J. Myanmar Acad. Arts Sci. 2026 **Vol. XXIII. No.3**

VERTICAL DISTRIBUTION OF HEAVY METALS IN MUDFLAT AND MANGROVE SEDIMENTS OF BILU ISLAND, MYANMAR

Ei Thinzar Phyo[1], Nyo Nyo Tun[2], Kyaw Thura[3]

Abstract

Mangroves are examples of coastal blue carbon ecosystems that play significant roles in the environment. This study measured the concentrations of heavy metals (Cd, Cr, Pb, and Cu) using profile samples from two different habitats: mangrove and mudflat. The study was conducted on Bilu Island in Mon State, Myanmar. Findings from this study demonstrated that the top 20 cm of the mangrove sediment profile had higher concentrations of heavy metals compared to the mudflat sites. This research suggests that coastal blue carbon ecosystems are effective at retaining trace elements, which can help to mitigate the negative effects of heavy metals on marine environments.

Introduction

Mangrove forests are tropical or subtropical habitats defined by the presence of plant species that have adapted to high temperatures, high levels of organic matter, and high salinity. These ecosystems also protect coastlines from the effects of tides and waves, and serve as nurseries for many species of birds, fish, and shellfish. They also support a complex community of saltwater benthic organisms and provide a significant portion of the fish, shellfish, and crustaceans that coastal communities consume or sell (Lee et al., 2014).

Globally, mangrove sediments have been shown to have elevated concentrations of heavy metals, which often indicates long-term pollution from human activity (Lacerda et al., 1992; Perdomo et al., 1998). Due to their toxicity, persistence, and bioaccumulation potential, heavy metals are among the most dangerous pollutants in the natural environment (MacFarlane and Burchett, 2000). The exceptional ability of mangrove muds to retain contaminants released into the near-shore marine environment is a result of their natural physical and chemical characteristics (Harbison, 1986). Mangrove sediments are rich in organic matter and sulfides, and they are also reduced and anaerobic, which is conducive to the retention of heavy metals in the sediment (Silva et al., 1990; Tam and Wong, 2000). The concentrations of heavy metals in sediments are typically three to five orders of magnitude higher than those in the surrounding water (Zachetoglou et al., 2002). Because of these high concentrations, the bioavailability of even a small portion of the total metal content in the sediment is crucial for the bioaccumulation of metals in mangrove-dwelling animal and plant species. Heavy metals are not biodegradable, so they are taken up and concentrated in plant tissues from the soil, causing long-term harm to plants (Defew et al., 2005).

Cadmium is a hazardous heavy metal that builds up in living organisms. Workers in the electroplating, battery manufacturing, and pigment industries are most at risk for exposure, and elevated blood and urine cadmium levels have been reported in these populations. Due to its long half-life, cadmium bioaccumulates in aquatic invertebrates, vertebrates, and plants. In addition to being found naturally—volcanoes and rock weathering are two processes that mobilize cadmium from the earth's crust—anthropogenic activities can also release cadmium into the environment. These activities include the disposal of food and agricultural wastes, urban refuse, municipal sewage sludge, various organic wastes, and atmospheric fallout (WHO, 2003; Akguc et al., 2008; Sabiha-Javied et al., 2009; Osma et al., 2012; Ozyigit et al., 2016).

[1] Department of Chemistry, Mawlamyine University
[2] Department of Marine Science, Mawlamyine University
[3] Department of Marine Science, Mawlamyine University

Because of its widespread industrial use, chromium is a common metal contaminating groundwater, soil, and sediments, which presents a severe environmental risk. When Cr builds up in plants, it can cause structural alterations and is highly toxic, leading to reduced growth and biomass accumulation. Certain plant species can accumulate large amounts of Cr without experiencing harm. According to ATSDR (1998), Cr is a naturally occurring element found in rocks, soil, vegetation, animals, and volcanic dust and gases. Concentrations in most finfish species ranged from 0.1 to 0.6 mg Cr/kg fresh weight (Hall et al., 1978).

