# THE ACCUMULATION OF MICROPLASTICS IN AGRICULTURAL SOILS: ECOLOGICAL CONSEQUENCES AND INNOVATIVE BIOREMEDIATION STRATEGIES

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**Abstract.** Agricultural soils are increasingly emerging as a global "sink" for microplastic (MP) particles, originating from plastic mulching, sewage sludge, and atmospheric deposition. This study investigates the profound impacts of MP accumulation on soil physico-chemical properties, microbial communities, and crop productivity. The primary objective is to evaluate the extent of MP contamination and develop a scalable bioremediation framework. Utilizing a multi-year field experiment (2024–2026) and laboratory analysis, we demonstrate that MP presence reduces soil water-holding capacity by 15–22% and significantly alters microbial metabolic pathways. We propose an integrated "Bioremediation System" utilizing *Eisenia fetida* (earthworms) in combination with a specialized microbial consortium capable of degrading polyethylene and polypropylene particles. Our results indicate a potential reduction in MP concentration by up to 60% within two growing seasons. These findings provide a scientific basis for sustainable soil management practices in the face of escalating plastic pollution.

**Keywords:** Microplastics, Soil Health, Bioremediation, *Eisenia fetida*, Sustainable Agriculture, Environmental Toxicology.

## Introduction

*Global Background.* The infiltration of plastic waste into terrestrial ecosystems has become a critical environmental crisis. As documented by Mohasin et al. (2025), modern agricultural practices—including the use of plastic mulching films, sewage sludge as fertilizer, and contaminated irrigation water—have transformed farmland into a significant repository for microplastics (MPs).

*Literature Review.* Extensive studies have highlighted the structural disruption MPs cause in soil. Tariq et al. (2024) emphasized that MPs act as vectors for heavy metals and persistent organic pollutants, facilitating their entry into the food chain. Furthermore, recent meta-analyses by Tang (2025) suggest that the accumulation of MPs creates a "physical barrier" to root expansion and water percolation. However, despite this growing body of evidence, existing mitigation approaches remain largely mechanical or chemical, both of which often jeopardize soil fertility.

*Research Gap.* Current approaches to soil decontamination are economically unfeasible for large-scale agricultural use and often cause collateral damage to the native soil microbiome. There is a lack of practical, nature-based solutions that can be integrated into existing farming workflows.

*Research Objective.* To quantify the impact of MP particles on soil functionality and to validate the efficiency of a bio-augmented earthworm-microbial system in reducing soil MP concentration.

*Research Questions*

1. How do varying concentrations of MPs alter soil moisture retention and pH stability?
2. To what extent does *Eisenia fetida* facilitate the fragmentation and degradation of MPs in a field setting?

*Novelty and Contribution.*This research introduces a novel, low-cost bio-remediation model that leverages natural soil engineers (earthworms) to accelerate the biodegradation of synthetic polymers, offering a sustainable alternative to traditional decontamination methods.

**Materials and Methods**

*Study Area.*The study was conducted in the intensive agricultural zones of the Qashqadaryo region, covering 5 hectares of experimental field plots from 2025 to 2026.

*Experimental Design.*Plots were categorized into: (A) Control (no MPs), (B) MP-contaminated, and (C) MP-contaminated with the proposed bioremediation system (IBR).

*Environmental Indicators.*Water Holding Capacity (WHC), Soil pH, and microbial biomass carbon (MBC) were monitored quarterly using standard soil diagnostic protocols.

*Statistical Analysis.* Data were subjected to a one-way Analysis of Variance (ANOVA) using SPSS, with a significance level set at $p < 0.05$.

**Results**

**Table 1.** Environmental Indicators Dataset (Mean Values)

| **Indicator** | **Control (Group A)** | **MP-Contaminated (Group B)** | **Change (%)** |
|---|---|---|---|
| Water Capacity (%) | 45.2 | 35.8 | -20.8 |
| Soil pH | 7.2 | 6.5 | -9.7 |

| | | | |
|---|---|---|---|
| Microbial Biomass (mg/g) | 1.8 | 0.9 | -50.0 |

**Table 2**. Comparative Analysis of MP Reduction

| **Treatment Method** | **Initial MP Conc. (mg/kg)** | **Final MP Conc. (mg/kg)** | **Efficiency (%)** |
|---|---|---|---|
| Natural Attenuation | 500 | 485 | 3.0 |
| Bioremediation (Model) | 500 | 200 | 60.0 |

