

# Assessing Soil Pollution: An Investigation into Heavy Metal Contaminations in Roadside Soil in Aizawl, Northeast India

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**Abstract**— The study investigates the heavy metal contamination in the roadside soils of Aizawl, located in Northeast India, where the roadside soil is vulnerable to heavy metal pollution due to vehicular traffic and human activities. A systematic analysis was conducted at twelve sampling sites throughout the city from August 2020 to July 2021, with three replicates taken at each location. Metal concentrations were measured using atomic absorption spectrophotometry after acid digestion, following the USEPA 3050B method. The heavy metals analysed include copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn). The mean metal concentrations at the selected sites range from 0.46 – 0.99 for Cu, 0.25 - 0.54 for Ni, 0.29 - 0.50 for Pb, and 1.35 – 1.84 for Zn. All measured metal concentrations exceeded the local average background values (ABVs), but they generally fall within the safe limits established by the Canadian and Chinese soil quality standards for residential areas. While all contamination levels fall within the moderately contaminated category based on the geo-accumulation index (I<sub>geo</sub>), the pollution load index (PLI) indicated moderate to high levels of contamination by Cu at site S9 (Chanmari) and by Zn at sites S1 (Kulikawn), S5 (Bazar Bungkawn), S9 (Chanmari), and S12 (Khatla). The Pearson correlation analysis revealed a moderate positive correlation between copper and zinc, indicating a common source of pollution. Effect of monsoon Pb and Zn is also observed. The findings revealed varying metal concentrations at the different sites, with variations in the different sampling periods due to the influence of urbanization, human activities, vehicular traffic, and weather.

**Keywords:** Contamination, anthropogenic, vehicular traffic, contamination factor, pollution load index, geo-accumulation index.

## INTRODUCTION

Environmental pollution is a major concern globally, with heavy metal contamination posing a significant threat to ecosystems and human health (Wang 1998). The widespread release of heavy metals into the environment, mainly through industrial activities and transportation, has led to the degradation of soil quality (Chowdhury *et al.* 2021). Soil pollution has become a growing environmental concern in both developed and developing countries. The presence of heavy metals in soils poses a particular threat to human health and the integrity of natural ecosystems,

as these contaminants can accumulate through the food chain and have detrimental effects on wildlife and the overall functioning of terrestrial environments (Dhokpande *et al.* 2024; Wan *et al.* 2024). Soil, as a major sink for the accumulation of different contaminants, such as heavy metals released through human activities, requires immediate attention (Keshavarzi *et al.* 2021).

Roadside soil and dust can be exposed to significant levels of heavy metals due to the accumulation of heavy metals in soils, which can be attributed to a range of human activities,

including automobile emissions, industrial activities, and land use practices (Abdullahi *et al.* 2023; Huang *et al.* 2022). It has been observed that roadside soil is highly contaminated with various heavy metals, namely Cu, Ni, Pb, and Zn, which poses a significant environmental concern with potential implications for human health and ecological systems (Chen *et al.* 2022; Arora *et al.* 2023). Thus, understanding the impact of heavy metal concentration on roadside soil is crucial for implementing effective mitigation strategies and safeguarding the environment (Kaur *et al.*, 2022). Many studies have been conducted to explore the spatial distribution of heavy metal pollution in roadside soils (Wang *et al.* 2017; Kaur *et al.* 2022; Ayaz *et al.* 2023; Ma *et al.* 2023).

Human activities are the main cause of heavy metal pollution (Liu *et al.* 2024). The level of heavy metal contamination of soils depends on its type, climate, human activity, and atmospheric conditions, including wind direction and speed, type of precipitation, type of terrain, and type of vegetation (Skorbiłowicz *et al.* 2021). The surface layer of roadside soil near roads with heavy traffic in urban areas is a good indicator of heavy metal pollution, and heavy metals are released through different parts of vehicles. Metals such as Cu, Pd, and Zn enter the environment through the consumption of brake pads, lubricating and industrial oils, while Ni enters through the wear of metal parts and Ni-plated accessories (Altaf *et al.* 2021; Skorbiłowicz *et al.* 2021). Moreover, heavy metal content in soils along the road is strongly related to traffic and decreases with distance from the road and traffic volume (Arslan and Gizir 2006; Duong and Lee 2011). Therefore, soil contamination caused by vehicular transport has received much scientific attention in recent years and should be monitored to preserve environmental quality and prevent degradation (Wan *et al.* 2024; Kaur *et al.* 2022).

