



Comparative Evaluation of Compost Amendments for Heavy Metal Reduction in Polluted Soil Using Fenugreek (*Trigonella foenum-graecum*)

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KEYWORDS

Heavy Metal Reduction, pollution, soil fertility, Fenugreek.

ABSTRACT:

Heavy metal contamination of agricultural soil due to industrial and urban activities poses a serious threat to crop safety and environmental sustainability. The present study investigates the effectiveness of different compost amendments in reducing heavy metal content in polluted soil cultivated with fenugreek (*Trigonella foenum-graecum*). Fenugreek was grown in polluted soil amended with vermicompost, NPK fertilizer, and municipal compost prepared by Indore Municipal Corporation, along with an untreated polluted soil control and an organically cultivated reference soil. Heavy metal concentrations in soil and plant tissues were analysed to evaluate the remediation potential of each treatment. Results demonstrated that compost-amended soils exhibited significantly lower heavy metal availability compared to untreated polluted soil. Among the treatments, vermicompost and municipal compost were more effective in reducing metal accumulation than inorganic fertilizer. The study highlights the potential of compost-assisted cultivation of fenugreek as an eco-friendly and sustainable approach for mitigating heavy metal contamination in polluted agricultural soils.

1. Introduction

Heavy metal pollution of agricultural soils has emerged as a critical environmental issue due to rapid industrialization, urban waste disposal, and the use of contaminated irrigation water. Unlike many organic pollutants, heavy metals are persistent, non-biodegradable, and tend to accumulate in soil and plant systems, thereby entering the food chain and posing serious risks to human health. Consumption of crops grown in contaminated soils may lead to chronic toxicity, metabolic disorders, and increased risk of various diseases.

Cultivation of food crops in polluted soil necessitates the development of sustainable strategies to reduce heavy metal availability without compromising soil fertility. Among various remediation approaches, the use of organic soil amendments has gained attention due to their ability to improve soil physicochemical properties and immobilize heavy metals. Compost and vermicompost enhance organic matter content, microbial activity, and cation exchange capacity, which collectively influence metal mobility and uptake by plants. In contrast, prolonged application of inorganic fertilizers may contribute to further soil degradation and metal accumulation.

Fenugreek (*Trigonella foenum-graecum*), an economically and nutritionally important legume widely cultivated in India, is commonly grown in semi-arid regions where soil contamination is increasingly reported. Its fast growth and adaptability make it a suitable crop for evaluating soil remediation strategies. Municipal compost generated from biodegradable urban waste, such as that produced by Indore Municipal Corporation, represents a sustainable resource with potential agricultural applications; however, its effectiveness in reducing heavy metal contamination in polluted soils remains insufficiently explored.

Therefore, the present study aims to comparatively evaluate the impact of vermicompost, municipal compost, and inorganic fertilizer on heavy metal reduction in polluted soil cultivated with fenugreek. The findings of this study contribute to understanding the role of compost-based soil amendments in sustainable management of heavy metal-contaminated agricultural lands.

Keywords- Heavy metal contamination, Polluted agricultural soil, Compost amendments, Vermicompost, Municipal compost, Fenugreek (*Trigonella foenum-graecum*).



2. Aim and Objective

Aim

To evaluate the effectiveness of different compost amendments in reducing heavy metal contamination in polluted agricultural soil cultivated with fenugreek (*Trigonella foenum-graecum*).

Objectives

- To assess the initial heavy metal status of polluted and organic soils prior to fenugreek cultivation.
- To study the effect of vermicompost, municipal compost, and NPK fertilizer on heavy metal levels in polluted soil after crop growth.
- To compare heavy metal accumulation in fenugreek leaves and seeds grown under different soil treatments.
- To evaluate the relative efficiency of organic compost amendments versus inorganic fertilizer in minimizing heavy metal uptake by fenugreek.
- To identify a sustainable soil amendment strategy for managing heavy metal-contaminated agricultural land.

3. Material & Method

Plant: *Trigonella foenum-graecum* (fenugreek).

Field: This study has been done in 3 fields of M.R. 10 region of Indore city out of which, one is control and two test fields. Control field was organic and test field was polluted.

Organic fertilizer: Vermi-compost and compost prepared by Municipal Corporation of Indore city has been used.

Inorganic fertilizer: N.P.K. (10:26:26).

Seed material: For the present study, Seeds have been collected from the Jaivik Setu 66 bicholi-mardana, bypass Indore M.P.

