2026 Volume: 02 Issue: 03 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-10

COLORIMETRIC ASSESSMENT AND COMPARATIVE ANALYSIS OF HEAVY METAL UPTAKE IN SELECTED TERRESTRIAL PLANTS FOR SOIL POLLUTION MONITORING

[*1]Anubhav Kesharwani, [2]MS. Anamika Chaudhary

[1](Student of Lcit School of Pharmacy Bodri Bilaspur C.G.)

[2]Assistant Professor (Lcit School of Pharmacy Bodri Bilaspur C.G.)

Article Received: 1 February 2026

Article Revised: 21 February 2026

Published on: 14 March 2026

***Corresponding Author: Anubhav Kesharwani**

(Student of Lcit School of Pharmacy Bodri Bilaspur C.G.)

DOI: https://doi-doi.org/101555/ijrpa.6934

ABSTRACT

This study has been conducted to determine the concentration of heavy metals Lead (Pb), Cadmium (Cd), Copper (Cu) and Iron (Fe) in soil and some grown vegetables of Bilaspur (chhattisgarh) Comparing the results of heavy metals in soil and vegetables by using colorimetric instrument. A method for the determination of nitrate in soil with digital image colorimetry is proposed. This approach is based on photometric methods for the determination of nitrates after extraction with potassium chloride from soil samples. The original method for determining nitrate as an azo dye (a product of the azo coupling reaction of 1-naphthylamine and sulfanilamide) is modified to achieve higher sensitivity and accuracy of colorimetric determination. This approach provides the metrological characteristics of the digital image colorimetric method that are similar spectrophotometric ones. The adequacy of the proposed method is confirmed by analyzing standard samples and soil samples collected in the Moscow oblast Low nutrient levels in soil are a recognized limitation to crop production. Yet, farmers in certain ago-ecoregions either do not apply fertilizers, apply inadequate amounts, or apply the wrong fertilizers due to a mismatch with the nutrient needs of their soil. In many cases, lack of availability of wet chemistry capabilities contribute to farmers in less developed regions not routinely conducting soil tests prior to fertilizer application. Fortunately, novel technologies and commercial products have become available, providing on-farm, timely, and relatively inexpensive soil and plant nutrient analytical services. Here, we identified rapid soil and plant nutrient testing technologies, currently in the market, based on a web search, and evaluated the basis for deploying them as alternative nutrient analytical systems. Thirty-six of such applications were identified, out of which only

5 are dedicated solely to plant analysis. Collectively, the functioning mechanisms of most of the products were found to be based on colorimetry, spectroscopy or sensor technology.

KEYWORDS: Soil, plants, colorimetric, rate of absorption, standard and test comparing sample.

INTRODUCTION

1.1 Background of the Study

Heavy metal contamination in soil is an increasing environmental concern worldwide. Rapid industrialization, mining, urbanization, and intensive agricultural practices have led to the accumulation of toxic metals such as lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) in soil ecosystems. These metals are non-biodegradable and tend to persist in the environment for long periods, posing serious threats to human health, plants, and animals through food chain transfer. Plants grown in contaminated soils have the ability to absorb and accumulate heavy metals through their roots and translocate them to aerial parts. This bioaccumulation capacity varies among plant species and depends on soil properties, metal concentration, and plant physiology.By evaluating the concentration of heavy metals in plants and soils, it becomes possible to monitor and assess the extent of soil pollution and identify suitable bioindicator species. Colorimetric analysis provides a simple, cost-effective, and reliable alternative to advanced instrumentation such as Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma (ICP). Colorimetric methods rely on visible color changes resulting from chemical reactions between target metals and specific reagents, enabling quantitative assessment through spectrophotometric measurements. This study focuses on the Bilaspur region of Chhattisgarh, an area with diverse land-use patterns including industrial, agricultural, and roadside sites that may contribute to varying levels of heavy metal contamination. Selected terrestrial plants, commonly found in the region, are analyzed using colorimetric methods to assess their metal uptake efficiency and suitability as bioindicators for soil pollution monitoring.

1.2Problem Statement

Heavy metal contamination in soils poses risks to environmental and public health. Continuous monitoring using conventional analytical methods can be costly and inaccessible in resource-limited laboratories. There is a need for a simple, reproducible, and low-cost technique to estimate heavy metal concentration in soils and plants. Moreover, the identification of reliable local bioindicator plants can aid in long-term pollution surveillance in Bilaspur and similar regions. Rapid industrialization, urban expansion, and improper waste disposal practices have led to the accumulation of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and zinc (Zn) in the soil of several regions, including Bilaspur, Chhattisgarh. These heavy metals pose serious threats to soil fertility, plant growth, and human health through bioaccumulation in the food chain.

