



### FROM SOIL SAFETY TO PUBLIC HEALTH: RESEARCH AND ENTERPRISE IN SUSTAINABLE HEALTHCARE THROUGH HEAVY METAL MONITORING

*\* Asst Prof. Ankita Gupta & \*\*Mr. Gautam Jha*

*\* Assistant Professor, \*\* Research Scholar, Department of Chemistry, SET's Rajiv Gandhi College of Arts, Commerce & Science, Vashi Navi Mumbai, Maharashtra-400703*

#### **Abstract:**

*Sustainable healthcare systems depend not only on hospitals and medical services but also on environmental safety, food security, and preventive public health strategies. Heavy metal contamination in agricultural inputs poses long-term risks to soil quality, water safety, food chains, and human health. This study evaluates the concentration of heavy metals in organic fertilizers collected from Uran Taluka, Raigad District (Navi Mumbai), Maharashtra using Sequential Extraction Procedure and ICP-AES analysis. The research integrates environmental science, public health, and regulatory perspectives to highlight how scientific research, educational awareness, and enterprise-level quality control can collectively strengthen sustainable healthcare systems.*

**Keywords:** *Sustainable Healthcare, Heavy Metals, Organic Fertilizers, Public Health, ICP-AES, Environmental Health, Policy Regulation*

**Copyright © 2026 The Author(s):** This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

#### **Introduction:**

The issue of environmental pollution has become increasingly serious as a result of rapid economic growth and advancements in various industries such as manufacturing and agriculture, which have led to the release of contaminants into the environment. Heavy metals are a type of metallic element that has a high atomic weight and a density of over 5 g/cm<sup>3</sup>, and their chemical properties are of particular concern due to their potential for environmental toxicity that exceeds established maximum residue limits (MRL). Heavy metals such as cadmium (Cd), lead (Pb), copper (Cu), and zinc (Zn) pose significant risks to the environment and human health. These heavy metals originate from multiple sources including industrial activities, mining operations, and agricultural practices.[1]

Pollutants are dangerous compounds that find their way into the environment from both natural and human sources. Both living things like people, animals, and

plants as well as inanimate objects like water, air, and soil are seriously endangered by industrial manufacturing, the use of coal, and garbage incineration. Common contaminants in the environment include pesticides and heavy metals, which threaten the ecosystem as a whole and seriously impair its structure and function.[2] In India, there are an estimated 512.05 million cattle that generate 1095 million MT of manure annually, according to the 19th Livestock Census. The use of organic fertilizers in agriculture has become increasingly popular due to their alleged benefits for the environment and health. However, concerns have been raised about the potential accumulation of heavy metals in these fertilizers, which could harm crop yield, soil quality, and human health. Therefore, it is essential to understand the extent to which organic fertilizers are contaminated with heavy metals to promote sustainable agriculture practices. The goal of this research is to conduct a comprehensive analysis of the sources, distribution, and possible

effects of heavy metals on soil ecosystems in organic fertilizers. The study's primary objective is to fill in the knowledge gaps concerning heavy metal contamination in organic fertilizers by reviewing existing literature, empirical data, and regulatory frameworks.[3]

Sustainable agriculture techniques depend on knowing how contaminated organic fertilizers are with heavy metals. The goal of this dissertation is to conduct a thorough analysis of the sources, distribution, and possible effects of heavy metals on soil ecosystems in organic fertilizers. This research aims to fill important information gaps about heavy metal contamination in organic fertilizers by thoroughly reviewing the body of literature, empirical data, and regulatory frameworks. Sustainable healthcare systems extend beyond medical treatment and focus on disease prevention, environmental protection, and long-term public health resilience. Environmental contaminants such as heavy metals contribute significantly to chronic diseases, including cancer, neurological disorders, kidney failure, and developmental disabilities. According to WHO reports, exposure to toxic chemicals such as lead accounts for significant global disease burden measured in DALYs, which indirectly increase healthcare burden and by proposing integrated research, education, and enterprise-based solutions.