Crop duration: 20-25 day for leaves and 90-100days for grains. In this study the entire tests have been done in leaves and heavy metal analysis has been done in seeds.

4. Result and Discussion

Heavy Metal Analysis

Heavy metal concentrations in soil and fenugreek (*Trigonella foenum-graecum*) plant samples were determined using Atomic Absorption Spectroscopy (AAS). The analysis was carried out at the Pollution Control Board (PCB), Indore, Madhya Pradesh, using an ELICO SL-176 Atomic Absorption Spectrophotometer, following standard analytical protocols.

Soil samples were air-dried at room temperature, homogenized, and sieved to obtain uniform particle size. Plant samples were thoroughly washed with distilled water to remove surface contaminants and then oven-dried to constant weight. The dried samples were finely powdered prior to analysis. For heavy metal estimation, accurately weighed samples were subjected to acid digestion using appropriate concentrated acids until a clear solution was obtained. The digested samples were filtered and diluted to a known volume with deionized water.

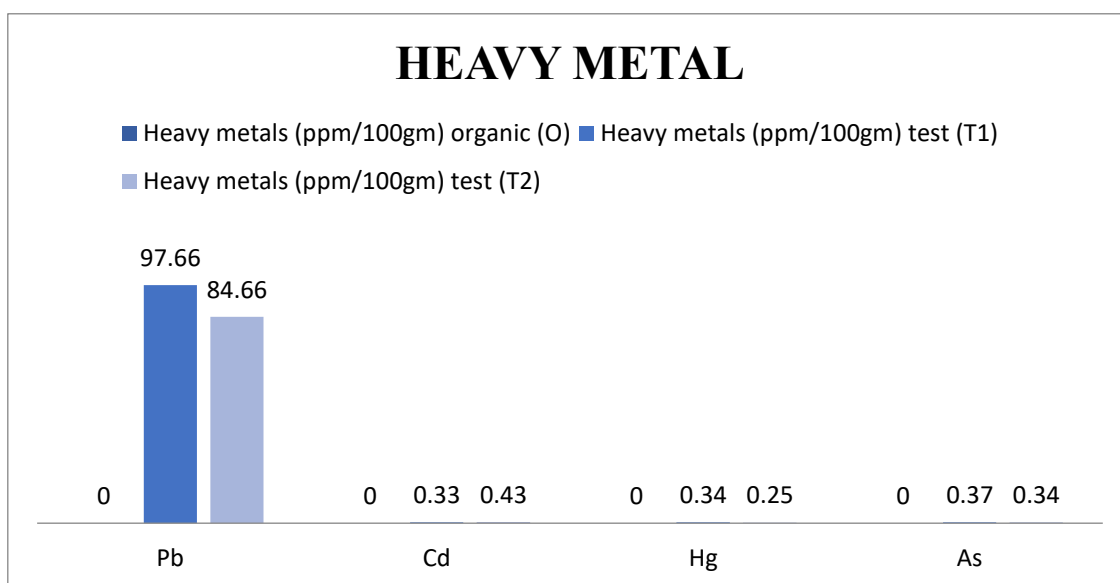
Calibration of the instrument was performed using certified standard solutions for each metal. Blank samples were run simultaneously to ensure accuracy and eliminate background interference. Heavy metal concentrations were quantified by measuring absorbance at metal-specific wavelengths under optimized operating conditions of the AAS instrument. The results were expressed as mg kg⁻¹ dry weight of soil and plant samples.

Quality control measures, including replicate analysis and standard reference checks, were followed to ensure precision and reliability of the data. The obtained values were used to compare heavy metal levels among different soil treatments and to assess the effectiveness of compost amendments in reducing metal accumulation in polluted soil.

Table 1. Showing soil analysis before growing fenugreek (Jan-2021)



Parameters	Heavy Metals	Normal range	Polluted field T1	Polluted field T2	Organic field
Heavy Metals (ppm/100gm)	Lead	0	97.66	84.66	ND
	Cadmium	0	0.33	0.43	ND
	Mercury	0	0.34	0.25	ND
	Arsenic	0	0.37	0.34	ND



