

Recycled low-density polyethylene (LDPE), widely used in agriculture (e.g., as mulch films or plastic covers for tunnels), is gaining attention as an environmentally friendly material. It is increasingly promoted within circular economy strategies aimed at reducing the use of primary raw materials and minimizing plastic waste. Despite its apparent ecological potential, current studies do not provide conclusive data on the long-term environmental safety of such materials. Unlike so-called “clean” polymers, recycled LDPE originates from diverse sources, resulting in high variability in chemical composition. It may contain residues of technological additives (such as UV stabilizers or plasticizers), thermal degradation products formed during previous use, and traces of environmental contaminants. These substances, initially trapped in the polymer matrix, can be released into the environment - particularly during mechanical breakdown and fragmentation into microplastics. Once formed, microplastics become active carriers of toxic compounds, which may affect soil organisms, aquatic systems, and agricultural crops.

This research project aims to conduct a comprehensive and multifaceted assessment of the interactions between recycled LDPE microplastics and soil and aquatic environments, reflecting realistic exposure conditions. Particular emphasis will be placed on analyzing the chemical composition of these particles, their sorption capacity towards agricultural pollutants, and their potential effects on living organisms. The study will include both fresh and artificially aged microplastics, allowing changes in material properties over time to be captured and simulating a realistic environmental lifecycle. Selected agrochemicals will be tested, representing major groups of environmental concern: glyphosate-based herbicides and surfactant-type adjuvants, antibiotics (tetracycline and/or ampicillin), and high-priority heavy metals (Cd and/or Pb). The goal is to determine whether recycled microplastics may increase or decrease the toxicity of these pollutants, alter their mobility and bioaccumulation potential, and influence their uptake by soil organisms and plants.

Biological effects will be evaluated using soil bacteria (*Pseudomonas putida* and/or *Bacillus subtilis*) and crop plants (*Brassica napus* and/or *Sorghum*), selected for their agricultural relevance and differing sensitivity. Measured parameters will include oxidative stress levels, changes in cell membrane lipid composition (fatty acid profiles), amino acid profiles, and growth inhibition. For plants, the study will assess biomass development, photosynthetic pigment content, and antioxidant enzyme activity. Additionally, modern molecular biology techniques (16S rRNA gene sequencing) will be used to analyze microbial diversity in the rhizosphere and identify potential disruptions to ecosystem functionality. Furthermore, the use of ¹³C-labeled compounds will enable precise tracking of contaminant fate in the environment - including sorption, degradation, transport, and assimilation into biological structures. This approach will allow differentiation between pollutants merely adsorbed onto plastic surfaces and those actually taken up by organisms.

The project introduces a novel and integrated approach to evaluating environmental risks associated with recycled LDPE microplastics. Unlike previous studies, which focused mainly on simplified aquatic toxicity tests, this research includes long-term effects under realistic soil conditions, considering the complex interactions between plants, microbes, and pollutants. The results will help identify key mechanisms responsible for disrupting plant-microbiome cooperation and limiting the capacity of these systems to detoxify their environment. The project will also provide a basis for developing new environmental risk indicators and regulatory guidelines concerning the use of recycled plastics in agriculture. The findings will contribute to more informed implementation of circular economy principles - considering not only waste reduction, but also actual ecological risks. The results may also support the development of strategies to minimize the negative environmental impact of recycled plastics, through improved safety assessments and by identifying more sustainable material alternatives for the agricultural sector. Ultimately, this research will help answer one of the central questions of sustainable development: does plastic recycling truly protect the environment, or does it introduce new, underestimated threats?