This research aims to determine the concentrations of specific heavy metals [cadmium (Cd), chromium (Cr), copper (Cu), and lead (Pb)] and to compare their concentrations in mangrove and mudflat sediments across different sediment depths.

Materials and Methods

Study Area

The present research was conducted at Sepala and Nathmaw in the Mon Coastal Region (Figure 1). The sampling sites are located in the estuary where freshwater runs off from the Thanlwin River and encounters the semi-diurnal tide.

Sample Collection

The soil samples were collected from the mangrove and mudflat areas of Nathmaw and Sepala villages (Bilu Island) in July 2022. The sampling methods will be adopted from the methods by Foruquean *et al.* (2014). The PVC (poly vinyl chloride) pipes with a length of 50 cm were used for sampling and labeled with the types of Core ID and locations systematically. Triplicate samplings were carried out for each habitat (mudflat or mangrove). After that, the collected cores were wrapped with aluminum foil to reduce gaseous exchanges and then carried to Marine Science Department at Mawlamyine University. The cores were kept in the ice box before sample preparation.

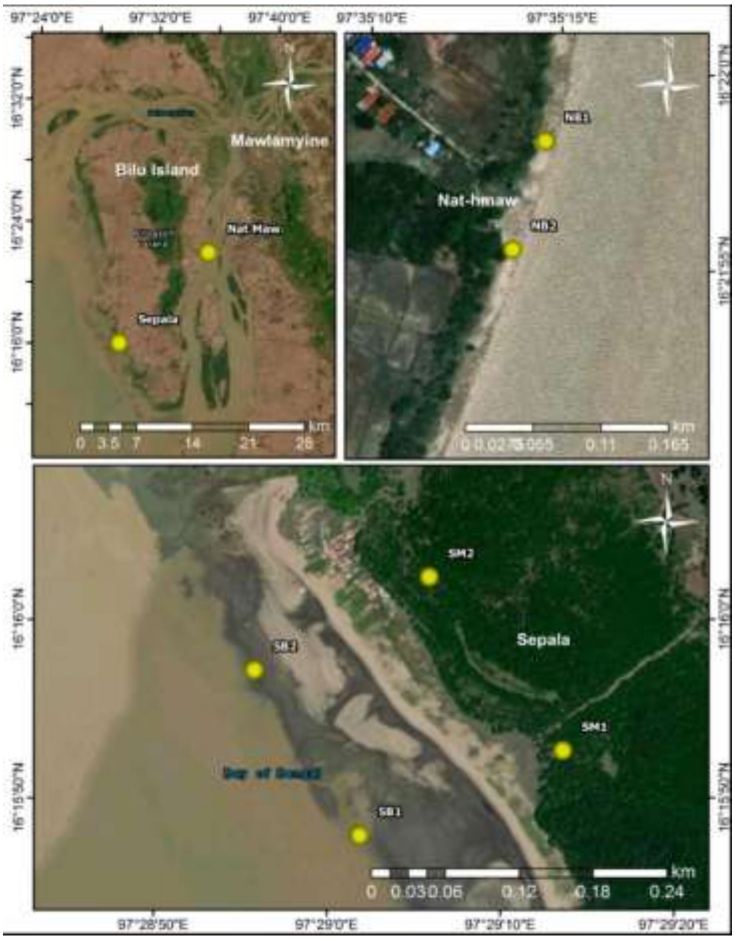

Figure 1. Map showing the location of the study area in Bilu Island and sampling sites. SM: Sepala Mangrove Soils, SB: Sepala Mudflat Soils and NB: Sepala Mudflat Soils

Sample preparation

The collected PVC cores will be halved lengthwise using an electric saw. The soil samples were sectioned at 4 cm intervals with a blade and labelled with specific depth and Core ID. The wet samples were weighed using a precise electronic balance. The weighed samples will be dried in the oven at 60ºC. This cycle will be repeated until successive weight differences are less than 4% (always use the same balance). Typically, this process requires at least 48–72 hours. The weights were recorded every 24 hours.