Graph 1. Heavy metal content of different soil samples before growing plants

Table 2. Showing soil analysis after growing plant

Parameters	Heavy Metals	Normal range	Polluted field 1	Polluted field 2	Organic field
Heavy Metals (ppm/100gm)	Lead	0	VC- 60.20 IMC-60.00 NPK-70.25 W.F -90.21	VC- 65.21 IMC-60.20 NPK-72.21 W.F -80.22	ND
	Cadmium	0	VC- 0.32 IMC-0.30 NPK-0.32 W.F -0.32	VC- 0.40 IMC-0.39 NPK-0.41 W.F -0.42	ND
	Mercury	0	VC- 0.32 IMC-0.33 NPK-0.34 W.F -0.34	VC- 0.22 IMC-0.21 NPK-0.23 W.F -0.22	ND
	Arsenic	0	VC- 0.32 IMC-0.32 NPK-0.31	VC- 0.31 IMC-0.33 NPK-0.32	ND



Parameters	Heavy Metals	Normal range	Polluted field 1	Polluted field 2	Organic field
			W.F -0.30	W.F -0.34	

VC- Vermicompost

IMC- compost of Indore city

NPK- nitrogen-phosphorus- potash

W.F- without fertilizer

Effect of Treatment on Heavy Metal Content (Leaves) of *Trigonella Foenum-Graecum*

In the control group, the **Heavy metal Content** was 0.00; however, heavy metal was found in all other samples. Polluted field (T1) - treatment 1 with Vermicompost exhibited increase in **Heavy metal Content** i.e.2.16 ($p \leq 0.05$) (Table 3). Treatment 2 with Compost of IMC, treatment 3 with N.P.K. and treatment 4 without any other fertilizer showed increase in **Heavy metal Content**

i.e.2.66 ($p < 0.05$), 3.15 ($p < 0.05$) and 5.3 ($p < 0.05$), respectively. Polluted field (T2) - treatment 1 with Vermicompost exhibited increase in **Heavy metal Content** i.e. 1.56 ($p \geq 0.05$) (Table 1). Similarly, treatment 2 with Compost of IMC, treatment 3 with N.P.K. and treatment 4 without any other fertilizer showed percentage increase in **Heavy metal Content** i.e. 2.00 ($p \geq 0.05$), 2.35 ($p < 0.05$) and 5.1 ($p < 0.05$), respectively.

Table 3. Effect of different treatment on Heavy metal Content (leaves) of *Trigonella foenum-graecum*

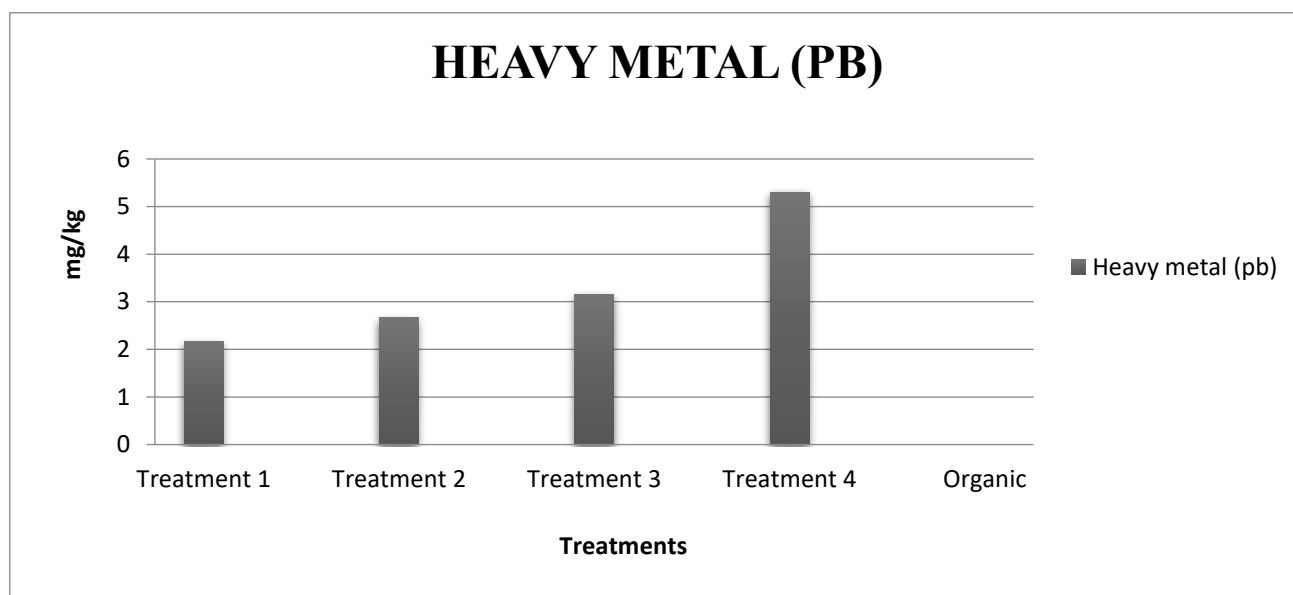
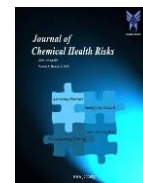
S.NO.	Different treatments	Heavy metal	% Change	p-value
Organic field (control)	Organic field	0	0	0
Polluted field (T1)	Vermicompost (Treatment 1)	2.16±0.28	Nil	0.0002
	Compost by IMC (Treatment 2)	2.66±0.28	Nil	0.0008
	N.P.K. (Treatment 3)	3.15±0.13	Nil	0.0002
	Without Fertilizer (Treatment 4)	5.3±0.17	Nil	0.0007
Polluted field (T2)	Vermicompost (Treatment 1)	1.56±0.05	Nil	0.00012
	Compost by IMC (Treatment 2)	2±0.10	Nil	0.25
	N.P.K. (Treatment 3)	2.35±0.30	Nil	0.00018
	Without Fertilizer (Treatment 4)	5.1±0.1	Nil	0.0009