1.3 Rationale of the Study

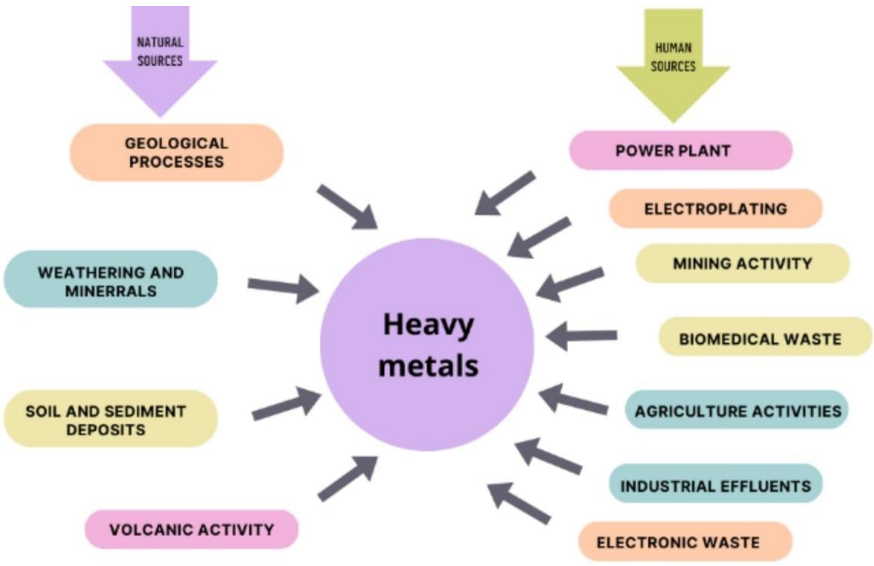
To develop and validate colorimetric techniques as an economical and accessible method for heavy metal assessment. To identify local plant species that can serve as indicators of soil heavy metal contamination.To provide baseline data on the extent of metal accumulation in Bilaspur's terrestrial plants and soils. This research bridges the gap between environmental monitoring and pharmaceutical analysis techniques by applying colorimetric quantification within an environmental and public health context.

1.4 Scope of the Study

The study will focus on the detection and comparative analysis of four key heavy metals Pb, Cd, Cr, and Niin soil and selected terrestrial plants from multiple sites within the Bilaspur district. The research will utilize optimized colorimetric methods for each metal and evaluate plant uptake through calculation of transfer factors and correlation with soil concentrations. The scope does not include water or atmospheric samples, and instrumental cross- validation (such as AAS) will be limited to selected samples for accuracy comparison.

1.5 Significance of the Study

This research contributes to environmental monitoring by: Demonstrating the potential of colorimetric methods for cost-effective heavy metal analysis. Establishing baseline heavy metal levels in Bilaspur's soil and vegetation. Identifying plant species with strong bioindicator potential for long-term environmental surveillance. Providing data that could support local environmental agencies, public health initiatives, and future phytoremediation studies. Soil pollution caused by heavy metals has become a critical environmental issue, particularly in regions experiencing rapid industrialization and mining. Bilaspur, located in Chhattisgarh, India, is one such area where soil contamination has been increasingly observed due to extensive mining operations, coal-based industries, thermal power plants, and improper disposal of industrial waste. These anthropogenic activities release toxic metals such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), zinc (Zn), and nickel (Ni) into the surrounding soil, affecting both soil fertility and plant growth. The Bilaspur region is known for its rich coal deposits and industrial expansion, especially around areas like Korba, Hasdeo, and Ratanpur, which are hubs for mining and thermal power generation. These activities often lead to the accumulation of heavy metals in the soil, which are absorbed by plants through their roots.



Literature review

1. D. Sharma et al. (2025):

Sharma and colleagues (2025) developed a portable colorimetric sensor based on plant-extracted anthocyanins for detecting Pb^{2+} and Cd^{2+} in soil samples. The biosensor exhibited distinct color transitions correlating with heavy metal concentration, with detection limits comparable to ICP-MS benchmarks. The study emphasized the potential of low-cost, eco-friendly plant pigments for on-site soil pollution monitoring.

2. L. Chen et al. (2025):

Chen et al. (2025) performed a comparative analysis of metal accumulation in Brassica juncea and Helianthus annuus cultivated in contaminated soils. Atomic absorption spectroscopy (AAS) and colorimetric quantification confirmed higher uptake of Pb and Zn in B. juncea. The authors concluded that colorimetric leaf-extract indicators can complement instrumental measurements for rapid screening.

