

Assessment of Nickel and Iron levels in soil of Khulna City, Bangladesh

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ABSTRACT

Nickel and iron are fundamental elements of soil composition. Due to urbanization, industrialization, and human activities, the accumulation of these metals is increasing in the soil, crossing the permissible limit, and threatening the ecosystem, humankind, and animals. This study's objective was to evaluate the amount of Ni and Fe in the soil of Khulna, a city in Bangladesh. 26 Samples were collected from several locations, including living and non-living area, industrial, roadway, riverbank, and dumping sites. The soil sample was processed, and then heavy metal contents of the soil sample was analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The WHO specifies an acceptable level for Fe is 50,000 ppm and for Ni is 35 ppm. After analyzing the soil by ICP-MS, the quantity of Ni ranged between 22.6 ppm-137 ppm, and for Fe, it was 11100 ppm-59000 ppm. The amount of Ni in the sample region is relatively high; all the samples except sample-5 exceed the permissible limit. Conversely, only sample-10 of Fe crosses the permissible limit. These results provide information on the concerning buildup of nickel in Khulna's soil, whereas the level of iron is quite tolerable. This study offers useful data for research investigations and decisions the concerned authority will need to make addressing Ni and Fe concentration.

Keywords: Soil, Khulna, ICP-MS, Permissible, Contamination



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1. Introduction

Nickel and iron are essential soil elements that plays a crucial role in soil chemistry. These are some fundamentals of soil, but the levels need to be within an acceptable limit so as not to affect human welfare and the surroundings.[1]. Nickel and iron are the two most used metals industrially and in households these metals in soil if not disposed of properly[2] [3]Due to urbanization and industrialization the scope of careless dumping increases, and so does the chances of accumulation in soil. The increasing level is also due to anthropogenic reasons such as industrial emissions, fertilizer and soil amendments, construction, waste disposal, household activities, agriculture, practices, population, expansion, etc. [4]Excessive accumulation of Ni and Fe affects the soil health creating an imbalance as they are some mandatory soil elements. Soil might become toxic for plants damaging the soil chemistry[5].The metals can accumulate in the plants thus entering the food chain and leading to some health complications including liver damage, respiratory issues, cardiovascular effects, kidney damage, diabetes, cancer risk, etc [6], [7]. The elevated levels of Ni and Fe can seep into surface and groundwater, affecting the aquatic environment. Khulna is one of largest city in Bangladesh which is a major location for both industrial and residential activities[8].The improper disposal of industrial and residential waste can cause certain metals to accumulate in the soil. Ni and Fe are two commonly used metals both industrially and in residential settings. Iron is essential in construction and manufacturing, especially in the production of machinery and vehicles and in houseware like furniture and utensils. Nickel on the other hand is comparatively stronger and more corrosion resistant, used in kitchenware and industries including food processing. Nickel is fundamental for the construction of rechargeable batteries

used in electronics and vehicles[9]. The vast uses of these metals can result in improper disposal and seep into the soil crossing the permissible limit. Nickel concentrations in soil below 35 ppm are frequently regarded as acceptable for plants for agricultural and ecological uses. Significant ecological effects can result from higher concentrations that are hazardous to plants and soil organisms. High nickel concentrations can contaminate crops, endangering the health of people and animals by way of the food chain. Long-term exposure to foods or soils containing nickel can lead to respiratory problems, allergic responses, and even cancer in people. Because nickel is persistent in the environment, environmental problems include long-term soil damage and remediation difficulties [10]. The WHO recommends that the acceptable limit for Fe be 50,000 ppm. Iron is a vital micronutrient for plants since it is necessary for the synthesis of chlorophyll and the movement of electrons during cellular respiration. Iron can be harmful plant roots and prevent growth when it is present in excess, especially when the area is wet. These restrictions are established to prevent any toxicity to the soil environment while maintaining the availability of iron for plant nutrition[11].This study is subjected to find out the levels of nickel and iron in the soil of the city Khulna, choosing locations close to industries such as food processing, battery production, jute industries, and around the residential area including the dumping sites for it. For analyzing the Ni and Fe levels the ICP-MS method is used. ICP-MS is a widely used analytical method that has gained a lot of attention in the food, environmental, forensic, chemical, and nuclear industries. It is also one of the most intriguing detection techniques. This multi-element method can analyze samples with great selectivity and sensitivity, and it has much lower detection limits than previous multi-element methods. This study assesses a strategy for utilizing

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ICP-MS to identify many trace elements in soil, frequently found in polluted soil. The unique method standards, which cover linearity, precision, accuracy, detection limit, and quantitation limit, validate the procedure[12].