**The research aims to achieve the following objectives:**

- Investigate the natural sources, industrial processes, and agricultural inputs that lead to the accumulation of heavy metals in organic fertilizers.
- Examine the distribution and variation of heavy metal concentrations in different types of organic fertilizers, taking into account factors such as source materials, processing techniques, and geographic regions.
- Evaluate the potential risks of soil contamination,

crop uptake, and human exposure through the food chain resulting from heavy metal contamination in organic fertilizers.

- Identify the most effective ways to reduce the presence of heavy metals in organic fertilizers through quality control procedures, regulatory measures, and alternative recycling methods.

This dissertation uses a multidisciplinary approach that integrates perspectives from agronomy, environmental science, and public health to provide critical insights into the complex dynamics of heavy metals.

#### **Literature Review :**

1. With the growing worry about possible environmental contamination and health concerns to humans, this study explores the critical investigation of heavy metal concentrations in organic fertilizers. Lead, cadmium, arsenic, and mercury concentrations in a variety of organic fertilizers were measured using a variety of analytical techniques. Our research shows that the heavy metal content of various organic fertilizers varies significantly, underscoring the significance of strict quality control procedures in the handling of organic waste and fertilizer manufacturing. We also go over the consequences of heavy metal buildup in crops and soils, highlighting the necessity of strict laws and sustainable farming methods to reduce any potential harm to ecosystem health and food safety.
2. Studies the accuracy, evaluated by comparing the overall concentration of trace elements using various methods.
3. A study indicates that an alternate organic fertilizer was made from fly ash waste that was formed from the combustion of coal that was used to generate power. The essential micronutrients (copper, manganese, and zinc) found in organic fertilizers

were discovered to be significantly lower in concentration compared to the heavy metals (arsenic, cadmium, mercury, and lead) present in them, according to the study.

4. Organic material is crucial for soil fertility and its overall physical and biological characteristics. However, it's worth noting that some organic fertilizers may contain harmful heavy metals, posing risks to human health. Three distinct varieties of organic fertilizers were utilized to investigate heavy metal levels in the soil of Iran's province. The concentration of heavy metals in maize roots was assessed as part of the study.

5. A recent study sheds light on environmental issues that have consistently garnered significant attention from scientists. Toxic substances are a major environmental worry, presenting a significant threat to human health. The research centers on the harmful impact of heavy metals such as cadmium, lead, copper, zinc, as well as pesticides, herbicides, and fungicides. Negatively impacting both the agricultural ecosystem, including plants and soil, and human health. Additionally, diseases resulting from exposure to heavy metals and pesticides have been documented. The research offers comprehensive insights into the comprehension of environmental toxins and their harmful impacts.

#### Research Methodology:

Organic fertilizers that were used in this research are shown below:

Figures 1 and 2 are the organic fertilizers which are available in the market while Figure 3 represent the Cow dung, which has been used as the organic manure since ancient times.

**Figure 1: Hariyali Organic Fertilizer**



**Figure 2: Bagicha Organic Fertilizer**



**Figure 3: Cow dung**

Two different organic fertilizers were taken from the local market named as Hariyali Organic Fertilizer,

Biogrowth Organic Fertilizer and Bagicha Organic Fertilizer were the only organic fertilizer that was available in the market of Navi Mumbai.

Hence, we tested the presence of trace elements and heavy metals in these two fertilizers. By following 2 Methodologies or procedure as described below:

#### Methodologies:

- Sequential Extraction Procedure (Tessier's Method)
- Wet Digestion using Aqua Regia (HCl:HNO<sub>3</sub>, 3:1 ratio)
- Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) at IIT Bombay

Heavy metals analyzed: Chromium (Cr), Lead (Pb), Copper (Cu), Nickel (Ni), and Potassium (K).