Values expressed are means ± standard deviation.

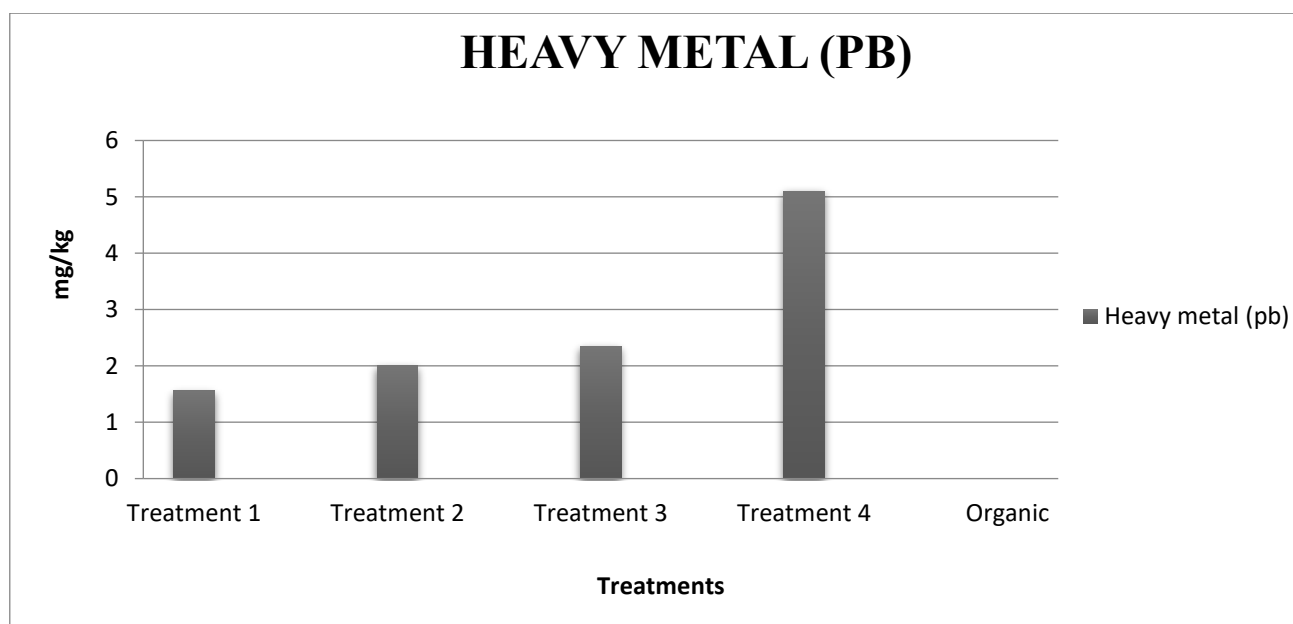
*Indicates $p < 0.05$ and is significant.

NS Indicates $p > 0.05$ and is not significant.

↑ ↓ Indicates percent increase and decrease as compared to control.