2. Methodology

2.1 Study Area

One of the largest cities of Bangladesh, Khulna, is located along the Rupsha and Bhairab rivers [13]. The city is situated within the longitudinal range of $89^{\circ}28'$ to $89^{\circ}37'$ East and the latitudinal range of $22^{\circ}46'$ to $22^{\circ}58'$ North. It is surrounded by the Jashore and Narail Districts, on the south by the Bay of Bengal, on the east by the Bagerhat District, and on the west by Satkhira District[14]. It has 663,342 residents and covers an area of 59.57 km^2 [15]. The largest mangrove forest in the world, the Sundarbans, is in the southern part of the city. As the gateway to the Sundarbans, Khulna is considered the home of the Bengal tiger[16].

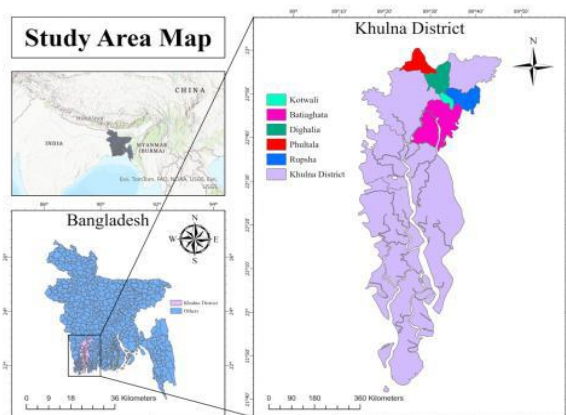


Figure-1: Study area map

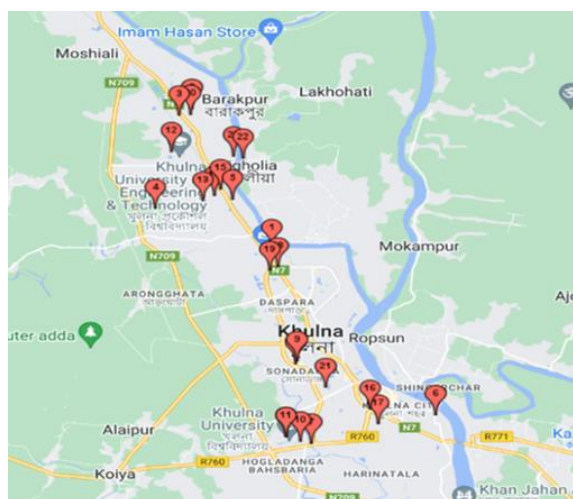


Figure-2: Study area with co-ordinates.

2.2 Sample Collection

The soil was collected from different areas of Khulna. About 26 samples were collected and both living and nonliving areas were considered while collecting the soil samples. Every soil subsample was taken between 0 and 25 centimeters below the surface. After being cleaned and dried, the samples were placed in laboratory bags and kept at room temperature[17]. The location of every point was geolocated using GPS throughout the sample procedure.

2.3 Sample Preparation

Soil samples were removed from the polyethylene bags and placed in bowls. All the water particles in the soil samples were eliminated by placing the bowls containing the samples in a dryer and drying them for 90 minutes at 75 to 80°C . After drying, samples were crushed in a mortar to turn them into powder. Wastes, tree leaves, and other contaminants were filtered by sieving through a mesh[18]. Then each sample was weighed at 250 mg using the balance. Next, a bottle containing hydrogen peroxide and 10 milliliters of nitric acid was filled with the 250 mg samples. The bottle was placed in the Ethos Easy Advanced Microwave Digestion System to be digested. Thirty-five minutes were spent digesting[19]. After that, a 30-minute settlement was reached. After that, the samples were diluted 200 times using type 1 de-ionized water. From the Wasserlab Automatic Plus 1+2 water purifier, type 1 (ultrapure) water was extracted. After being filtered using filter paper, the diluted samples were transferred to a pipette and placed in the test container. The samples were analyzed using ICP-MS system to get the observed result [20]. After the material was atomized, it created atomic and small polyatomic ions, which the machine then measured. The device identified the heavy metals and provided both qualitative and quantitative data. The Zeemaps website and ArcGIS software[21] were used to plot the sample region on a map.