Given the environmental and public health implications of heavy metal pollution in urban soils, it is crucial to conduct comprehensive assessments of the spatial patterns and underlying factors contributing to soil contamination, particularly in rapidly developing regions (Feng *et al.* 2024). Rapid urbanization and industrial growth have placed significant pressure on delicate ecological systems (Ma *et al.* 2023). Aizawl, the capital city of Mizoram state, Northeast India, which is situated in hilly terrains, presents a unique geographic context for understanding the spatial distribution of heavy metal pollution. In a rapidly growing city like Aizawl, there is potential for roadside environments to accumulate heavy metals from vehicular emissions,

and other human sources. This study aims to assess the extent of heavy metal contamination in roadside soils in Aizawl, addressing the level of pollution, the effect of monsoon, and highlighting the possible factors contributing to the pollution.

## MATERIALS AND METHODS

### SAMPLE COLLECTION AND ANALYSIS

Samples were collected monthly from 12 different sites within Aizawl City from August 2020 to July 2021, with three replicates at each site, maintaining at least 10-meter spacing between the replicates. The soil samples collected also contain sediments and dust most of the time. Sampling sites were carefully chosen, avoiding the sites where ongoing buildings and road construction were nearby. The sampling was conducted during the Covid-19 pandemic when the public activities and vehicular movements were restricted due to the imposed lockdowns the Mizoram state government during these periods. Pristine soil samples were also collected from the undisturbed sites of Pachhunga University College campus and ITI Veng area, Aizawl, for comparison. Soil from each site was transferred to air-tight polythene bags and taken to the laboratory. Samples were processed for metal concentration analysis using the USEPA 3050B acid digestion method. In brief, unwanted and larger particles were removed, and drying was done at 75°C for 12 hours, followed by sieving through a 150-micron mesh. For digestion, 1 g of soil was mixed with 10 ml of 8.5 M nitric acid, heated, and again treated with nitric acid, hydrogen peroxide, and hydrochloric acid. After cooling, the samples were filtered and diluted to 100 ml with deionized water (USEPA 1996; Nnodum *et al.* 2022). All reagents were obtained from HiMedia, India. The contents of heavy metals such as Cu, Ni, Pb Zn were measured using an atomic absorption spectrophotometer (Shimadzu, AA-7000F).

### POLLUTION INDICES

The pollution load index (PLI) serves as valuable tools for establishing simple but comparative means for assessing pollution levels while the geo-accumulation index (Igeo) evaluates pollution status and quantifies the influence of human activities, and the PLI and Igeo were assessed as detailed in previous literature (Chen *et al.* 2015; Mafuyai *et al.* 2015; Kaur *et al.* 2022). The Pollution load index (PLI) for the entire sampling site was determined as the nth root of the product of the n CF, i.e.,  $PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n}$ , where CF is the ratio of the metal concentration in the sample to the metal concentration in background.

This empirical index provides a simple, comparative means for assessing the level of heavy metal pollution. The PLI is classified as either background concentration (PLI = 0), unpolluted (PLI ≤ 1), unpolluted to moderately polluted (PLI ≤ 2), moderately polluted (PLI ≤ 3), moderately to highly polluted (PLI ≤ 4), highly polluted (PLI ≤ 5), or very highly polluted (PLI > 5) to indicate the degree of contamination. Igeo is a geochemical criterion to evaluate pollution levels. It was calculated using the formula,  $I_{geo} = \log_2(C_n / 1.5B_n)$ , where  $C_n$  is the measured concentration of metal in soils or sediments and  $B_n$  is the geochemical background value of the corresponding metal and 1.5 is a constant. The Igeo consists of 7 classes: Igeo value of < 0, practically unpolluted; > 0–1, unpolluted to moderately polluted; > 1–2, moderately polluted; > 2–3, moderately to strongly polluted; 3–4, strongly polluted; 4–5, strongly polluted to extremely polluted > 5 extremely polluted.

