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Impact of polyethylene microplastic accumulation on the physiological health of *Eisenia fetida* and resultant depletion of soil nutrient richness: A comparative ecotoxicological study

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Abstract
Terrestrial microplastic (MP) pollution is an escalating threat to soil productivity. This study investigates the impact of polyethylene (PE) microplastics (50–150 µm) on the model earthworm species *Eisenia fetida* and the subsequent effects on soil nutrient cycling. Over a 28-day experimental period, we observed dose-dependent reductions in earthworm biomass (15.2%) and cocoon production (64.8%) at high concentrations (1000 mg/kg). Concurrently, the study quantifies a 25% decline in available Nitrogen and a 17.6% decrease in available Phosphorus. These findings demonstrate that MPs disrupt the biological and chemical synergy of soil, leading to a measurable decline in soil richness.

Keywords: Microplastics, *Eisenia fetida*, polyethylene, soil fertility, nutrient cycling, ecotoxicology, reproductive inhibition

Introduction

Agricultural land is increasingly becoming a sink for microplastics due to sewage sludge application and the degradation of mulching films (Bläsing & Amelung, 2018; Chen *et al*., 2020) [11, 17]. Unlike aquatic systems, soil MP pollution directly impacts "ecosystem engineers" like earthworms that maintain soil structure and nutrient bioavailability (Huerta Lwanga *et al*., 2016) [3]. Earthworms are vital for soil fertility, yet they are highly susceptible to MP-induced intestinal damage and oxidative stress (Wang *et al*., 2019; Lahive *et al*., 2019) [1, 19]. This research evaluates the connection between invertebrate health and soil nutrient depletion, comparing results with global datasets.

Materials and Methods

Soil was collected and sieved (2mm) following protocols by Zhang *et al*. (2018[15]). PE microplastics were mixed at 0, 100, 500, and 1000 mg/kg concentrations. Ten adult *Eisenia fetida* were introduced into each replicate. After 28 days, growth and reproduction were recorded. Soil richness was evaluated by measuring available Nitrogen and Phosphorus using spectroscopic methods to assess changes in the nutrient network (Sun *et al*., 2020; Cao *et al*., 2022) [8, 9].

Results and Comparative Analysis

The high-dose group (1000 mg/kg) showed a significant weight loss of 15.2%, aligning with international benchmarks. **Table 1** justifies these findings through a direct comparison with previous peer-reviewed studies.

Table 1: Comparative Data Analysis and Research

Parameter	Current Study (1000 mg/kg)	Reference Data (Verified)	Scientific Justification
Biomass Loss	-15.2%	-12.7% (Wang *et al*., 2019) [1]	Confirms gut abrasion theory.
Cocoon Production	-64.8%	-58.0% (Wang *et al*., 2019) [1]	Proves reproductive inhibition.
Available Nitrogen	-25.0%	-21.0% (Sun *et al*., 2020) [8]	Disruption in mineralization.
Available Phosphorus	-17.6%	-15.0% (Zhang *et al*., 2020) [10]	Altered soil porosity.

Discussion

The biomass loss is attributed to gut inflammation (Lahive *et al*., 2019) [19] and a shift in energy allocation from reproduction to tissue repair (Boots *et al*., 2019) [2]. MPs also alter soil physical properties, reducing the stability of aggregates and nutrient mobility (Zhang *et al*., 2020; Rillig *et al*., 2021) [4, 10]. Furthermore, MPs act as vectors for pesticides, amplifying toxicity within the gut (Liu *et al*., 2019; Yang *et al*., 2021) [12, 20]. These factors combined lead to a collapse in soil richness.

Conclusion

Polyethylene microplastics significantly impair earthworm physiology and disrupt Nitrogen and Phosphorus cycling. This degradation poses a long-term risk to terrestrial biodiversity and agricultural sustainability.

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