Soil properties and heavy metal analysis

The physical properties of the soil samples and soil texture, were determined using the hydrometer method (Bouyoucos, 1962). For sediment chemical properties: soil pH and salinity at each depth will be determined by using the electrode pH meter (Eutech Instruments pH 700, Massachusetts USA) by using the method of Tan (2005) and a refractometer. Five grams of oven-dried soil were mixed with 25 mL of distilled water (1:5).

The heavy metal concentrations were determined using the Atomic Absorption Spectrophotometer (AAS) method. To extract the heavy metals from the samples before being analyzed in AAS, inorganic acids: hydrochloric acid (HCl) and nitric acid (HNO_3) were used. The AAS method was used because there are no spectral and ionization interferences.

The heavy metals analysis was carried out immediately on the consequence digests using atomic absorption spectrophotometer (AAS), with the use of prepared standards to determine the sample concentrations. To ensure the accuracy of AAS results, three replicates of each sample were run to ensure that measured absorbencies were consistent. These metal concentrations were calculated from each replicate absorbance value, which was then used to calculate an average sample metal concentration. For mangrove and mudflat samples, four metals were analysed by using AAS: Cd, Cr, Cu and Pb. Heavy metal concentrations were expressed by ppm (mg/L) for each sample and an average was calculated from the three replicates.

Results

Physical and Chemical Properties in Soils

In this study, four cores were taken at Sepala: two from mangrove soils (SM1 and SM2) and the other two from mudflat soils (SB1 and SB2). At the other study area, Nathmaw, two cores were collected from mudflat soils (NB1 and NB2). The pH values from the study area are shown in Figure 2. A comparison of pH values in mangrove and mudflat soils at both sites showed that the highest value was 8.8 at a depth of 0-4 cm in mudflat soil at Sepala, while the lowest value was 8.09 at a depth of 0-4 cm at Nathmaw. Thus, the pH value at Sepala was consistently higher than that at Nathmaw (Figure 2).

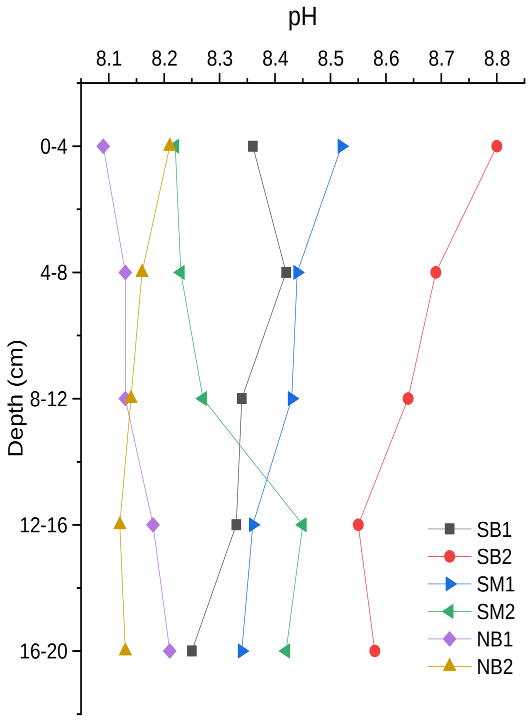

Figure 2. The comparison of pH at different depths of Sepala and Nathmaw in the soils