## RESULTS AND DISCUSSION

### MEAN HEAVY METAL CONCENTRATIONS

Table 1 shows the mean of heavy metal concentrations in roadside soil samples at different selected sites within Aizawl City during August 2020 to July 2021. Significant variations

in the concentrations of Cu, Ni, Pb, and Zn are observed in different sampling periods at each site. The concentrations Zn are the highest, and the Cu concentrations are also higher than Ni and Pb in all the sites. Due to the absence of specific Indian soil guidelines, both the Canadian and the China soil guidelines for residential sites are utilized to assess the safety levels of contamination. The heavy metal concentrations are mostly higher than the average background values (ABVs), but they still fall within safe limits when compared with the soil guidelines of China and Canada (Teng *et al.* 2014; CCME 2023). The surface layer of roadside soil in urban areas is a good indicator of heavy metal pollution. It was reported that heavy metal pollution in urban areas primarily arose from anthropogenic activities, including vehicular emissions, construction activities, and improper waste disposal. Vehicles contributed significantly through emissions, tire and brake wear, and the deposition of lead and zinc from fuels and paints (Altaf *et al.* 2021; Skorbiłowicz *et al.* 2021). Additionally, improper waste management, including the disposal of electronic waste and batteries, added to heavy metal contamination in urban environments (Ali-Taleshi *et al.* 2022; Motuzova *et al.* 2014).

**Table 1: Mean Metal Concentration at the Study Site in Aizawl (in ppm).**

Site	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
S1 (Kulikawn)	0.54±0.45	0.54±0.59	0.50±0.40	1.61±0.50
S2 (Vaivakawn)	0.46±0.20	0.31±0.27	0.29±0.27	1.53±0.63
S3 (Sikulpuikawn)	0.77±0.37	0.34±0.35	0.40±0.42	1.55±0.51
S4 (Bethlehem Vengthlang)	0.71±0.51	0.38±0.24	0.49±0.37	1.49±0.56
S5 (Bazar Bungkawn)	0.92±0.76	0.25±0.14	0.36±0.39	1.65±0.62
S6 (Laiputlang)	0.63±0.55	0.25±0.18	0.31±0.23	1.55±0.66
S7 (Temple Square)	0.94±0.96	0.31±0.31	0.49±0.52	1.58±0.58
S8 (Ramhlun)	0.64±0.46	0.34±0.30	0.44±0.46	1.55±0.58
S9 (Chanmari)	0.99±0.49	0.26±0.07	0.33±0.27	1.77±0.59
S10 (Bawngkawn)	0.65±0.34	0.35±0.24	0.36±0.36	1.60±0.67
S11 (MINECO)	0.47±0.41	0.43±0.68	0.32±0.34	1.35±0.60
S12 (Khatla)	0.61±0.27	0.37±0.33	0.43±0.52	1.84±0.76
ABVs in Aizawl	0.24	0.14	0.14	0.49
China soil guidelines	100	50	300	250
Canada soil guidelines	64	50	140	200

## ASSESSMENT OF CONTAMINATION LEVEL USING POLLUTION INDICES

### Pollution Load Index

The PLI was used to assess the contamination levels and the PLI value is depicted in Figure 1. The figure reveals notable fluctuations in heavy metal contamination among various sampling locations, showcasing discernible variations in the concentrations of the studied heavy metals. The site S1 displays the highest PLI for Pb (2.67). S1, S4, S10, and S11 are classified as moderately polluted, while all other sites are categorized as unpolluted to moderately polluted. The highest PLI for Zn (3.34) is observed at site S9. S1, S5,

and S12 are also under moderate to highly polluted levels with respect to Zn, like site S9, and the rest are under the moderately polluted category. Site S9 demonstrates the highest, with a moderate to highly polluted PLI for Cu (3.55), while seven sites fall under the moderately polluted category. Site S1 exhibits the highest PLI for Ni with a value of 2.67, indicating a moderately polluted environment. Three sites (S4, S10, and S12) exhibit moderately polluted levels, while most of the sites (PLI 1.58 – 1.99) fall under unpolluted to moderately polluted levels. These observations imply that local activities or emissions have a notable impact on each site, contributing to heightened pollution levels (Kozáková *et al.* 2019; Comber *et al.* 2022).