3. Result & Discussion

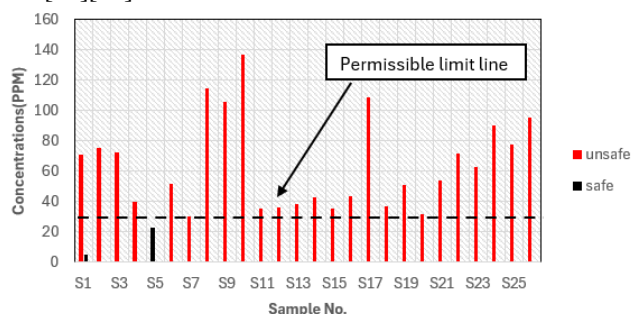
Table-1: Concentrations of Heavy Metals (including Fe & Ni) in micrograms per liter of 26 samples (ICP-MS method)

Sample No.	Concentrations of Heavy Metals in milligrams per liter (ppm)	
	Ni	Fe
S1	71.30	33800
S2	75.60	35900
S3	72.30	33700
S4	40.00	18900
S5	22.60	11100
S6	51.40	25000
S7	30.10	14400
S8	115.00	49500
S9	106.00	47100
S10	137.00	59000
S11	35.20	16800
S12	36.00	16100
S13	38.30	19400
S14	43.00	20000
S15	35.20	17200
S16	43.50	20400
S17	109.00	46300
S18	36.60	17600
S19	51.20	22200
S20	31.80	15800
S21	53.90	22500
S22	71.80	34100
S23	63.00	28500
S24	90.10	39600
S25	77.70	33800
S26	95.50	41800

Table-2: Permissible limit of heavy metal ions in soil

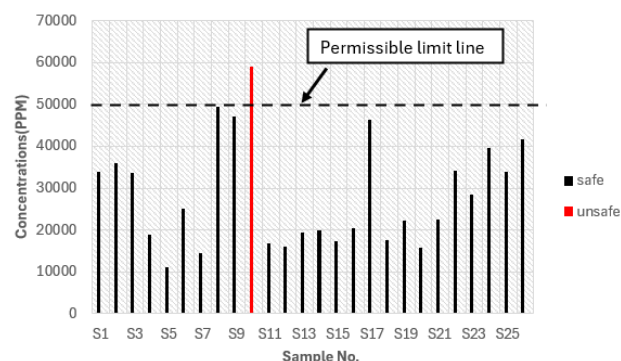
Heavy metals	WHO's permissible limit (ppm)
Ni	35.0
Fe	50000

This research involves determining the Nickel (Ni) and Iron (Fe) content in the 26 soil samples using ICP-MS [22]. This information was then compared with the thresholds that were set by WHO. Accordingly, the content of heavy metals in soil should not exceed 35 ppm for Ni [23] while 50,000 ppm for Fe [24]. Furthermore, the results suggest that Ni levels exceed the WHO recommended levels in 13 out of the 26 samples which comes down to 50% with concentrations of between 40.0 and 137.0 ppm. The Ni content in sample S10 was the highest at 137.0 ppm and was 102 ppm over the threshold. Nickel (Ni) is a versatile metal used in coins, stainless steel, batteries, magnets, jewellery, and industrial uses such as pipelines, turbines, and alloys. Its widespread usage leads to increased soil levels through corrosion, improper disposal, e-waste, and industrial emissions, creating environmental and health problems, particularly in urban and industrial regions. The neurological system is one of the primary targets for Ni poisoning; in fact, Ni may cause harm to the brain. This metal can produce an allergy, which can cause as contact dermatitis, headaches, gastrointestinal and respiratory symptoms[25]. Given the extent of Ni level across the region, it is speculated that its origins could be anthropogenic due to industrial activities, vehicular emissions, or metallurgical activities and that there are chances that these have negative impacts on the environment and potential risk implications to human health [26][27]. Bio-available Ni and Ni accumulation in biota should pose threats because of their toxicities and cancer treatment efficacy even in farming areas where it can be taken up by food [28][29].