Heavy Metals Accumulation in Mangrove and Mudflat Soils

In this study, six cores were taken from Sepala and Nathmaw which are 2 cores from mangrove soils (SM1 and SM2) and the other 4 cores from mudflat soils (SB1, SB2, NB1 and NB2). Some heavy metals (Cd, Cr, Cu and Pb) concentrations were shown in Figure 4.2a-d. When Cd was taken into consideration at Sepala, the maximum value was found (0.025 mg/L) at 8-12 cm depth of mangrove soil and the minimum content was found (0.012 mg/L) at 4-8 cm depth in mudflat soil. The concentrations of Cd at 0-4 cm and 12-20 cm were nearly the same. The concentration of Cd is decreased more at the surface than near the deeper part of the surface. For the surface layer, Cd content in each point of the mangrove soils was found to be higher than that of the mudflat soils. When Cd was considered at Nathmaw, the maximum content was found at the depth (0.041 mg/L) in the surface layer of 0-4 cm at mudflat soil and the minimum value is (0.025 mg/L) in 4-8 cm depth at mudflat soil. The second highest value of Cd is 0.029 mg/L at 16-20 cm depth in the mangrove soil. The concentration of Cd is increased at the surface (0-4 cm) of the core sample when compared with that from 16-20 cm depth. The concentration of Cd at 0-4 cm and 8-16 cm were almost the same.

In the cases of mangrove and mudflat soils at Sepapla (Figure 3b), Cr content was found to have the highest value (0.344 mg/L) in 4-8 cm depth at mangrove soil and the lowest value (-0.074 mg/L) in 0-4 cm depth of mangrove soil. At Nathmaw, the maximum value of Cr was found to be (0.164 mg/L) in 12-16 cm depth and the minimum value is (-0.171 mg/L) in 0-4 cm depth of mudflat soils. In some areas, the presence of chromium contents is almost non-existent, as it showed negative signs (e.g. -0.034, -0.036 mg/L) and so on.

In the case of Sepala, the maximum content of Pb was found to be (1.646 mg/L) in the surface layer of 0-4 cm depth at mangrove soil and the minimum level is (0.013 mg/L) in 0-4 cm depth of mudflat soil. In the deeper layer of the core, values for Pb content ranged from 0.012 to 0.014 mg/L and 0.020 to 0.023 mg/L in 0 – 12 cm depth of mangrove and mudflat soils respectively (Figure 3). While it is compared with the mangrove soil, every layer of Pd concentration in the mangrove soils is found higher than that of the mudflat areas.

In the study area, the concentration of Cu is higher than that of Pb, Cr and Cd. According to Figure 3d, it is noticed that in the case of mangrove soil, the maximum value of Cu was found to be (1.747 mg/L) in the depth of 4-8 cm and the minimum value is (0.006 mg/L) in 12-16 cm depth of mudflat soil at Sepala. Copper concentration is higher in a depth of 16-20 cm (3.471 mg/L) and the lowest value is 0.120 mg/L in 12-16 cm depth in mudflat soils. The values for Cu content ranged from 0.006 to 0.020 mg/L in 0-12 cm depth, from 0.041 to 0.096 mg/L and in 12-20 cm depth, the range from 0.180 to 0.476 mg/L 0-12 cm depth and 12-20 cm depth are found 0.120 to 0.171 mg/L, respectively (Figure 3).