Graph 2: Effect of different treatments on Heavy metal content (Leaves) of *Trigonella foenum-graecum* (polluted field T1)

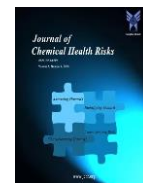


Graph 3: Effect of different treatments on Heavy metal content (Leaves) of *Trigonella foenum-graecum* (polluted field T2)

Effect of Treatment on Heavy Metal Content (Seeds) of *Trigonella Foenum-Graecum*

In the control group, the **Heavy metal Content** was 0.00, also heavy metal was found 0.00 in vermicompost and compost of IMC of the polluted fields. Polluted field (T1) - treatment 3 with N.P.K. and treatment 4 without any

other fertilizer showed increase in **Heavy metal Content** i.e.1.33 ($p<0.05$) and 2.20 ($p<0.05$) respectively. Polluted field (T2)- treatment 3 with N.P.K. and treatment 4 without any other fertilizer showed percentage increase in **Heavy metal Content** i.e.1.24 ($p<0.05$) and 1.51($p<0.05$) respectively.

**Table 4.** Effect of different treatment on Heavy metal Content (Seeds) of *Trigonella foenum-graecum*

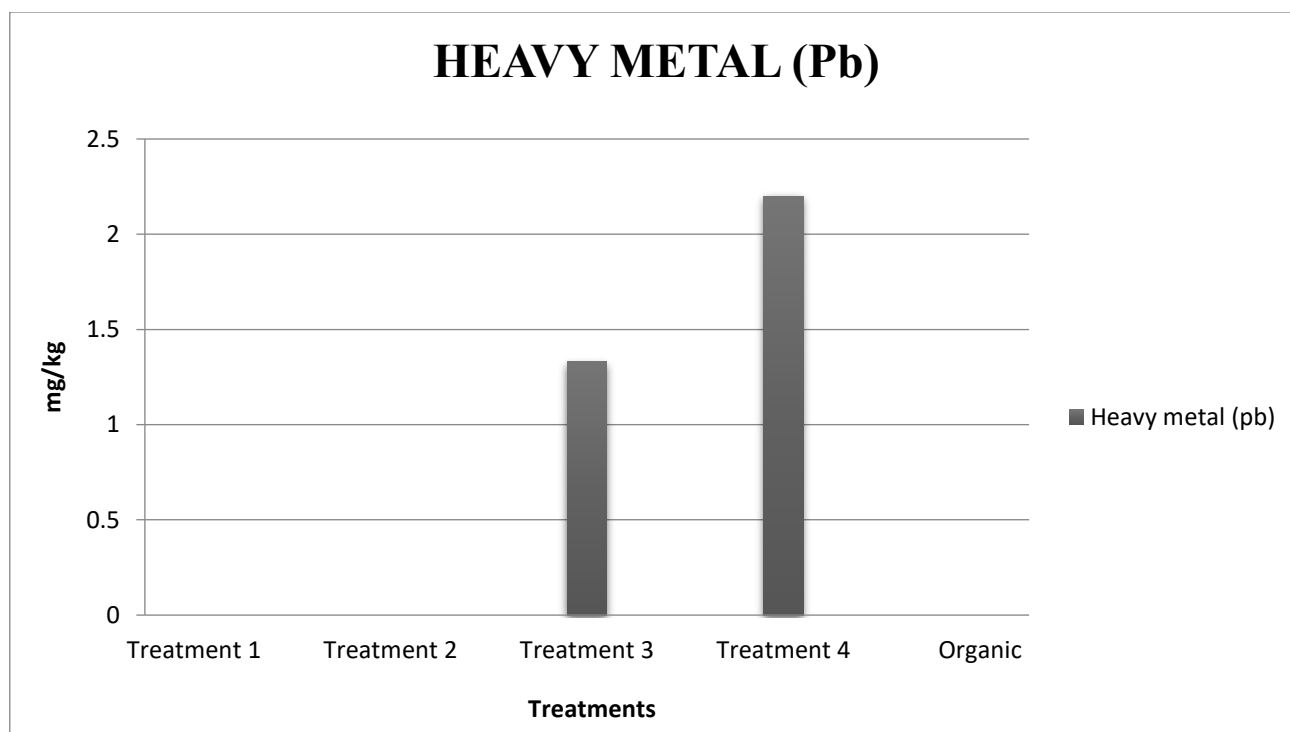
S.NO.	Different treatments	Heavy metal	% Change	p-value
Organic field (control)	Organic field	0	0	0.00
Polluted field (T1)	Vermicompost (Treatment 1)	0	Nil	0.00
	Compost by IMC (Treatment 2)	0	Nil	0.00
	N.P.K. (Treatment 3)	1.33±0.28	Nil	0.0013
	Without Fertilizer (Treatment 4)	2.2±0.26	Nil	0.0001
Polluted field (T2)	Vermicompost (Treatment 1)	0	Nil	0.00
	Compost by IMC (Treatment 2)	0	Nil	0.00
	N.P.K. (Treatment 3)	1.24±0.27	1.24↑	0.001
	Without Fertilizer (Treatment 4)	1.51±0.02	1.5↑	0.0003