**Figure-3:** Concentration of Ni in all samples with permissible limit

Conversely, the amounts of concentration of Fe in most of the samples did not exceed the WHO's recommended limit. Fe concentrations ranged from 11,100 ppm to 59,000 ppm, with Sample S10 recording the highest Fe concentration at 59,000 ppm, which slightly exceeds the threshold limit. However, while this sample exceeded the permissible level, the proximity of other high Fe values to the limit may be reflective of natural regional geochemistry rather than anthropogenic contamination [30] [31] [32]. The great abundance and occurrence of Fe in most soils suggests that these values are more likely to the region's natural background rather than the anthropogenic incursions[33] [34]. Iron (Fe) is an essential element present in both environment and manufacturing settings. Geologically, it

derives predominantly from iron oxides like hematite (Fe_2O_3) and magnetite (Fe_3O_4), which originated through sedimentation or oceanic processes[35]. As Fe is important for both soil and plant health, within these concentrations, it has no adverse environmental impact [36]. The steady iron concentration in the soil is beneficial for plant growth, environmental safety, and overall soil health. This stability likely come from iron's natural availability, low mobility, environmental buffering capability, and minimal industrial pollution compared to nickel. Iron is necessary for biological processes such as transportation of oxygen and reactions involving enzymes. However, too much iron can cause organ damage as liver and heart. Low levels of iron, on the other hand, results in anemia, weariness, and mental decline.[37].

**Figure-4:** Concentration of Fe in all samples with permissible limit

Finally, it was however seen that about half (50%) of the samples tested had very high levels of Ni contamination and hence rehabilitation strategies are needed. On the other hand, the concentration of Fe corresponds to the natural level of soils and thus poses no threat now. Further studies focusing on spatial distribution and source attribution may help to expose the processes of contamination, therefore making it possible to target soil management and policy options for sustainable land use.

4. Conclusion

The contamination of soil by heavy metals includes iron (Fe) and nickel (Ni), regarding a serious threat to environmental health as well as human health especially in the industrialized agricultural region[38]. Anthropogenic sources contribute to increased levels of Fe and Ni in soils, these include mining, metal processing as well the application of fertilizers or pesticides containing metals[39]. These pollutants contaminate the soil quality and plant health as well as result in bioaccumulation within the food chain affecting the organisms at various trophic levels. As a critical micronutrient, iron can cause oxidative stress in plants when present in excess amounts of soils and modifies root morphology as well as nutrients uptake mechanisms[40]. On the other hand, nickel is a vital trace element and a harmful toxin under high production concentration that can obstruct plant metabolism in enzyme activities as well as photosynthesis in plants[41], [42]. Continuous exposure of soils to Ni, however, adversely affects microbial communities and may result in soil fertility loss/reduction in plant productivity as well as the chronic health problems connected with human intake of Ni contaminated crops such

as respiratory problems; diseases affecting digestive organs etc[43].

The remediation of Fe and Ni contaminated soils should combine physical, chemical, and biological approaches. Monitoring and managing heavy metal levels in soil are necessary to prevent adverse effects on ecosystems and agricultural output. Therefore, it is important that policies address sustainable land use practices, including preventing further contamination of the resource. Further research into innovative remediation techniques and the ecological impacts of heavy metal exposure will contribute to bolstering more effective soil management strategies to ensure long-term environmental and public health.