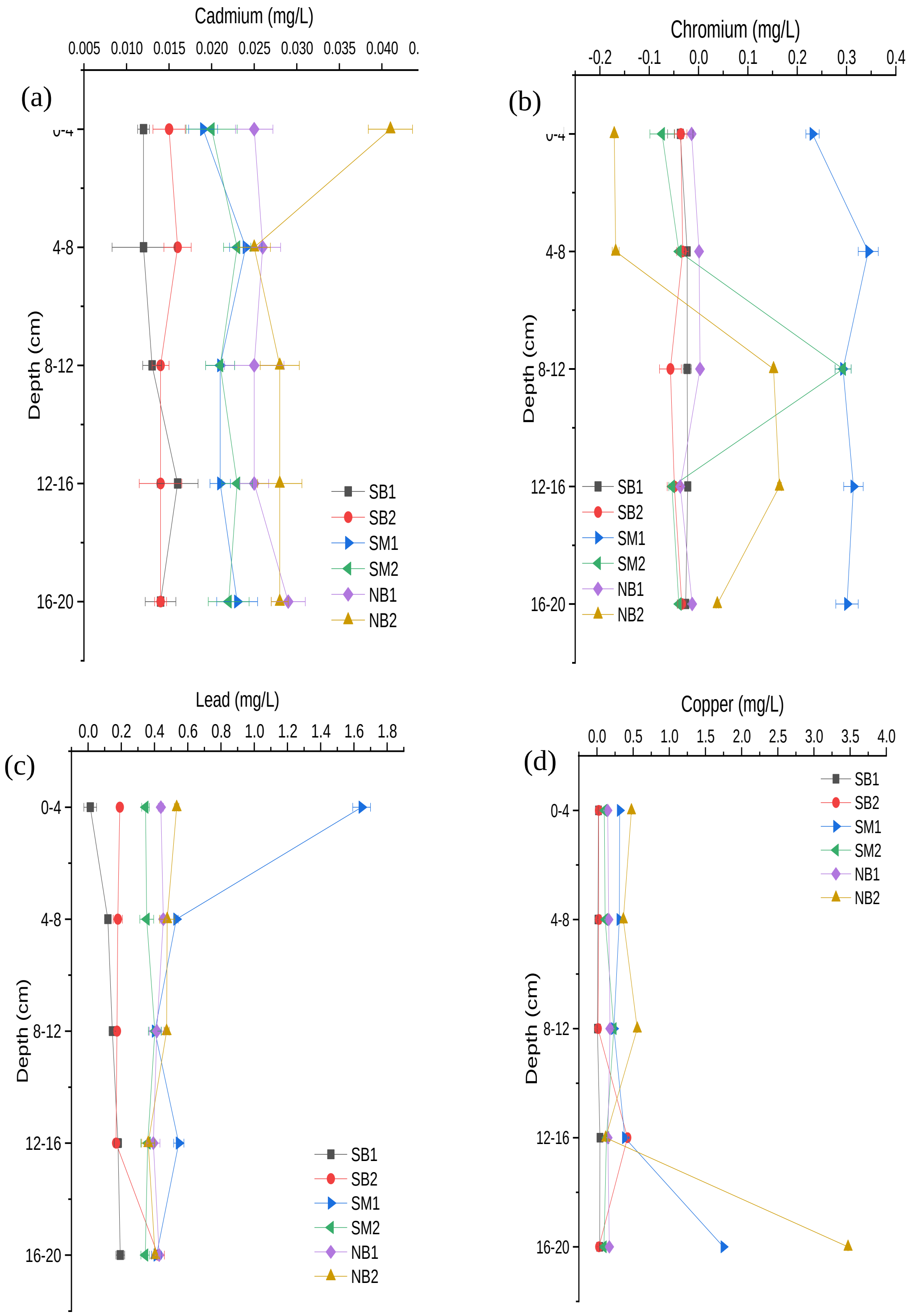

Figure 3. Comparison of heavy metals: a) Cadmium, b) Chromium, c) Lead and d) Copper in different depth intervals of mangrove and mudflat soils

Discussion

Generally, soil pH is one of the main parameters for determining the extent of pollution, as it has been identified as a principal factor affecting the mobility and availability of metals in soil (Inobeme et al., 2014). When comparing the pH range at Sepala and Nathmaw, Sepala had a higher pH value (8.8 > 8.09) than Nathmaw, indicating neutral to slightly alkaline soils.

The Cd concentration in every layer of mangrove soil was found to be higher than that of the mudflat soil. The highest Cd concentration was 0.041 mg/L, observed at a 12-16 cm depth in mudflat soil, while the lowest was 0.015 mg/L at a 12-16 cm depth of mudflat soil. In all samples from both mangrove and mudflat soils, Cd content exceeded the maximum permissible limit (0.0008 mg/L) recommended by WHO (1996).

The Cr concentration was higher in every layer of mangrove soil compared to mudflat soil, with the exception of the 4-8 cm depth, which had a value (0.344 mg/L) higher than the corresponding value in mudflat soil. The Cr content in all samples from both mangrove and mudflat soils did not exceed the maximum permissible limit (0.1 mg/L) recommended by WHO (1996).