The Sequence extraction procedure is the method that is used for the extraction of heavy metals from organic fertilizers. Tissier's method was opted for the analysis purpose

#### 1. Tissier's method is as follows:

- 1 g of dried fertilizer of the original sample were used for the initial extraction purpose, as shown in below figure number 5.



Figure 4: Samples kept for drying



Figure 5: Weighing 1 gram fertilizer

- Then 8 ml of 1N MgCl<sub>2</sub> ( pH = 7 ) was added and shaken using a shaker for the duration of 1 hour at 25°C.
- After that 8 ml of 1N CH<sub>3</sub>COONa was added and shaken for 5 hours the pH was maintained at 5 and the temperature was kept at 25 °C

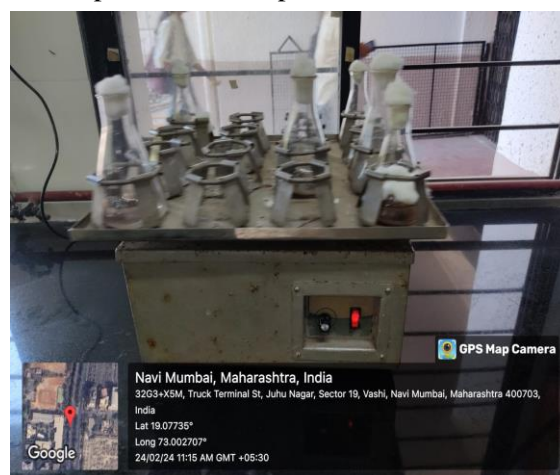


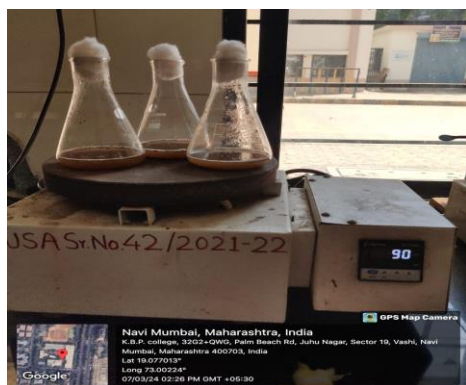
Figure 6: Kept on shaker



Figure 7: On magnetic stirrer with intermittent heating

20 ml 0.04N NH<sub>2</sub>OH-HCL (Dissolved in 25% CH<sub>3</sub>COOH) was intermittently shaken at 90°C for 6 hours

Figure 8: Hot Plate



## 2. The Wet digestion method:

- Then aqua regia (HCl: HNO<sub>3</sub>) (with ratio 3:1) was prepared and washed with 5 ml to the 4-sample prepared and washing was repeated 3 times to each sample altogether 15 ml. And kept on a hot plate at a temperature of 90°C till the solution almost got reduced to its one-fourth and the container was packed.
- This process almost took 15 days to dry up the solution.

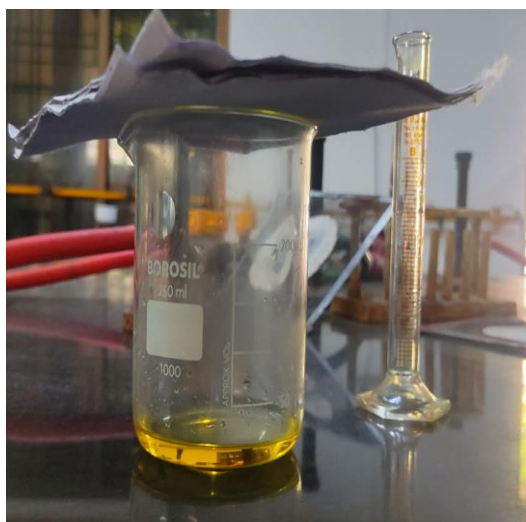


Figure 9: Aqua Regia 3:1

- Once the solution from 40 ml reduced down to its one-fourth i.e, to 10 ml and then 0.5M nitric acid 20 ml each to the sample was added, the mixture was then boiled on burner, and filtered with Whatman filter paper no 41.