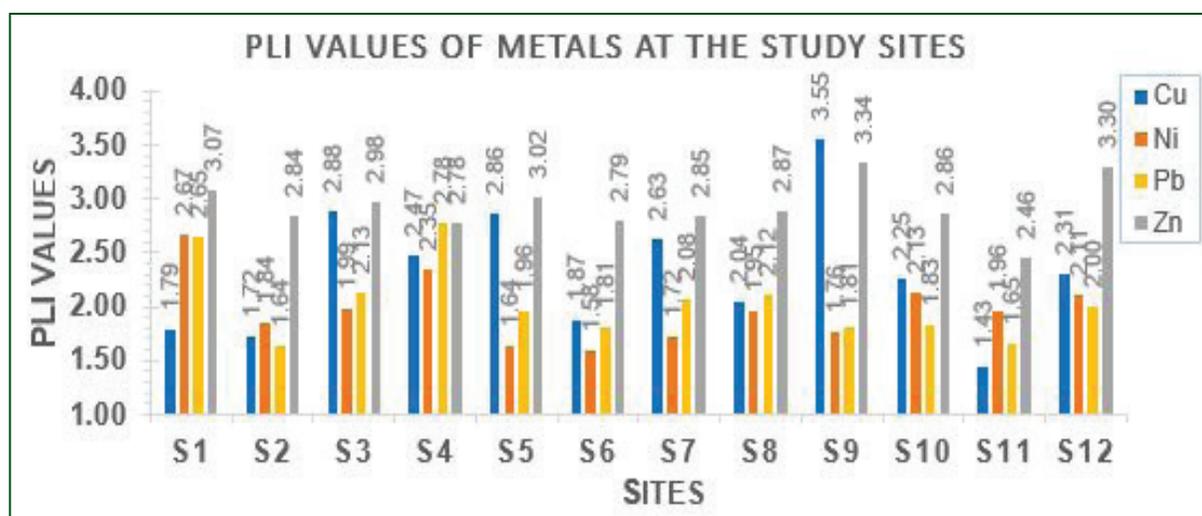


Fig. 1: PLI Values of Metals at the Study Site.

### Geo-accumulation Index (Igeo)

The Igeo values calculated from the mean concentrations of metals at different months are presented in Figure 2 and it provides a comprehensive assessment of heavy metal contamination. Sites S1, S5, S7, and S9 exhibit higher Igeo values of 1.10, 1.35, 1.38, and 1.45, respectively, for Cu, indicating unpolluted to moderately polluted levels. The Igeo for Cu showed values ranging from 0.37 at S2 to 1.45 at site S9, from unpolluted to moderate pollution levels, suggesting localized pollution sources and varying degrees of anthropogenic impact at different sites (Ayaz *et al.* 2023). For Ni, Igeo values ranged from 0.26 (S5) to 1.26 (S1), indicating localized pollution sources and varying degrees of anthropogenic impact (Ali-Taleshi *et al.* 2022). The Igeo for Pb showed values ranging from 0.47 (at S2) to 1.26 (at S1),

suggesting unpolluted to moderate contamination. Zn contamination was moderately high across all sites, with Igeo values ranging from 0.88 at site S11 to 1.33 at site S12. Notably, some sites displayed higher contamination at least for some of the studied heavy metals, emphasizing their vulnerability to heavy metal pollution. The Igeo values for Cu, Ni, Pb, and Zn across various sites highlight the distribution of these metals, suggesting localized sources such as human activities, vehicular traffic activities, or construction work (Kaur *et al.* 2022). Anthropogenic activities such as vehicular traffic, industrial activities, rusting and degradation of metallic structures and materials bearing these metals could affect the contamination levels (Abdullahi *et al.* 2023; Dhaliwal *et al.* 2021).

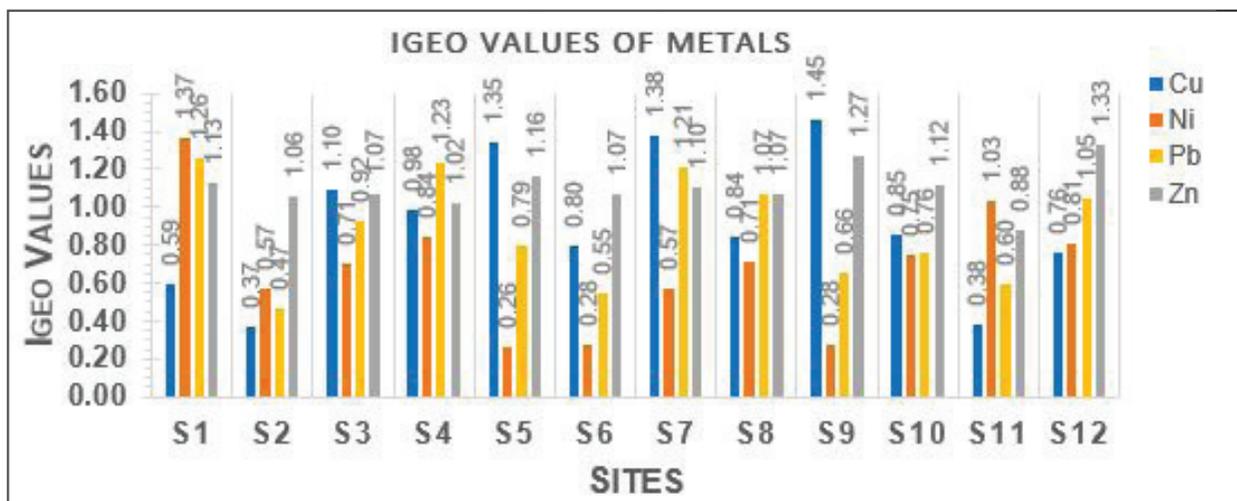


Fig. 2: Igeo Values of Metals at the Study Site.

