



## Impact of limestone mining refuse on the community structure and biomass of soil macro-invertebrates (Earthworms) in Baloda bazar district, Chhattisgarh, India

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### Abstract

Baloda Bazar-Bhatapara district of Chhattisgarh is a major limestone-producing and cement-industrial region. The district administration identifies limestone as its principal major mineral and records numerous limestone mines and storage points, while Indian Bureau of Mines records document large limestone leases in the district. The present investigation evaluated the response of soil earthworm communities to limestone-mining refuse along a four-site impact gradient during July 2025-June 2026. Four sites were selected: S1, an agricultural control; S2, a refuse-dumping site adjacent to limestone waste; S3, a mining periphery; and S4, a three-year reclaimed site. Earthworms were sampled using  $50 \times 50 \times 30$  cm soil quadrats, hand sorting and supplementary chemical expulsion. Soil pH, electrical conductivity, organic carbon, moisture, calcium and bulk density were measured. Eleven earthworm species were reported at S1, three at S2, six at S3 and eight at S4. Annual mean density declined from 142.6 individuals  $m^{-2}$  at S1 to 18.4 individuals  $m^{-2}$  at S2, while biomass declined from 48.32 to 5.12 g  $m^{-2}$ , corresponding to reductions of 87.1% and 89.4%. S2 had the highest pH (8.92), EC (1.42 dS  $m^{-1}$ ), calcium (18.42 mg  $g^{-1}$ ) and bulk density (1.72 g  $cm^{-3}$ ), and the lowest organic carbon (0.21%) and moisture (6.12%). The reclaimed site showed partial recovery, reaching 66.5% of control density and 61.0% of control biomass. Site-level correlations were strongly positive for organic carbon and moisture and negative for pH and calcium, but these relationships are exploratory because only four site means were available. The study indicates that limestone refuse is associated with substantial simplification of earthworm communities and reduced biomass, while reclamation can support partial biological recovery.

**Keywords:** Limestone mining, mining refuse, earthworms, soil macro-invertebrates, biomass, soil quality, Baloda Bazar, reclamation, bioindicator

### Introduction

Limestone is the principal major mineral of Baloda Bazar district. Official district information identifies limestone deposits in Simga and Baloda Bazar tehsils and notes major cement facilities associated with Hirmi, Rawan, Sonadih and Risda. The district mining-resource page reports 26 cement-grade limestone mines, including 12 reported as running, in addition to numerous lower-grade limestone mines and storage points. These records establish the strong industrial and mining context of the study area.

Open-cast limestone extraction can disturb soil by removing topsoil, exposing subsoil, generating overburden and refuse, depositing mineral dust, compacting soil through machinery traffic and changing surface drainage. These processes can influence the physical habitat and resource base of soil organisms. Fine carbonate-rich material may increase soil alkalinity, while compaction can reduce pore space and infiltration. Loss of vegetation and litter input can further decrease soil organic matter and moisture.

Earthworms are major soil macro-invertebrates and important ecosystem engineers. Their burrowing, casting and feeding activities contribute to soil aggregation, aeration, infiltration and decomposition. Indian earthworm taxonomy has been documented extensively by the Zoological Survey of India, including the major monograph by Julka. Because earthworms respond to soil moisture, organic matter, pH, structure and contamination, community-level changes can provide an integrated indication of soil habitat condition.

A mining-impact gradient provides a useful framework for separating the effects of disturbance from background

variation. A control agricultural site represents comparatively undisturbed soil, while a refuse dump represents maximum local disturbance. A mining periphery represents intermediate influence, and a reclaimed dump provides an opportunity to examine recovery. The present study uses this gradient to compare richness, density, biomass and diversity and to examine their relationships with selected soil variables.

The main hypothesis was that limestone refuse would be associated with lower earthworm richness, density and biomass because of increased alkalinity, compaction, reduced moisture and lower organic carbon. A secondary hypothesis was that reclamation through plantation and organic-matter addition would result in partial recovery of earthworm community structure.

