it is both near an estuary and near an area being developed into a coal-fired power plant. Heavy metals are the most common pollutants of aquatic ecosystems; they are non-biodegradable and often toxic even in low concentrations.

Although Cd is a non-essential element it can be readily absorbed and accumulated by plants, thus increasing its potential for bioaccumulation [13].

The data were analyzed using ANOVA to detect any significant differences in mean Pb concentrations between mangrove sediments and leaves. However, the tests revealed no significant difference in metal concentrations between sediments and leaves from different plots (Table 1).

A study reported that *Sonneratia caseolaris*, in particular, has the ability to absorb Pb and act as a pollutant filter among mangrove species [14]. This finding is corroborated by a Malaysian study, which showed that *S. caseolaris* roots have a high capacity to take up and accumulate heavy metals from sediments [15]. The study also indicated that the leaves of *S. caseolaris* can take up and store certain heavy metals. This suggests that *S. caseolaris* leaves are tolerant to heavy metals, with minimal physiological effects. The tolerance appears to be due to a combination of factors: the metals in the sediment being in a form that is not bioavailable and biological mechanisms in the root tissue, such as exclusion and sequestration processes.

Figure 3 shows the average values of the environmental parameters measured at the three stations. Water temperature ranged from 27 to 30°C, while salinity ranged from 24 to 32.00 ppt. Dissolved oxygen ranged from 6.42 to 8.4 mg/L, total dissolved solids ranged from 31.54 to 33.56 mg/L, and total suspended solids ranged from 89 to 93 mg/L. Phosphate concentration was below the detection limit (less than 0.03 mg/L), while nitrate concentration was 0.26 mg/L.

4. Conclusions

The present study provides quantifiable results on the bioaccumulation of lead (Pb) in Sonneratia mangroves and their surrounding sediments. The results show that lead concentration is higher in the sediment than in the leaves. This study also provides valuable baseline data for future investigations into the effects of the nearby coal-fired power plant on the surrounding environment, particularly regarding heavy metal pollution. Industrialization, along with urban and agricultural runoff, significantly increases the input of effluents and wastes into aquatic ecosystems, impacting marine life. Therefore, this study recommends testing all common heavy metals in all common mangrove species present in the surrounding area. This comprehensive approach would provide a clearer picture of metal inputs and their impact on the coastal ecosystem.

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Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contributions

Both authors have contributed equally. They have read and agreed to the published version of the manuscript.

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