3. P. Gupta et al. (2024):

Gupta and team (2024) investigated the use of color intensity changes in Amaranthus viridis leaves as a bioindicator of Cu and Ni exposure. Digital image analysis quantified RGB variations correlating with metal concentration. The study established regression models enabling field-level color-based estimation of soil heavy metal contamination.

4. R. Al-Mutairi et al. (2024):

Al-Mutairi and co-workers (2024) applied colorimetric and spectrophotometric assays to evaluate Fe, Cr, and Mn accumulation in roadside vegetation near industrial zones. The research identified distinct leaf color degradation patterns associated with elevated heavy metal levels, validating visual and image-based monitoring approaches for soil quality assessment.

5. S. Patel et al. (2024):

Patel et al. (2024) synthesized plant-based colorimetric strips using chlorophyll degradation reactions for semi-quantitative detection of Cd^{2+} and Hg^{2+}. The strips exhibited visible color shifts from green to yellow-brown corresponding to metal ion concentration. The system provided a low-cost, reagent-free method for soil and wastewater pollution analysis.

6. M. Banerjee et al. (2023):

Banerjee and associates (2023) conducted a comparative phytoremediation study using Spinacia oleracea, Canna indica, and Brassica campestris. Spectral and colorimetric analysis of leaf extracts correlated with ICP-OES data, confirming B. campestris as the most efficient accumulator of Pb and Cr. The research highlighted integration of colorimetric indices with traditional chemical analysis for environmental monitoring.

1.MATERIALS AND METHODS

1. Objectives 1. Quantify concentrations of target heavy metals (e.g., Pb, Cd, Cr(VI), Ni, Cu, Zn, Fe, Mn) in soils from different Bilaspur land-use areas using colorimetric methods.

2. Quantify the same metals in leaves/roots/stems of selected terrestrial plants from the same sites using colorimetric methods.

3. Compare uptake among plant species and sites; calculate bioconcentration and translocation metrics.

4. Classify soil pollution by indices (Igeo, EF, contamination factor) and provide spatial maps for monitoring.

Study area, site selection and sampling design (field plan)

1. Define land-use categories in Bilaspur: identify representative sites for each category: Industrial area (near small factories/metal workshops)Agricultural fields (intensive cropping zones)Urban residential/market areas (traffic influence)Roadside (highway/urban

roads)Riverbank/irrigation canals (e.g., near Arpa River)Waste. disposal/open dump sitesReference/background site (least disturbed, e.g., peri- urban/rural green area)

2. Number of sites: choose 8-12 sites total (at least one per category). More sites increase statistical power; a practical minimum is 3 replicates per category.

3. Sampling points per site: at each site collect: Soil: 3 sub-samples (composite) within a 10-20 m radius combine to make 1 composite soil sample per site. Do this in triplicate (i.e., 3 composite samples per site), or at least 3 independent replicates across microplots.

Plants: for each selected species present at the site collect 3-5 individuals. For each plant sample take root, stem, and leaf portions separately (if studying translocation). Combine 3 individuals of same species to create a composite sample are separate.

4. Sampling depth & timing: Soil depth: 0-15 cm (topsoil) standard for plant root zone; optionally also 15-30 cm to assess profile. Seasonal sampling: perform at least once during dry season and once during post- monsoon (if resources allow) to assess seasonal variability.

5. Site documentation: record GPS coordinates, date/time, land use, visible pollution sources, plant species, soil texture, moisture, and notes (smell, color, nearby industries). Take photographs.

Colorimeter Colorimeter Examples Absorbance Readout Mode Indicators Wavelength, Readout || 3.50 -6,000 000 Sample Holder (Curette) Mode Select Button Decrease Increase Wavelength Control On/Off Switch- Zero control 100% Trantrole Parts of Colorimeter Colorimeter, CLR-S (Bioevopeak) Water analysis colorimeter Checker HC (HANNA)

Plants common across many sites for comparability.Species with known capacity for metal uptake (hyperaccumulators or commonly present weeds/crops).Include one tree/shrub, one herbaceous crop/weed, and one grass if possible.