References

- [1] O. Laccourreye and H. Maisonneuve, "French scientific medical journals confronted by developments in medical writing and the transformation of the medical press," Nov. 01, 2019, Elsevier Masson SAS.
- [2] "Cempel M., Nikel G. 376 Occurrence and Sources."
- [3] M. Sikander Hayyat et al., "Effect of heavy metal (Ni) on plants and soil: A review," vol. 6, no. 7, pp. 313–318, [Online]. Available: www.allresearchjournal.com
- [4] C. K. Swain, "Environmental pollution indices: a review on concentration of heavy metals in air, water, and soil near industrialization and urbanisation," *Discover Environment*, vol. 2, no. 1, Jan. 2024.
- [5] O. Sytar, S. Ghosh, H. Malinska, M. Zivcak, and M. Brestic, "Physiological and molecular mechanisms of metal accumulation in hyperaccumulator plants," *Physiol Plant*, vol. 173, no. 1, pp. 148–166, Sep. 2021.
- [6] G. Genchi, A. Carocci, G. Lauria, M. S. Sinicropi, and A. Catalano, "Nickel: Human health and environmental toxicology," Feb. 01, 2020, MDPI AG.
- [7] A. S. El-Sorogy, K. Al-kahtany, T. Alharbi, and S. S. Alarifi, "Distribution patterns, health hazards, and multivariate assessment of contamination sources of As, Pb, Ni, Zn, and Fe in agricultural soils," *J King Saud Univ Sci*, vol. 36, no. 11, p. 103489, Dec. 2024.
- [8] P. Kumar Mahanta and I. M. Rafizul, "Human health risk assessment due to the presence of heavy metals in soil of waste disposal site at khulna in bangladesh," 2019.
- [9] A. Baral, I. M. Rafizul, S. Das, and S. Berner, "Economic and environmental benefits of optimized waste transportation routes in Khulna," *Environmental Challenges*, vol. 17, Dec. 2024.
- [10] O. Directive, "Ecological Soil Screening Levels for Nickel Interim Final," 2007.
- [11] W. Azuka Iyama, K. Okpara, and K. Techato, "Assessment of Heavy Metals in Agricultural Soils and Plant (*Vernonia amygdalina* Delile) in Port Harcourt Metropolis, Nigeria," 2021.
- [12] P. K. Dhar, N. Uddin, M. H. Ara, and N. T. Tonu, "Heavy metals concentration in vegetables, fruits and cereals and associated health risk of human in khulna, bangladesh," *J. Wat. Env. Sci*, vol. 3, pp. 453–459, 2019, [Online]. Available: <http://revues.imist.ma/?journal=jwes>
- [13] P. Kumar Mahanta and I. M. Rafizul, "Human health risk assessment due to the presence of heavy metals in soil of waste disposal site at khulna in bangladesh," 2019.
- [14] "An Investigation on Soil Quality and Heavy Metal Levels in Soil of Rajbandh Waste Disposal Site at Khulna, Bangladesh," *Iranica Journal of Energy and Environment*, 2017.
- [15] M. A. Akber, M. A. Rahman, M. A. Islam, and M. A. Islam, "Potential ecological risk of metal pollution in lead smelter-contaminated agricultural soils in Khulna, Bangladesh," *Environ Monit Assess*, vol. 191, no. 6, Jun. 2019.
- [16] A. H. M Shofiul Islam Molla Jamal et al., "Aynun Nahar, Rokaia Sultana, Md. Ripaj Uddin, Tajnin jahan, Shahnaz Sultana, and Mehedi Hasan," *Journal of Environment Pollution and Human Health*, vol. 8, no. 2, pp. 49–54, 2020.
- [17] B. Hu, X. Jia, J. Hu, D. Xu, F. Xia, and Y. Li, "Assessment of heavy metal pollution and health risks in the soil-plant-human system in the Yangtze River delta, China," *Int J Environ Res Public Health*, vol. 14, no. 9, Sep. 2017.
- [18] A. K. H. Al-Rubaiee and M. R. A. Al-Owaidi, "Assessment of Heavy Metal Contamination in Urban Soils of selected areas in Hilla City, Babylon, Iraq," *Iraqi Journal of Science*, vol. 63, no. 4, pp. 1627–1641, 2022.
- [19] S. Sharma, A. K. Nagpal, and I. Kaur, "Heavy metal contamination in soil, food crops and associated health risks for residents of Ropar wetland, Punjab, India and its environs," *Food Chem*, vol. 255, pp. 15–22, Jul. 2018.
- [20] N. Khan et al., "Method validation for simultaneous determination of chromium, molybdenum and selenium in infant formulas by ICP-OES and ICP-MS," *Food Chem*, vol. 141, no. 4, pp. 3566–3570, 2013.
- [21] I. Yilmaz, M. Yildirim, and I. Keskin, "A method for mapping the spatial distribution of RockFall computer program analyses results using ArcGIS software," *Bulletin of Engineering Geology and the Environment*, vol. 67, no. 4, pp. 547–554, 2008.
- [22] E. C. Mazarakioti, A. Zotos, A. A. Thomatou, A. Kontogeorgos, A. Patakas, and A. Ladavos, "Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), a Useful Tool in Authenticity of Agricultural Products' and Foods' Origin," Nov. 01, 2022, MDPI.
- [23] T. M. Osobamiro, O. Awolesi, O. M. Alabi, A. Y. Oshinowo, M. A. Oshinowo, and F. A. Busari, "Heavy Metal Levels of Soil Samples Collected From a Major Industrial Area in Abeokuta, Southwestern Nigeria," *International Journal of Scientific and Research Publications (IJSRP)*, vol. 9, no. 8, p. p92125, Aug. 2019.
- [24] R. Ogunlana, A. I. Korode, and Z. F. Ajibade, "Assessing the level of heavy metals concentration in soil around transformer at Akoko community of OndoState, Nigeria," *Journal of Applied Sciences and Environmental Management*, vol. 24, no. 12, pp. 2183–2189, Feb. 2021.
- [25] G. Genchi, A. Carocci, G. Lauria, M. S. Sinicropi, and A. Catalano, "Nickel: Human health and environmental toxicology," Feb. 01, 2020, MDPI AG.
- [26] O. Laccourreye and H. Maisonneuve, "French scientific medical journals confronted by developments in medical writing and the transformation of the medical press," Nov. 01, 2019, Elsevier Masson SAS.
- [27] Y. A. Ayaka, "Nickel in soils: A review of its distribution and impacts," Dec. 2011.
- [28] U. Okereafor, M. Makhatha, L. Mekuto, N. Uche-Okereafor, T. Sebola, and V. Mavumengwana, "Toxic metal implications on agricultural soils, plants, animals, aquatic life and human health," Apr. 01, 2020, MDPI AG.
- [29] M. Kaur, A. Sharma, and Aditya, "A review on heavy metal accumulation and toxicity in biotic and abiotic components," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Dec. 2021.
- [30] G. Sarti, I. Sammartino, and A. Amorosi, "Geochemical anomalies of potentially hazardous elements reflect catchment geology: An example from the Tyrrhenian coast of Italy," *Science of the Total Environment*, vol. 714, Apr. 2020.
- [31] A. Argyraki and E. Kelepertzis, "Urban soil geochemistry in Athens, Greece: The importance of local geology in controlling the distribution of potentially harmful trace elements," *Science of the Total Environment*, vol. 482–483, no. 1, pp. 366–377, Jun. 2014.
- [32] T. T. T. Dung, V. Cappuyns, R. Swennen, and N. K. Phung, "From geochemical background determination to pollution assessment of heavy metals in sediments and soils," Dec. 2013.