### Objectives

- To document earthworm species richness and community composition across control, mining-affected and reclaimed sites.
- To compare annual mean earthworm density, biomass and diversity.
- To describe seasonal variation using the available observations without fabricating missing monthly values.
- To examine relationships between earthworm abundance and soil pH, EC, organic carbon, moisture, calcium and bulk density.
- To assess the biological response of the reclaimed site and recommend practical restoration measures.

## Study Area

The study was conducted in Baloda Bazar-Bhatapara district, Chhattisgarh, India. Four sites were selected to represent a mining-impact gradient. S1-Control (Kargil, Baloda Bazar) was described as an agricultural field approximately 5 km from mining influence, with no visible dust deposition. S2-Dumping (Rawan) was adjacent to a limestone refuse dump within approximately 0-100 m, with visible limestone dust and sparse vegetation. S3-Mining Periphery (Hirmi) was situated approximately 100-500 m from an active mine and showed moderate dust deposition. S4-Reclaimed (Khapradih) represented an old dump reclaimed approximately three years earlier using plantation and organic-matter addition. The district's official natural-resource information confirms limestone mining and cement-industry activity in these localities.

## Materials and Methods

### 1. Sampling design

Sampling was reported monthly from July 2025 to June 2026. Ten  $50 \times 50 \times 30$  cm quadrats were randomly placed at each site during each visit. The 0.25 m<sup>2</sup> quadrat area allowed conversion of counts to individuals m<sup>-2</sup>. Soil monoliths were hand-sorted, and 0.5% formalin was additionally used for chemical expulsion of deeper-burrowing individuals. TSBF-style soil macrofauna sampling commonly uses soil monoliths to approximately 30 cm depth and manual sorting. For future work, chemical handling should be documented carefully because formalin is hazardous.

### 2. Earthworm processing and identification

Earthworms were washed, counted and weighed live for wet biomass estimation and then preserved for identification.

Identification was based on Indian taxonomic literature, especially Julka's Fauna of India treatment. For publication-quality verification, each species should be linked to a voucher specimen, diagnostic photograph and, where possible, an institutional accession number.

### 3. Soil analysis

Soil was collected from 0-30 cm depth. pH and EC were measured with digital meters; organic carbon was estimated by the Walkley-Black method; moisture was determined gravimetrically; calcium was measured by EDTA titration; and bulk density was included as an index of compaction. Heavy metals were reportedly analyzed by AAS, but numerical metal data were not supplied in the present dataset. Therefore, the Results section does not make quantitative heavy-metal claims.

### 4. Data analysis

Density was expressed as individuals m<sup>-2</sup> and biomass as wet mass g m<sup>-2</sup>. Shannon-Wiener diversity was calculated as  $H' = -\sum p_i \ln(p_i)$ . Relative abundance and dominance were derived from species counts. Pearson correlations were calculated descriptively among the four annual site means. Because  $n = 4$  sites, these correlations are not treated as inferential evidence of statistical significance. A final journal analysis should use replicate- or month-level observations and an appropriate repeated-measures or mixed-effects model, with effect sizes and confidence intervals.

## Results

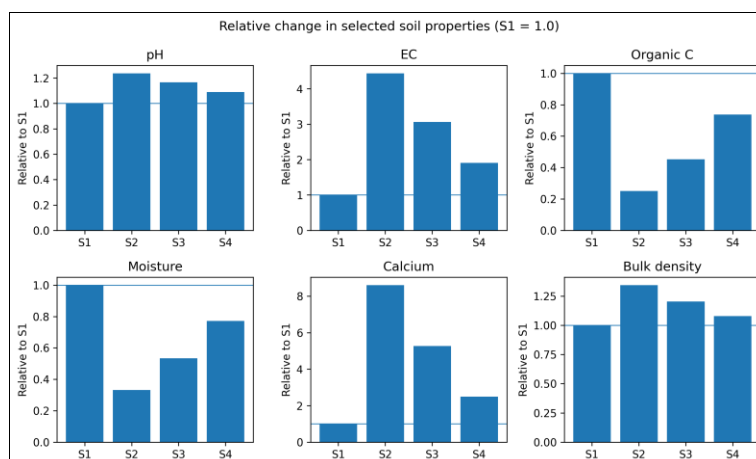
### 1. Soil physico-chemical characteristics