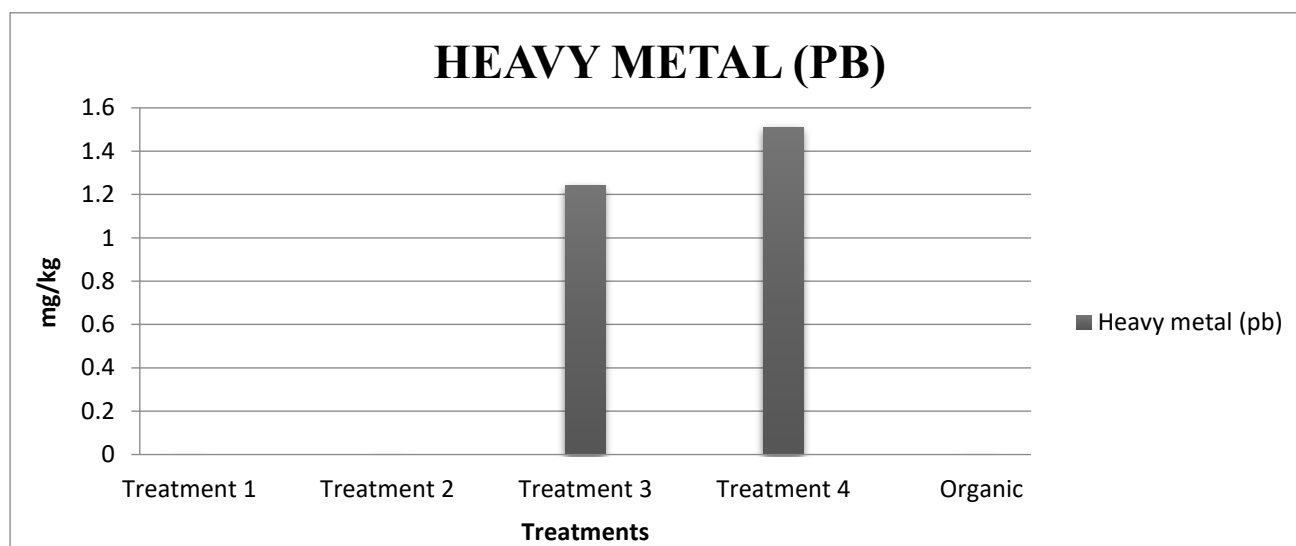
Values expressed are means ± standard deviation.

*Indicates $p < 0.05$ and is significant.

^{NS} Indicates $p > 0.05$ and is not significant.

^{↑↓} Indicates percent increase and decrease as compared to control.

**Graph 4:** Effect of different treatments on Heavy metal content (Seeds) of *Trigonella foenum-graecum* (polluted field T1)



Graph 5. Effect of different treatments on Heavy metal content (Seeds) of *Trigonella foenum-graecum* (polluted field T2)

5. Conclusion

The present study demonstrates that heavy metal contamination in polluted agricultural soils can be effectively reduced through the application of organic compost amendments. Fenugreek cultivated in polluted soils amended with vermicompost and municipal compost prepared by Indore Municipal Corporation exhibited a marked reduction in heavy metal availability in soil as well as significantly lower metal accumulation in plant tissues when compared to untreated polluted soil and NPK-fertilized plots. In contrast, inorganic fertilizer application showed comparatively higher heavy metal retention in both soil and crop samples. The findings indicate that organic amendments enhance soil quality and play a crucial role in immobilizing heavy metals, thereby limiting their uptake by fenugreek. Vermicompost and municipal compost proved to be safer and more sustainable alternatives to inorganic fertilizers for cultivation in contaminated soils. This study highlights the potential of compost-assisted cultivation of fenugreek as an eco-friendly and practical approach for mitigating heavy metal pollution in agricultural systems, contributing to safer crop production and sustainable soil management.

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