**Pearson Correlation**

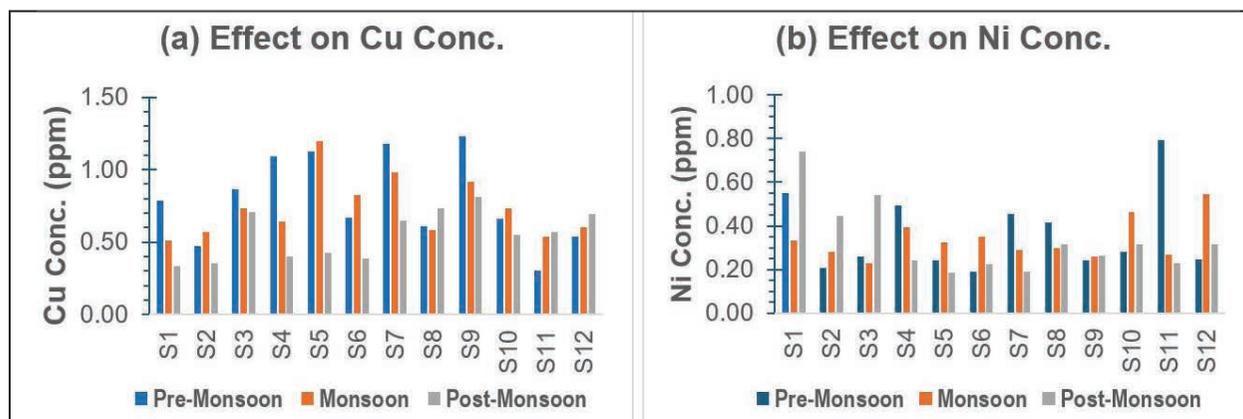
The Pearson correlation matrix represented in Table 2 provides insights into relationships between heavy metals, suggesting the common or distinct sources of pollution. A moderate positive correlation (0.361) between Cu and Zn suggests shared common sources like industrial activities or vehicular traffic-related pollution, as explained by Motuzova *et al.* (2014). Weak positive correlations between Ni and Zn (0.244); and Pb and Zn (0.229) indicate mixed sources, while Cu and Ni (0.122) have very weak correlations. In contrast, weak negative correlations between Cu and Pb (-0.201) and Ni and Pb (-0.224) imply different sources (Lu *et al.* 2014). These findings highlight the complex nature of factors influencing heavy metal contamination, emphasizing the need for more comprehensive source apportionment studies.

Table 2: Pearson Correlation Matrix for Metals.

Metals	Cu	Ni	Pb	Zn
Cu	1.000	0.122	-0.201	0.361
Ni	0.122	1.000	-0.224	0.244
Pb	-0.201	-0.224	1.000	0.229
Zn	0.361	0.244	0.229	1.000

**EFFECT OF MONSOON ON THE VARIATIONS OF HEAVY METAL CONCENTRATIONS**

The effect of monsoon on the variations of heavy metal concentrations is shown in Figure 3. The level of heavy metal contamination of soils can be affected by the atmospheric conditions, including wind direction and speed, type and level of precipitation, and the type of terrain and the soil physicochemical characteristics (Wang *et al.* 2017. Wang and Zhang 2018). The heavy metal contamination of soil can be influenced by variable factors.