**Table 1:** Annual mean soil properties supplied for the four sites

| Parameter                          | S1 Control | S2 Dumping | S3 Periphery | S4 Reclaimed |
|------------------------------------|------------|------------|--------------|--------------|
| pH                                 | 7.21       | 8.92       | 8.41         | 7.86         |
| EC (dS m <sup>-1</sup> )           | 0.32       | 1.42       | 0.98         | 0.61         |
| Organic carbon (%)                 | 0.84       | 0.21       | 0.38         | 0.62         |
| Moisture (%)                       | 18.42      | 6.12       | 9.84         | 14.21        |
| Calcium (mg g <sup>-1</sup> )      | 2.14       | 18.42      | 11.26        | 5.32         |
| Bulk density (g cm <sup>-3</sup> ) | 1.28       | 1.72       | 1.54         | 1.38         |

The largest departure from the control occurred at the refuse-dumping site. pH increased from 7.21 to 8.92, EC from 0.32 to 1.42 dS m<sup>-1</sup>, and calcium from 2.14 to 18.42 mg g<sup>-1</sup>. In contrast, organic carbon declined from 0.84% to

0.21% and moisture from 18.42% to 6.12%. Bulk density increased from 1.28 to 1.72 g cm<sup>-3</sup>. S4 showed partial movement toward the control condition.



**Fig 2:** Relative change in selected soil properties; S1 = 1.0.

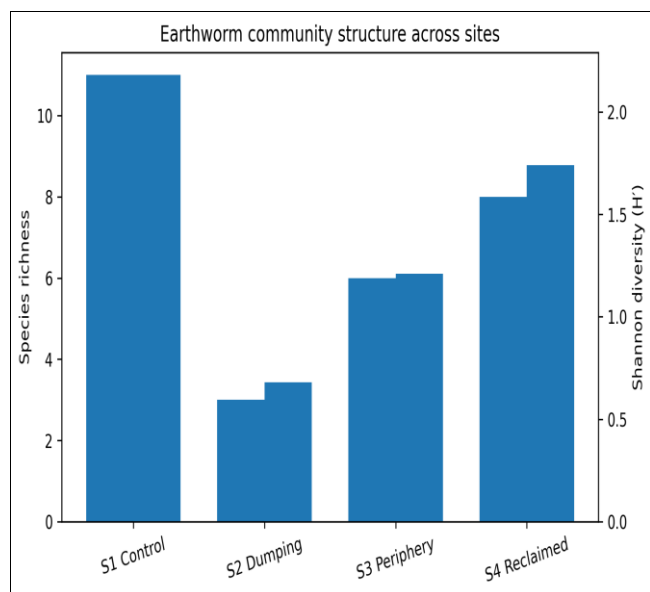
## 2. Earthworm community composition

Eleven species belonging to five families were reported from the overall study. S1 contained *Metaphire posthuma*, *Lampito mauritii*, *Perionyx excavatus*, *Eutyphoeus waltoni*, *Octochaetona surensis*, *Drawida nepalensis*, *Eisenia fetida*, *Pontoscolex corethrurus*, *Dichogaster bolau*, *Perionyx sansibaricus* and *Metaphire houlleti*. S2 contained only *Pontoscolex corethrurus*, *Metaphire posthuma* and *Dichogaster bolau*. S3 contained six species, and S4 contained eight species.

*Pontoscolex corethrurus* was reported to show approximately 72% dominance at S2. Its concentration in the disturbed site is interpreted as a pattern of tolerance or opportunistic persistence rather than proof of causation. Likewise, the absence of *Lampito mauritii* and *Perionyx excavatus* at S2 is consistent with sensitivity to the altered habitat, but formal bioindicator designation requires replicated occupancy and abundance data.