- [33] V. Cuculić, N. Cukrov, Ž. Kwokal, and M. Mlakar, "Natural and anthropogenic sources of Hg, Cd, Pb, Cu and Zn in seawater and sediment of Mljet National Park, Croatia," *Estuar Coast Shelf Sci*, vol. 81, no. 3, pp. 311–320, Feb. 2009.
- [34] A. Alengebawy, S. T. Abdelkhalek, S. R. Qureshi, and M. Q. Wang, "Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications," Mar. 01, 2021, MDPI AG.
- [35] B. M. Simonson, "Origin and evolution of large Precambrian iron formations," *Special Paper of the Geological Society of America*, vol. 370, pp. 231–244, 2003.
- [36] N. Arif et al., "Influence of high and low levels of plant-beneficial heavy metal ions on plant growth and development," Nov. 21, 2016, *Frontiers Media S.A.*
- [37] S. Akhtar et al., "Health risk implications of iron in wastewater soil-food crops grown in the vicinity of peri urban areas of the District Sargodha," *PLoS One*, vol. 17, no. 11 November, Nov. 2022.
- [38] A. Rashid et al., "Heavy Metal Contamination in Agricultural Soil: Environmental Pollutants Affecting Crop Health," Jun. 01, 2023, MDPI.
- [39] M. M. Poznanović Spahić et al., "Natural and anthropogenic sources of chromium, nickel and cobalt in soils impacted by agricultural and industrial activity (Vojvodina, Serbia)," *J Environ Sci Health A Tox Hazard Subst Environ Eng*, vol. 54, no. 3, pp. 219–230, Feb. 2019.
- [40] V. Harish, S. Aslam, S. Chouhan, Y. Pratap, and S. Lalotra, "Iron toxicity in plants: A Review," *International Journal of Environment and Climate Change*, vol. 13, no. 8, pp. 1894–1900, Jun. 2023.
- [41] S. A. Bhalerao, A. S. Sharma, and A. C. Poojari, "Toxicity of Nickel in Plants," 2015. [Online]. Available: www.ijpab.com
- [42] B. Shahzad et al., "Nickel; whether toxic or essential for plants and environment - A review," Nov. 01, 2018, Elsevier Masson SAS.
- [43] M. Jović and S. Stanković, "Human exposure to trace metals and possible public health risks via consumption of mussels *Mytilus galloprovincialis* from the Adriatic coastal area," *Food and Chemical Toxicology*, vol. 70, pp. 241–251, 2014.

NOMENCLATURE:

ICP-MS : Inductively Coupled Plasma Mass Spectrometry
 ppm : Parts per million
 WHO : World Health Organization