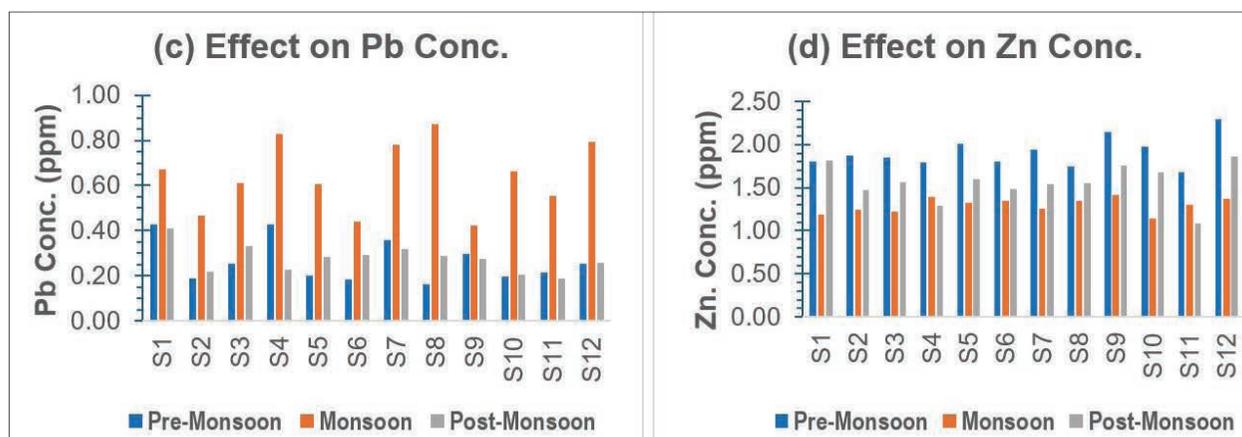


Fig. 3: Effect of Monsoon on the Variations of (a) Cu, (b) Ni, (c) Pb and (d) Zn.

It was observed from the figure that Pb concentrations reach a peak during the monsoon compared to pre-monsoon and post-monsoon, possibly due to rain washing lead-containing paints or leaching from other lead-containing materials. Previously, Schwarz (2016) reported that rain washed lead from old painted surfaces leached into the soil and exacerbating contamination. Zn exhibited the highest concentration in pre-monsoon, with a notable decrease during the monsoon and a slight increase in post-monsoon at most of the sites. The decrease in Zn concentration during the monsoon season could be due to the dilution effect by rainfall and diminished atmospheric deposition. It was reported previously that the heavy metal contamination of the dumpsite soil samples contained lowered in which revealed higher Fe, Cr and Cd levels in pre-monsoon than in post-monsoon (Guthula *et al.* 2018). Notable effect of monsoon on the change of concentrations of Cu and Ni was not observed. This could indicate that there could be many factors which govern the local contamination levels of these heavy metals.

## CONCLUSION

This research thoroughly examined the extent of heavy metal contamination in roadside soils within Aizawl, Northeast India, focussing on the concentrations of Cu, Ni, Pb and Zn across twelve discrete sampling sites. The sampling was conducted during the Covid-19 pandemic. The public activities and vehicular movements were restricted since the Mizoram state government-imposed lockdowns during these periods. The data indicated marked spatial and temporal discrepancies in metal concentrations among the sampled sites, with Zn levels the highest, and Cu levels

significantly exceeding those of Ni and Pb. The mean metal concentrations ranged from 0.46 (at S2) to 0.99 (at S9) for Cu, 0.25 (at S5) to 0.54 (at S1) for Ni, 0.29 (at S2) to 0.50 (at S1) for Pb, and 1.35 (at S11) to 1.84 (at S12) for Zn. Although the concentrations of heavy metals were observed to be elevated relative to the average background levels in the vicinity, they were generally found to be within acceptable limits when assessed against the soil quality standards established by Canada and China. Site S9 demonstrates the highest, with a moderate to highly polluted PLI value for Cu (3.55), while the sites S1, S5, S9 and S12 showed 3.07, 3.02, 3.34 and 3.34 for Zn respectively. The highest Igeo values for Cu, Ni, Pb, Zn observed are 1.45, 1.37, 1.26, 1.33 respectively and all these falls within the moderately contaminated category. Furthermore, the Pearson correlation analysis elucidated a moderate positive correlation (0.361) between Cu and Zn which suggests shared common sources like industrial activities or vehicular traffic-related pollution. The study noted decrease in Zn concentrations during the monsoon season likely because of dilution effects from rainfall. The increase in Pb levels during the monsoon could be due to rain-induced runoff from lead-based paints and lead containing materials. This seasonal variability indicates the dynamic characteristics of heavy metal pollution in Aizawl. The results highlight the widespread occurrence of heavy metal contamination, primarily resulting from anthropogenic activities such as vehicular emissions, industrial operations, and localized activities. The study underscores the necessity for ongoing monitoring and systematic evaluation of soil contamination to protect the environment and public health.

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