**Table 2:** Earthworm community metrics

| Site         | Species richness | Shannon H' |
|--------------|------------------|------------|
| S1 Control   | 11               | 2.18       |
| S2 Dumping   | 3                | 0.68       |
| S3 Periphery | 6                | 1.21       |
| S4 Reclaimed | 8                | 1.74       |



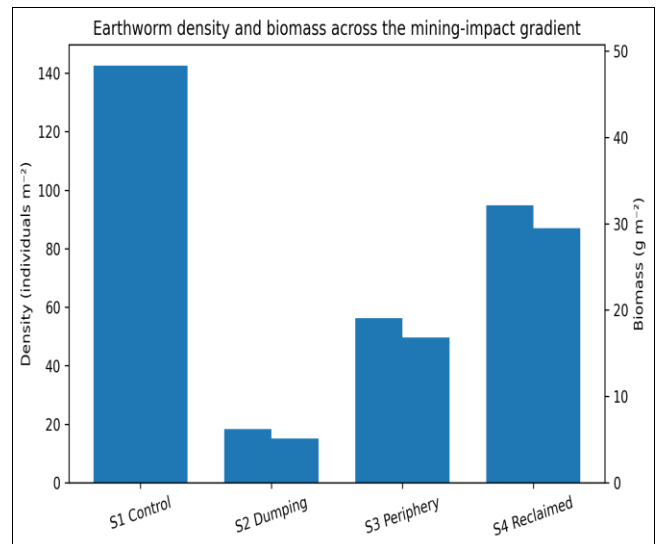
**Fig 3:** Species richness and Shannon diversity across sites

## 3. Density and biomass

**Table 3:** Annual mean earthworm density and biomass

| Site         | Density (ind. m <sup>-2</sup> ) | Biomass (g m <sup>-2</sup> ) | Mean individual mass (g) |
|--------------|---------------------------------|------------------------------|--------------------------|
| S1 Control   | 142.6                           | 48.32                        | 0.33                     |
| S2 Dumping   | 18.4                            | 5.12                         | 0.27                     |
| S3 Periphery | 56.2                            | 16.84                        | —                        |
| S4 Reclaimed | 94.8                            | 29.46                        | —                        |

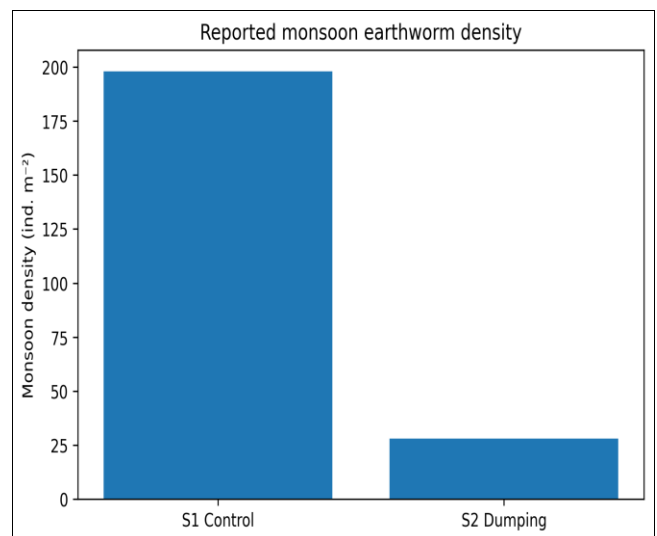
S2 showed an 87.1% reduction in density and an 89.4% reduction in biomass relative to S1. S4 reached 66.5% of control density and 61.0% of control biomass, indicating partial recovery.