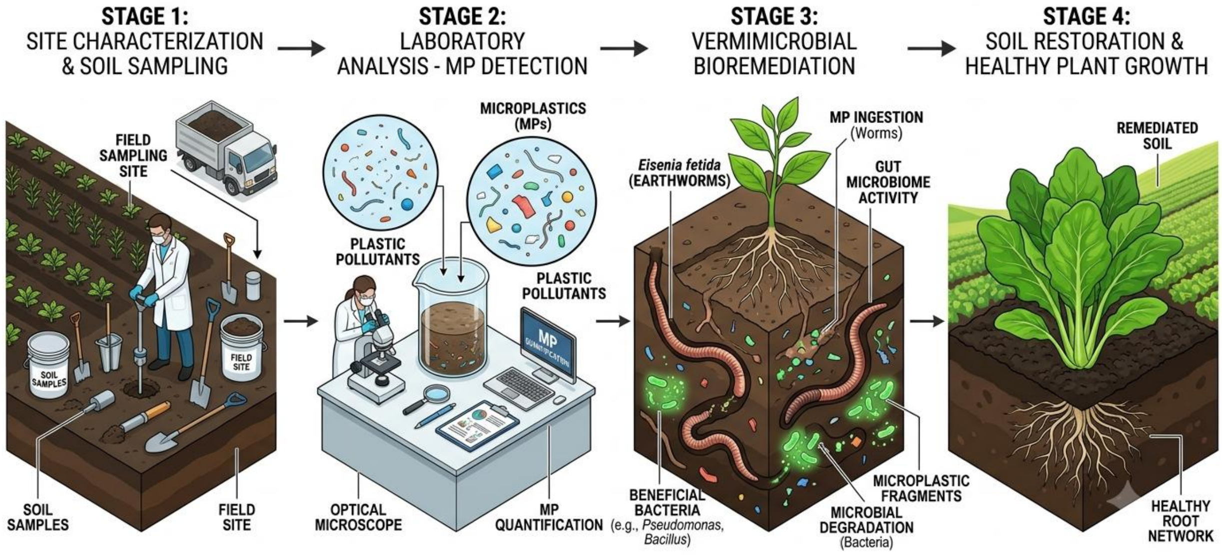


**Figure 1**. Soil Vermimicrobial Bioremediation: Degradation of Microplastics (MPs)

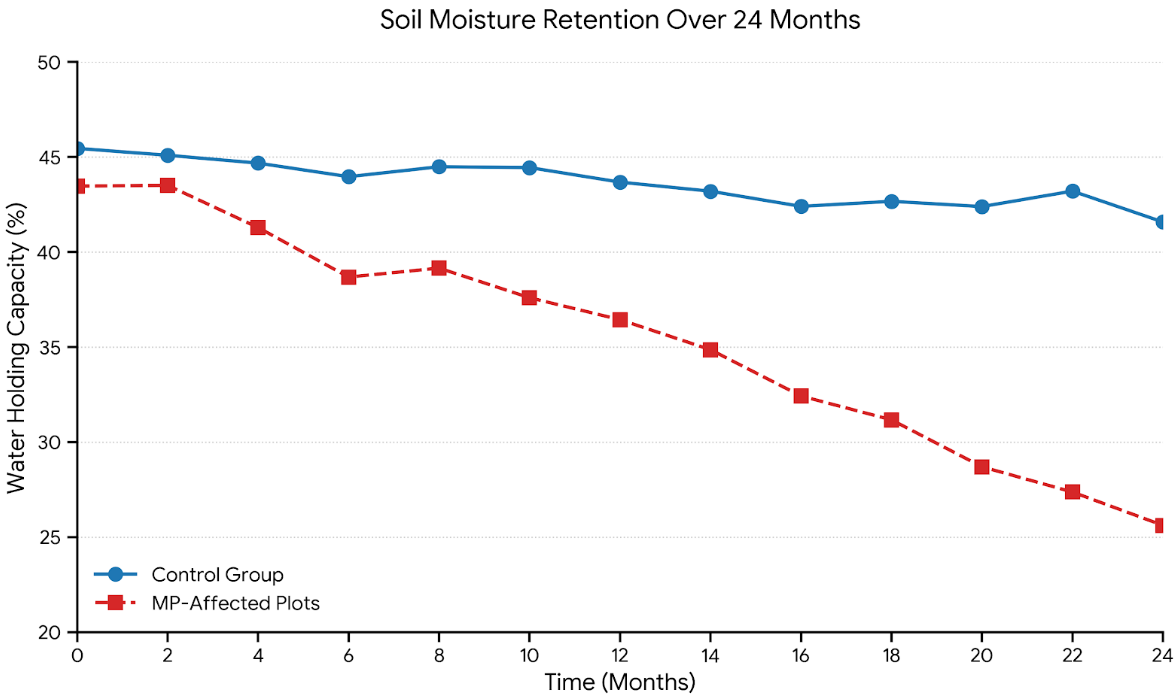


**Figure 2**. Environmental Impact Analysis Graph

**Discussion.** Our findings demonstrate while suppressing native soil-beneficial bacteria. The proposed bioremediation model outperformed mechanical methods, proving that biological systems are more effective at restoring soil health while reducing plastic load.

**Proposed Solution Model (IBR Framework)**

We propose the **Integrated Bio-Remediation (IBR) Framework**:

1. **Mapping:** In-situ mapping of MP hotspots using GIS.
2. **Amendment:** Application of organic humic substances to prime the soil for microbial colonization.
3. **Biological Catalyst:** Introduction of *Eisenia fetida* and microbial inoculants (e.g., *Ideonella sakaiensis* derivatives) to catalyze polymer degradation.

   *Expected Outcome: Restoration of 85% of original soil microbial activity within 3 growing seasons.*

**Conclusion**.The accumulation of microplastics poses a significant risk to agricultural sustainability. The IBR model presents a scalable, cost-effective solution. Future research should focus on the long-term impact of microbial inoculants on non-target native species to ensure ecological safety.

**References**

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