When comparing mangrove and mudflat soils, Pb concentrations in mangrove soil were higher in every layer than in mudflat soil, with the exception of the 0-4 cm depth, which had a value (1.646 mg/L) higher than the corresponding mudflat soil value (0.013 mg/L). Contrary to the permissible limit, the Pb concentration in the 0-4 cm mangrove soil layer (1.646 mg/L) exceeded the WHO (1996) limit of 0.085 mg/L.

When comparing mangrove and mudflat soils, Cu concentration in the mudflat soil was higher in every layer than in the mangrove soil, except for the 16-20 cm depth, where the mudflat soil value (3.471 mg/L) was higher than the mangrove soil value (1.747 mg/L). In this study, Cu concentrations in both mangrove and mudflat soils exceeded the WHO (1996) permissible limit of 0.036 mg/L in all layers.

In comparison to unvegetated mudflats, the present findings showed that mangrove sediments accumulated comparatively higher concentrations of most of the heavy metals. The higher accumulation of heavy metals by blue carbon ecosystems is due to their increased carbon sequestration rate, which is essential for heavy metal retention. Due to their capacity to disperse waves and capture particles from the water column, mangroves and saltmarshes have been shown to increase the organic matter content in sediments and maintain greater carbon stocks than terrestrial ecosystems (Duarte et al. 2013). As a result, they are particularly effective at sequestering heavy metals in sediments (Zhou et al., 2011).

Conclusion

This study provides a baseline record of heavy metal concentrations in the sediment profiles of the region’s blue carbon ecosystems. The present findings showed that the presence of mangroves in the coastal area is associated with significantly increased concentrations of most of the heavy metal components. The accumulation of Cd, Cr, Pb, and Cu toward the surface of both mangrove and mudflat sediments was likely accelerated by anthropogenic activity. While some heavy metals like Cu, Cd, and Pb exceeded the WHO permissible limits in certain layers, the findings from our quantitative contamination assessments suggest that the soils were not heavily contaminated throughout the entire profile.

Acknowledgements

We are deeply indebted to Dr. Chit Sein, the Rector of Mawlamyine University and Dr. Khing Khing San, Dr. Myint Thida and Dr. Thidar Htun, Pro-rectors of Mawlamyine University for their permission to carry out this research.

References

Akguc, N., I. I. Ozyigit, & C. Ozyigit, (2008) “Pyracantha coccinea Roem. (Rosaceae) as a biomonitor for Cd, Pb and Zn in Mugla province (Turkey)” *Pakistan Journal of Botany*, vol.40, pp.1767-1776.

ATSDR (Agency for Toxic Substances and Disease Registry) (1998) *Toxicological profile for chromium.* U.S. Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA.

Bouyoucos, G. J., (1962) "Hydrometer Method Improved for Making Particle size Analyses of Soils" *Agronomy Journal,* vol.54, pp.464-465.

Clark, M.W., D. McConchie, D.W. Lewis, P. Saenger, (1998) "Redox stratification and heavy metal partitioning in Avicennia-dominated mangrove sediments: a geochemical model" *Chemical Geology,* vol.149, pp.147–171.

Defew, L.H., M. James, J.M. Mair, & H. M. Guzman, (2005) "An assessment of metal contamination in mangrove sediments and leaves from Punta Mala Bay, Pacific Panama" *Marine Pollution Bulletin,* vol.50, pp.547–552.

Duarte, C.M., I.J. Losada, & I.E. Hendriks, (2013) "The role of coastal plant communities for climate change mitigation and adaptation" *Nat Clim Chang,* vol.3, pp.961–9680.

Foruquean, J., B. J.B. Johnson, H. Kauffman, & C.E. Lovelock, (2014) "Field sampling of soil carbon pools in coastal ecosystems" In: Howard, J., Hoyt, S., Isensee, K., Pidgeon, E., Telszewski, M. (Eds.), Coastal Blue Carbon: Methods for Assessing Carbon Stocks and Emissions Factors in Mangroves, Tidal Salt Marshes, and Seagrass Meadows" Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature, Arlington, Virginia, USA, pp. 39–66.