**Fig 1:** Annual mean earthworm density and biomass along the mining-impact gradient

## 4. Seasonal variation

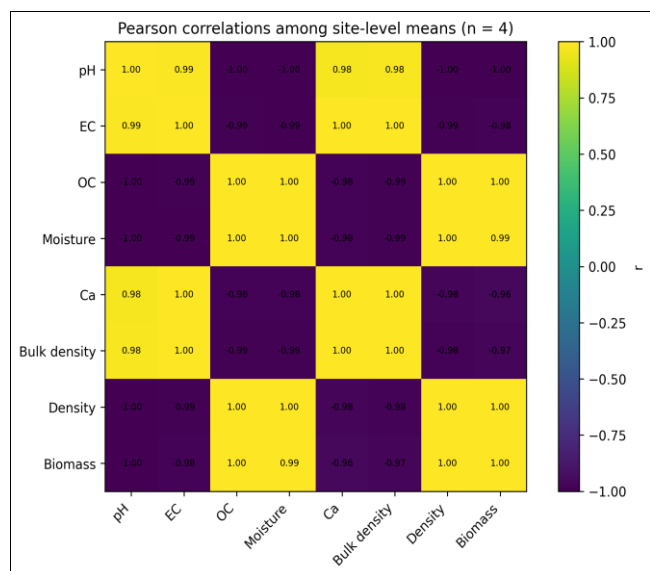
The supplied observations indicate maximum earthworm activity during the monsoon period, intermediate values during winter and minimum values during summer. At S1, reported monsoon density was 198 individuals m<sup>-2</sup>, whereas S2 had 28 individuals m<sup>-2</sup>. During summer, earthworms were described as almost absent at S2. Because the complete monthly values were not supplied in the present dataset, no artificial monthly series has been generated.



**Fig 4.** Reported monsoon density at S1 and S2; no unreported monthly values were interpolated

## 5. Correlation analysis

The supplied analysis reported  $r = -0.91$  between pH and density,  $r = -0.86$  between pH and biomass,  $r = -0.89$  between calcium and density,  $r = +0.94$  between organic carbon and density, and  $r = +0.88$  between moisture and density. Recalculation from the four site-level means gives similarly strong directional relationships. However, these values are exploratory because only four site means are available. They should not be described as statistically significant correlations without analysis of the underlying replicate-level dataset.



**Fig 5:** Pearson correlation matrix based on four site-level annual means; exploratory only

## Discussion

The central finding is the marked reduction of earthworm abundance and community complexity at the limestone refuse site. Density decreased from 142.6 individuals m<sup>-2</sup> at S1 to 18.4 individuals m<sup>-2</sup> at S2, and biomass decreased from 48.32 to 5.12 g m<sup>-2</sup>. Such a large response is consistent with strong habitat alteration. The refuse site simultaneously had higher alkalinity, EC, calcium and bulk density and lower organic carbon and moisture. The co-occurrence of these variables suggests that earthworms were exposed to multiple interacting stresses rather than a single environmental factor.

Soil moisture is critical to earthworm activity and survival because earthworms respire through the body surface and are generally more active in moist soils. The moisture value of 6.12% at S2 was markedly below that of the control. The summer decline and reported near-absence of earthworms at the dumping site are therefore ecologically plausible. At the same time, the high bulk density of 1.72 g cm<sup>-3</sup> indicates compaction, which can reduce pore space and restrict burrowing.

Organic carbon was also strongly reduced at S2. Earthworm populations depend directly or indirectly on organic residues, microbial production and decomposing plant material. A dump surface lacking vegetation and litter is therefore likely to provide a poorer food environment than an agricultural soil receiving organic inputs. Reclamation that establishes vegetation can gradually restore litter, root-derived carbon and microbial activity.

The high pH and calcium values deserve particular attention because they characterize the carbonate-rich nature of the refuse. The pH of 8.92 at S2 represents a clear shift from the near-neutral control. However, the present dataset cannot separate the individual effects of pH, calcium, moisture, organic carbon and compaction. The appropriate interpretation is therefore that the entire altered soil environment is associated with community decline.

The shift in species composition is also informative. The control site supported 11 reported species, whereas only three were recorded at the dump. *Pontoscolex corethrurus* dominated the disturbed site. Such dominance by a disturbance-tolerant or opportunistic taxon can accompany

loss of more sensitive taxa, but its use as a formal indicator requires comparison with a wider set of sites and taxonomic verification. Indian earthworm identification is challenging and voucher-based confirmation is particularly important for species-level publication.