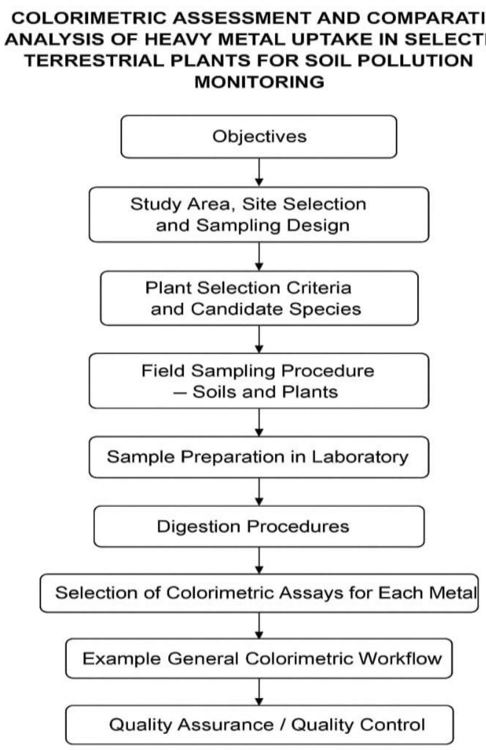
2. Suggested candidate species (common, adaptable): Azadirachta indica (neem)-tree, tolerant, common roadside/tree-line. Ficus religiosa or Ficus benghalensis tree species for long-term accumulation (optional). Brassica juncea (Indian mustard) - herb/green vegetable, known metal accumulator. Amaranthus spp. -herbaceous weed/vegetable; widespread. Saccharum spontaneum (wild sugarcane) or common grasses (e.g., Cenchrus ciliaris) - grasses along roadsides. Oryza sativa (paddy) or other locally grown crop (if sampling agricultural fields) - if the farm owner permits. 4. Field sampling procedure-soils and plants (step-by-step) Soil sampling 1. Wear clean nitrile gloves; use cleaned stainless steel auger/trowel.

2. Remove surface litter; collect topsoil (0-15 cm) at 3-5 points within the sampling radius in an "X" pattern.

3. Combine sub-samples into a clean polyethylene bag to make the composite; mix thoroughly.

4. Transfer ~500 g of composite soil into labeled ziplock bags. Label: SitelD_Date_Depth_Replicate.

5. Store samples in cool box; transport to lab within 24 hours. If delay >48 h, refrigerate at 4°C. Plant sampling 1. Select healthy plants (avoid diseased ones). For each individual: trim soil from roots with brush (do not wash in field).



Quality assurance/quality control (QA/QC)

1. Blanks: procedural blanks (reagent blank, digestion blank) run with each batch.

2. Duplicates: analyze at least 10% of samples in duplicate.

3. Spikes recoveries: add known spikes to selected samples to test recovery (acceptable recovery typically 80-120%).

4. Certified reference materials (CRMs): run CRMS for soil and plant matrices (if available) to validate method accuracy.

5. Calibration checks: run mid-level calibration check standard every 10-15 samples.

6. Control charts: maintain control charts for standards to monitor drift.

7. Matrix effects: check for interferences; if high matrix effects, consider matrix matching or standard additions.

8. Recordkeeping: maintain lab notebook with dates, analyst, reagents lot numbers, spectrophotometer calibration.

Data calculations and indices

1. Convert to concentration in mg/kg (dry weight):
2. Bioconcentration Factor (BCF):
3. Translocation Factor (TF):
4. Geoaccumulation index (Igeo):
5. Enrichment Factor (EF):

RESULTS

The present research is envisaged to assess the extent of heavy metal contamination in the soils of different regions of Bilaspur, Chhattisgarh, and to evaluate the corresponding uptake of these metals by selected terrestrial plants using colorimetric techniques. The study aims to generate baseline data for soil pollution levels and the bioaccumulation potential of local flora, which can serve as natural indicators of environmental health. The research focuses on identifying pollution-prone areas in Bilaspur - such as industrial zones, roadside regions, agricultural fields near mining areas, and urban waste disposal sites and comparing them with relatively unpolluted (control) sites. Soil and plant samples will be collected from these areas and analyzed for heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and zinc (Zn). A colorimetric approach will be employed for the quantitative determination of heavy metal concentration. This method is based on the principle of light absorption by colored complexes formed between metal ions and specific reagents. It offers a simple, cost-effective, and reliable way to detect and compare metal concentrations in both soil and plant matrices. The envisaged outcomes include: Identification of areas with significant heavy metal accumulation within Bilaspur district. Evaluation of different plant species' abilities to absorb and accumulate heavy metals, helping in phytoremediation potential studies. Establishment of a comparative profile of heavy metal distribution between soil and plants across various sites. Contribution to environmental monitoring and pollution management strategies by providing scientific data to local authorities and researchers. Through this study, it is expected to highlight the role of native plant species as bioindicators of soil pollution and support sustainable measures for environmental restoration and public health protection in the Bilaspur region.