## Figure 10: Boiling

Samples were further stored and sent for analysis to Indian Institute of Technology Bombay, Centre for research in Nano Technology and Science.



Figure 11: IIT Bombay, Centre for research in Nano Technology and Science

**Result and Discussion :**

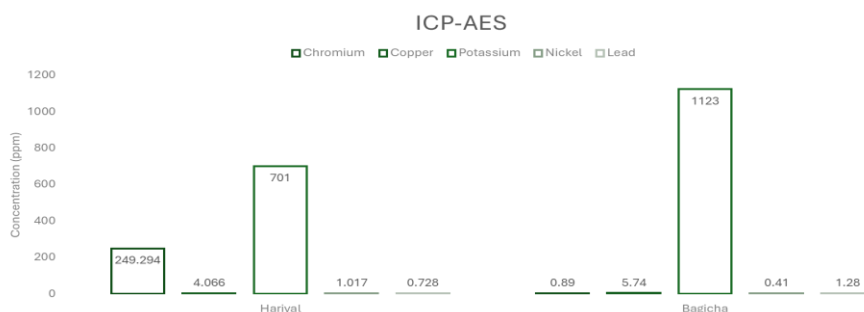
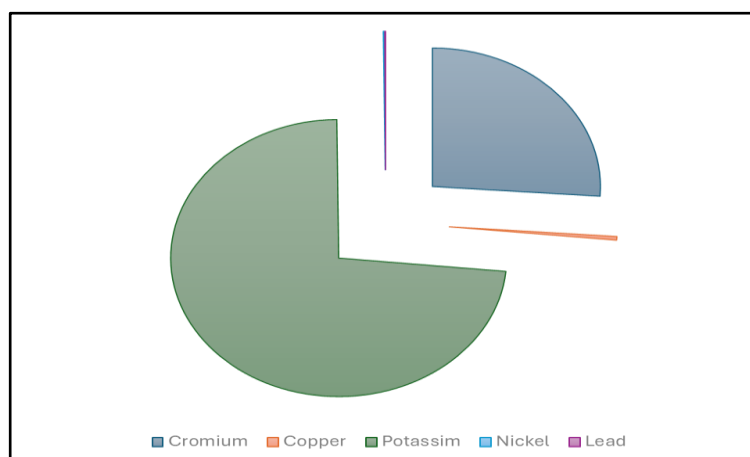
Inductive Coupled Plasma Atomic Spectroscopy (ICP-AES) was employed to detect the presence of Chromium, Copper, Potassium, Nickel and Lead.

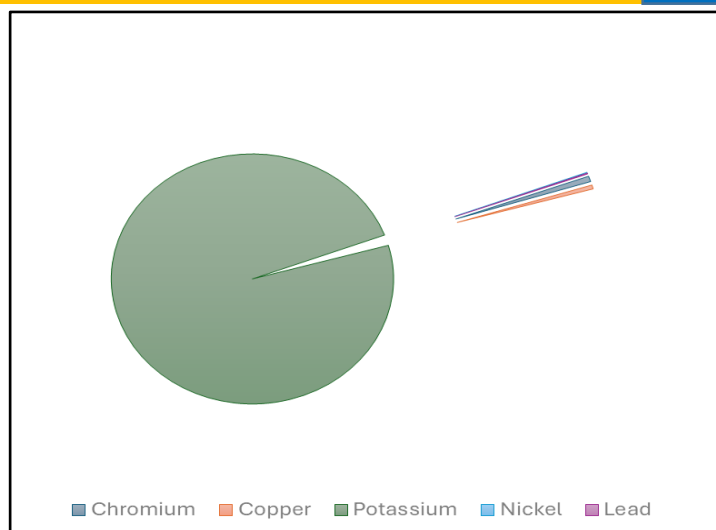
**Table 1: ICP-AES data**

Sample	Chromium (ppm)	Copper (ppm)	Potassium (ppm)	Nickel (ppm)	Lead (ppm)
Hariyali	>249.294	4.066	>701.682	1.017	0.728
Bagicha	0.89	5.74	>1123.47	0.41	1.298
Cow dung	0.394	1.3	57.447	0.403	0.103
Biogrowth Organic Fertilizer	2.508	4.633	>402.998	2.68	0.654