The reclaimed site provides a useful restoration signal. After approximately three years of plantation and organic-matter addition, density had recovered to 66.5% and biomass to 61.0% of the control. Species richness also increased to eight and Shannon diversity to 1.74. These results suggest that biological recovery can occur after physical and chemical rehabilitation. Nevertheless, three years may represent an early stage of recovery, and long-term monitoring is required to determine whether the trajectory approaches the reference community.

The study is important for Baloda Bazar because official records demonstrate a substantial limestone-mining footprint. The district administration identifies limestone as the principal major mineral and lists numerous mines and storage points, while Indian Bureau of Mines records document large limestone leases such as Rawan-Jhipan, Shree Limestone Mine and Sonadih. This industrial context makes biological monitoring of mine soils relevant to both ecological restoration and agricultural-land protection.

Several limitations must be stated clearly for publication. First, only annual means are available in the present working dataset, so standard errors, confidence intervals and formal hypothesis tests cannot be reconstructed. Second, the correlation analysis uses four site means and has extremely low statistical power. Third, the heavy-metal methods are described but numerical results are absent. Fourth, species identifications require voucher confirmation. Fifth, the control site's classification as having no mining impact should ideally be supported by dust-deposition measurements, distance, prevailing wind direction and other site metadata. These limitations do not invalidate the observed pattern, but they determine the strength of the conclusions that can responsibly be drawn.

## Conclusion

The supplied field dataset demonstrates a strong observational association between limestone-mining refuse and deterioration of the earthworm community in Baloda Bazar. At the dumping site, density and biomass were approximately 87% and 89% lower than at the control, while species richness fell from 11 to 3 and Shannon diversity from 2.18 to 0.68. The same site had higher pH, EC, calcium and bulk density and lower organic carbon and moisture. The reclaimed site showed substantial partial recovery, supporting the value of vegetation establishment and organic-matter restoration. Earthworm density, biomass, richness and diversity can therefore serve as useful biological components of mine-reclamation monitoring. The evidence should, however, be presented as an observational field association rather than proof that any single soil variable caused the decline.

## Conservation and Reclamation Measures

- Strip, store and reuse topsoil separately during mine development and dump reclamation.
- Cover refuse dumps with an appropriate layer of uncontaminated topsoil and add mature organic amendments before planting.

- Establish native and locally suitable grasses, shrubs and trees to increase litter input, root activity and moisture retention.
- Use dust-control measures on haul roads and dump surfaces and maintain vegetated barriers where appropriate.
- Maintain reference plots and reclaimed plots for annual biological monitoring.
- Include earthworm density, biomass, richness and Shannon diversity alongside pH, EC, organic carbon, moisture and bulk density in reclamation assessments.
- Archive representative earthworm vouchers, photographs and georeferenced site records for taxonomic verification.
- Use replicate-level statistical models for future monitoring so that recovery rates and uncertainty can be quantified.

## References

1. Julka JM. The Fauna of India and the Adjacent Countries: Megadrile Oligochaeta (Earthworms): Haplotaxida: Lumbricina: Megascolecoidea: Octochaetidae. Zoological Survey of India, Calcutta, xiv + 400 pp, 1988.
2. Edwards CA, Bohlen PJ. Biology and Ecology of Earthworms. 3rd ed. Chapman & Hall, London, 1996
3. Dash, M.C. & Patra, U.C. Density, biomass and energy budget of a tropical earthworm population, 1977 [Verify the original bibliographic details before submission.]
4. Indian Bureau of Mines. Limestone and Other Calcareous Materials / Indian Minerals Yearbook. Government of India. [Insert exact edition used for each production statistic.]
5. District Administration Baloda Bazar-Bhatapara. Natural Resources: Limestone and industrial profile. Government of Chhattisgarh.
6. District Administration Baloda Bazar-Bhatapara. Mining Resources: mine and storage-point information. Government of Chhattisgarh.
7. Zoological Survey of India. Fauna of India digital archives: Megadrile Oligochaeta and related earthworm literature.