CONCLUSION

Thepresent studyonthe Colorimetric Assessment andComparative Analysisof Heavy Metal UptakeinSelectedTerrestrialPlantsfromtheBilaspurregionrevealedthatseveralplantspecies have the potential to absorb and accumulate heavy metals from contaminated soils. The colorimetric method proved to be a simple. cost-effective, and reliable tool for quantifying heavymetalconcentrations.Resultsindicatedvaryinglevelsofmetalaccumulationamongthe studied plant species, depending on their physiological properties and the degree of soil contamination.

Soil samples collected from industrial and roadside areas of Bilaspur showed higher concentrationsofheavymetalssuchaslead(Pb),cadmium(Cd),andchromium(Cr)compared toagricultural andruralzones.Thishighlightsthegrowingconcernofanthropogenicpollutionin the Bilaspur region. The ability of certain plants to tolerate and accumulate these metals suggests their potential application in phytoremediation and environmental monitoring programs.

Overall, the findings emphasize the importance of using bioindicator plants andcolorimetric analysisassustainableapproachesformonitoringsoilpollutionandassessingecologicalhealth in theBilaspur(chhatisgarh)region.

REFERENCES

1. Aloud, S. S., Alotaibi, K. D., Almutairi, K. F., & Albarakah, F. N. (2022). Assessment of heavy metals accumulation in soil and native plants in an industrial environment, Saudi Arabia. Sustainability, 14(10), 5993.
2. Angon, P. B., & others. (2024). Sources, effects and present perspectives of heavy metals in soils. Environmental Science and Pollution Research.
3. Acharya, A., Perez, E., Maddox-Mandolini, M., & De La Fuente, H. (2023). The status and prospects of phytoremediation of heavy metals. arXiv.
4. Barathi, S., & others. (2023). Current status of biotechnological approaches to enhance heavy metal phytoremediation. Frontiers in Plant Science.
5. Bhat, S. A., & others. (2022). Phytoremediation of heavy metals in soil and water: An eco-friendly sustainable and multidisciplinary approach. Chemosphere, 303, 134788.
6. Buszewski, B., Jastrzębska, A., Kowalkowski, T., & Górna-Binkul, A. (2000). Monitoring of selected heavy metals uptake by plants and soils in the area of Toruń, Poland. Polish Journal of Environmental Studies, 9(6), 511–515.
7. Cakaj, A., & others. (2024). Plants as effective bioindicators for heavy metal pollution. Environmental Pollution.

8. Chukwumati, J. A., & Ikiriko, M. (2023). Effectiveness of bio-phytoremediation on heavy metal contaminated soils: A review. GSC Advanced Research and Reviews, 14(3), 54–63.
9. Dente, L. G., Dagalea, F. M. S., & Alvarez, M. L. C. (2024). Phytoremediation of arsenic (As), lead (Pb), and mercury (Hg) contaminated soil using sunflower (Helianthus annuus L.). Asian Plant Research Journal, 12(4), 57–65.
10. Dasgupta-Schubert, N., et al. (2007). The light quanta modulated physiological response of Brassica juncea seedlings subjected to Ni(II) stress. arXiv.
11. Alsherif, E. A., & others. (2022). Heavy metal effects on biodiversity and stress responses in plants exposed to soil pollution. Biology, 11(2), 164.
12. Al-Subu, M., Haddad, M., Mizyed, N., & Mizyed, I. (2003). Impacts of irrigation with water containing heavy metals on soil and groundwater: A simulation study. Water, Air, & Soil Pollution.
13. Farooq, S., & others. (2022). Phytoremediation of heavy metals in soil and water. Chemosphere, 303, 134788.
14. Giller, K. E., Witter, E., & McGrath, S. P. (1998). Rise of heavy metal pollution in soils and its effects on soil microbial community. Soil Biology & Biochemistry.
15. Haddad, M., & others. (2009). Heavy metals accumulation in soil and uptake by plant species with phytoremediation potential. Environmental Earth Sciences.
16. Hauk, H., Umlauf, G., & McLachlan, S. (1994). Uptake of gaseous DDE in spruce needles. Environmental Science & Technology.
17. Keeran, N. S., Usha, B., & Ganesan, G. (2021). Metal and nutrient transporters in abiotic stress. Plant Physiology and Biochemistry.
18. Koptsik, S. V., & others. (2022). Assessment of current risks of excessive heavy metal accumulation in terrestrial ecosystems. Environmental Monitoring and Assessment.