ICP-AES, a popular instrument in environmental labs, is highly efficient in analyzing metals in large sample sizes. With its high throughput capacity, ICP spectrometers can generate multiple reportable results per run. This method is suitable for almost every element, except halogens and inert gases, and is particularly useful for refractory elements such as Silicon, Aluminium, and Barium, which are difficult to analyze by flame Atomic Absorption.

The data in the table above was obtained by analyzing a solution sample that was prepared in the lab using a Single Extraction Process and then underwent wet digestion with nitric acid for digestion purposes.


**Figure 12: Inductive Coupled Plasma Atomic Spectroscopy (ICP-AES)**

**Figure 13: Inductive Coupled Plasma atomic Spectroscopy (ICP-AES) for Hariyali Organic Fertilizer**



**Figure 14: Inductive Coupled Plasma atomic Spectroscopy (ICP-AES) for Bagicha Organic Fertilizer Analysis :**

Natural and organic fertilizer samples were collected from Uran Taluka of Raigad, Navi Mumbai , Maharashtra are collected for two consecutive seasons from December 2023 to April 2024 and Have been analyzed by ICP-AES for estimating the concentration of hazardous elements and their levels of concentration.

**Table No.2 Seasonal Variation of Heavy Metal Analysis of sample collected in December2023 by ICP-AES method.**

Sample Code	Location	Cr	Pb	Cu	Ni	K	WHO/EPA Limit
W1	Uran	249.3	0.728	4.06	1.02	701.7	0.5 mg/L
W2	Uran	0.89	1.298	5.74	0.41	0.41	0.5 mg/L

In the study area, In the month of December 2023, amongst the various types of fertilizer samples collected, the concentration of Chromium ranges from 0.89 ppm to 249.3 ppm. The highest concentration of Chromium (Cr) 249.3 ppm, is found in Hariyali Fertilizer samples (W1) while the lowest Chromium concentration 0.89 ppm is found in Bagicha fertilizer samples (w2) collected in Uran. (Table 2).

The maximum permissible range for Chromium in Fertilizer /groundwater is 0.05 mg/l[R ] Therefore, the agriculture area may be adversely impacted by local environment and processing activities with respect to Chromium. Hence proper care has to be taken with respect to chromium.

Similar explanation for other 4 elements.in two different seasons.

**Table No.3 Seasonal Variation of Heavy Metal Analysis of sample collected in April 2024 by ICP-AES method.**

Sample code	Location	Cr	Pb	Cu	Ni	K	WHO/EPA limit
W3	Uran	0.39	0.10	1.3	0.4	57.4	
W4	Uran	2.51	0.65	4.6	2.7	403	

In April 2024, comparatively lower concentrations of Chromium were observed in W3 (cow dung), indicating safer levels. However, W4 (biogrowth fertilizer) showed elevated levels of Nickel and Lead, which may pose long-term risks to soil and crop health. Seasonal variation indicates that environmental factors and raw material differences affect metal concentration.

**Table No.4 :Permissible limit as per WHO/EPA/BIS standards for heavy metals in fertilizer samples .**

Sr. No	Heavy metal(s)	Permissible Limits		BIS/IS
		WHO	EPA	
1	Chromium (Cr)	0.1	100 mg/L	0.05
2	Lead (Pb)	0.01	50 ppb	0.01
3	Copper (Cu)	0.05	1.3	0.05,1.5
4	Nickel (Ni)	0.02	0.01	0.02

The table No 4 presents the permissible limits for heavy metals as recommended by international and national regulatory bodies such as WHO, EPA, and BIS. Comparing experimental values with these standards helps determine whether fertilizer samples are safe for agricultural use. Several observed values in this study exceed these limits, highlighting the need for strict monitoring and regulation.