Hall, R. A., E. G., Zook, & G. M. Meaburn, (1978) *National Marine Fisheries Service survey of trace elements in the fishery resources*. U. S. Dep. Comm. NOAA Tech. Rep. NMFS SSRF-721.

Harbison, P., (1986) "Mangrove muds: a sink or source for trace metals" *Marine Pollution Bulletin,* vol.17, pp.246-250.

Inobeme, A.; A.I., Ajai, Y.A. Iyaka, M. Ndamitso, & B. Uwem, (2014) "Determination of physicochemical and heavy metal content of soil around paint industries in Kaduna" *International Journal of Scientific & Technology Research*, vol.3, pp.221-225.

Lacerda, I.D., M.A. Fernandez, C.F. Calazans, & K.F. Tanizaki, (1992) "Bioavailability of heavy metals in sediments of two coastal lagoons in Rio de Janeiro, Brazil" *Hydrobiologia,* vol.228, pp.65–70.

Lee, H. M., D. K. Henze, B. Alexander, & L. T. Murray, (2014) "Investigating the sensitivity of surface-level nitrate seasonality in Antarctica to primary sources using a global model" *Atmos. Environ*., vol.89, pp.757-767.

MacFarlane, G.R., & M.D. Burchett, (2000) "Cellular distribution of Cu, Pb and Zn in the Grey Mangrove Avicennia marina (Forsk) Vierh" *Aquatic Botany,* vol.68, pp.45–59.

Osma, E., I. I. Ozyigit, Z., Leblebici, G. Demir, & M. Serin, (2012) "De termination of heavy metal concentrations in tomato (Lycopersicon es culentum Miller) grown in different station types" *Romanian Biotechnological Letters,* vol.17, pp.6963.

Ozyigit, I. I., S. Yilmaz, I. Dogan, M. S. Sakcali, G. Tombuloglu, & G. Demir, (2016) "Detection of physiological and genotoxic damages reflecting toxicity in kalanchoe clones" *Global Nest Journal*, vol.18, pp.223- 232.

Perdomo, L., I. Ensminger, L.F. Espinos, C. Elsters, M. Wallner Kersanach, & M.L. Schnetters, (1998) "The mangrove ecosystem of the Cie´naga Grande de Santa Marta (Colombia): Observations on regeneration and trace metals in sediment" *Marine Pollution Bulletin,* vol.37, pp.393–403.

Sabiha-Javied, T., M. Mehmood, M. Chaudhry, & I. Tufail, (2009) "Heavy metal pollution from phosphate rock used for the production of fertilizer in Pakistan" *Microchemical Journal,* vol.91, pp.94-99.

Silva, C.A.R., L.D. Lacerda, & C.E. Rezende, (1990) "Heavy metal reservoirs in a red mangrove forest" *Biotropica,* vol.22, pp.339–345.

Tam, N.F.Y., & W.S. Wong, (2000) "Spatial variation of heavy metals in surface sediments of Hong Kong mangrove swamps" *Environmental Pollution,* vol.110, pp.195–205.

Tan, K. H., (2005) *Soil Sampling, Preparation, and Analysis 2nd Edition*. New York, CRC Press.

WHO, (2003), World Health Organization. Cadmium review. www.who.int/ifcs/documents/forums/ forum5/nmr_cadmium. pdf, Last accessed on July 26, 2020.

Zachetoglou, K., D. Voutsa, &, C. Samara, (2002) "Toxicity and heavy metal contamination of surficial sediments from Bay of Thessaloniki (Northwestern Aegean Sea) Greece" *Chemosphere,* vol.49, pp.17–26.

Zhou, Y.,Peng, Y. Peng, X. Li, & G. Chen, (2011) "Accumulation and partitioning of heavy metals in mangrove rhizosphere sediments" *Environ Earth Sci,* vol.64, pp.799–807.