**W3 (cow dung fertilizer)** has the lowest heavy metal content and is the safest for soil and crops. **W2 shows moderate contamination** with high lead levels, while **W4 has elevated nickel and lead, posing potential risks**. **W1 (Hariyali fertilizer) is the most contaminated** due to extremely high chromium levels, making it unsafe for use without treatment.

#### Risks to Human Health Due To These Metals :

The ICP-AES analysis reveals that it contains elevated levels of Chromium in certain samples, significantly exceeding permissible limits (0.05 mg/L as per standards). Hexavalent chromium, also known as Chromium (VI), cause harm to the body as it is hemotoxic, genotoxic, and carcinogenic.[7] When this compound enters the bloodstream, it triggers oxidation

reactions that can damage blood cells, leading to hemolysis, and eventually, liver and kidney failure. Dialysis is a common treatment for patients suffering from this condition.[8]

Seasonal variations showed fluctuations in heavy metal concentrations.

### Public Health Implications:

**Chromium (VI):** Carcinogenic, hemotoxic, genotoxic

**Lead (Pb):** Linked to intellectual disability, cardiovascular disease, and kidney disorders

**Nickel (Ni):** Carcinogenic in chronic exposure cases

**Copper (Cu):** Associated with Wilson’s Disease when dysregulated

However, the average daily exposure to nickel does not threaten human health. Most of the nickel absorbed by the body is eliminated through the gastrointestinal tract without being absorbed or passed out of the body through urine by the kidneys. Although nickel is not a cumulative poison, chronic inhalation exposure or larger doses may be toxic and even carcinogenic, posing an occupational hazard.[10]

According to the World Health Organization’s 2021 update of the Public health impact of chemicals: knowns and unknowns estimates that nearly half of the 2 million lives lost to known chemicals exposure in 2019 were due to exposure to lead. Lead exposure is estimated to account for 21.7 million years lost to disability and death (disability-adjusted life years, or DALYs) worldwide due to long-term effects on health, including 30% of the global burden of idiopathic intellectual disability, 4.6% of the global burden of cardiovascular disease and 3% of the global burden of chronic kidney diseases. [11]

### Role for Sustainable Healthcare:

Sustainable healthcare depends on more than just hospitals—it requires a strong connection between research, education, and industry.

**Research** helps us understand and detect environmental risks like heavy metals at an early stage. It provides the scientific evidence needed to create policies, set safety limits, and monitor changes over time, ultimately helping prevent diseases before they occur.

**Education** builds awareness and skills. By teaching students and informing farmers and communities about environmental health, it promotes safer agricultural practices and reduces exposure to harmful contaminants. It also encourages collaboration across different fields for better solutions.

**Enterprise and industry** play a key role in preventing pollution at its source. By maintaining strict quality control, following safety standards, and using cleaner technologies, industries can reduce harmful contamination and protect both the environment and public health.

### Conclusion:

In the study area, in the month of **December 2023**, amongst the various types of fertilizer samples collected, the concentration of Chromium ranges from **0.89 ppm to 249.3 ppm**. Out of the total samples, only a small proportion of fertilizer samples belong to the permissible level of **< 0.05 ppm**, while the majority of samples are above the permissible level of Chromium concentration. The highest concentration of Chromium (**249.3 ppm**) is found in **Hariyali fertilizer sample (W1)**, while the lowest concentration (**0.89 ppm**) is found in **Bagicha fertilizer sample (W2)**.

In the month of **April 2024**, the concentration of Chromium ranges from **0.39 ppm to 2.51 ppm**. The highest concentration (**2.51 ppm**) is found in **Biogrowth fertilizer sample (W4)**, while the lowest concentration (**0.39 ppm**) is found in **cow dung sample (W3)**. A greater number of samples in this period fall within or closer to permissible limits compared to December, although some still exceed safe levels.

Therefore, the agricultural and soil areas of **Mumbai and Navi Mumbai (Raigad district, Maharashtra)** may be adversely affected by local environmental conditions and processing activities with respect to Chromium contamination.

Similar trends are observed for other heavy metals such as Lead, Copper, Nickel, and Potassium. Thus, the study concludes that the fertilizer samples are contaminated with heavy metals, with concentrations in several cases exceeding desirable limits. These elevated levels may have toxic effects on the natural ecosystem. The water and soil conditions also influence metal concentration, with acidity playing a role in metal availability.

When such contaminated fertilizers are used for irrigation and agriculture, they may affect crops, ecosystems, and biodiversity. Therefore, this study indicates that heavy metal contamination significantly impacts soil and water quality in and around **Uran Taluka of Raigad district**. The noticeable presence of hazardous metals in fertilizer samples highlights the need for precautions to prevent environmental and health risks.

#### References:

1. Wang, J. et al. (2022) *Speciation analysis method of heavy metals in organic fertilizers: A Review*, MDPI. Available at: <https://doi.org/10.3390/su142416789>
2. Tessler, A. *Sequential extraction procedure for the speciation of Particulate Trace Metals*
3. *Analytical Chemistry*. Available at: <https://pubs.acs.org/doi/10.1021/ac50043a017>
4. Utami, S. W., Tarigan, R. A. P., & Widianingsih, B. (2019). *Characterization of Micronutrients and Heavy Metal Content in Organic Fertilizer Made From Fly Ash and Organic Waste*. *JOURNAL OF TROPICAL SOILS*, 24(1), 11. <https://doi.org/10.5400/jts.2019.v24i1.11-16>
5. Zhou, H., Shen, Y., Li, R., Meng, H., Zhang, X., Wang, J., Cheng, H., Dong, S., Song, L., Ding, J., & Cheng, Q. (2020). *Heavy metals and community structure of microorganism changes during livestock manure composting with inoculation of effective microorganisms*. *International Journal of Agricultural and Biological Engineering*, 13(6), 125–132. <https://doi.org/10.25165/j.ijabe.20201306.5674>
6. Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M.-Q. (2021). *Heavy Metals and Pesticides Toxicity in Agricultural Soil and Plants: Ecological Risks and Human Health Implications*. *Toxics*, 9(3), 42. <https://doi.org/10.3390/toxics9030042>
7. Yari, M., Rahimi, G., Ebrahimi, E., Sadeghi, S., Fallah, M., & Ghesmatpoor, E. (2016). *Effect of Three Types of Organic Fertilizers on the Heavy Metals Transfer Factor and Maize Biomass*. *Waste and Biomass Valorization*, 8(8), 2681–2691. <https://doi.org/10.1007/s12649-016-9719-6> doi:10.1081/CLT-100102418
8. Barceloux DG, Barceloux D (1999). "Copper". *Journal of Toxicology: Clinical Toxicology*. 37 (2): 217–230. doi:10.1081/CLT-100102421.
9. Buttice, Claudio (2015). "Nickel Compounds". In Colditz, Graham A. (ed.). *The SAGE Encyclopedia of Cancer and Society (Second ed.)*. Thousand Oaks: SAGE Publications, Inc. pp. 828–831. ISBN 9781483345734.
10. World Health Organization. (2016, May 23). *The public health impact of chemicals: knowns and unknowns*.
11. Retrieved from [www.who.int/publications/i/item/WHO-FWC-PHE-EPE-16-01](http://www.who.int/publications/i/item/WHO-FWC-PHE-EPE-16-01)

**Cite This Article:** Asst Prof. Gupta A. & Mr. Jha G. (2026). *From Soil Safety to Public Health: Research and Enterprise in Sustainable Healthcare Through Heavy Metal Monitoring*. In **Aarhat Multidisciplinary International Education Research Journal**: Vol. XV (Number II, pp. 101–110) Doi: <https://doi.org/10.5281/zenodo.20321601>