Agricultural plastics as a potential threat of soil pollution by microplastics

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The dynamic expansion of Agricultural Plastics (AP) use has allowed for improved and sustainable agricultural production. The objective of this work is to analyse the relationship of AP characteristics, degradation, and End-of-Life (EoL) practices with the potential risk of micro-, nanoparticles (MNP) generation in soil.

Most AP categories are practically used for a single season due to contamination, damage, and degradation. Several categories of Aagricultural Plastic Waste (APW) are not recyclable due to high contamination, presence of different polymers in composition, physical characteristics, high cost of recovery etc. APW mismanagement practices prevail, while infrastructures and legislation are lacking behind.

A qualitative risk analysis was carried out, taking into consideration the corresponding criteria and scores of the environmental risk assessment technique of FAO applied for selected AP categories (FAO 2021). The risk assessment of the present work was based on the criteria of the source-pathway-receptor-consequence (SPRC) model, adapted from the FAO report with some changes: Source (AP extent of usage, applications/year), Pathway (degradation, damage, EoL/ recyclability), Receptor (direct contact with soil and water) and Consequence (potential for durable MNP generation). The obtained risk ratings were found to differ from those of some of the cases analysed in (FAO 2021), while 10 additional AP categories are included in the present risk assessment. The conventional AP categories are classified from high to low-risk probability for soil contamination by MNP, based on a worst-case scenario, assuming each AP category as non-recyclable and/or mismanaged. An alternative best-practice scenario is presented for the AP categories for which recycling is, or could be (under certain conditions), a feasible and viable EoL option. The best-practice scenario assumes that the recyclable APW are routed to recycling. The normalised total scores of soil pollution risk are graphically presented in Figure 1 for the two scenarios. It was confirmed that AP with high risk for soil pollution mainly include products in direct contact with soil due to their functionality and composition (non-biodegradable). EoL mismanagement practices, however, were shown to represent the major contributor to high-risk AP for potential soil contamination by MNP.

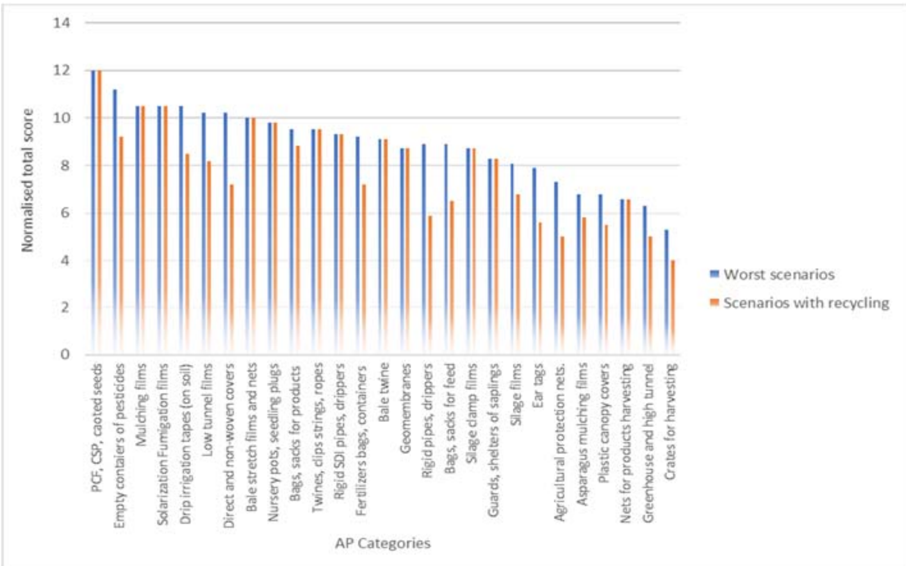

Figure 1. Soil pollution risk with AP EoL scenarios: a) non-recyclable and/or mismanaged, b) recyclable routed to recycling

Alternative risk mitigation strategies / policy measures, also considering the corresponding alternative solutions proposed in (FAO 2021) for selected AP categories, include: a) establishing mandatory EoL schemes for APW collection, and recycling, b) proper APW management with material recovery/ recycling / reuse, c) replacement of conventional AP products by certified compostable or biodegradable in soil ones, as applicable.

Quantitative case studies on agricultural soil contamination by microplastics (MP) revealed big variations with a wide range of estimated concentrations of microplastics in soil (particles.kg^{-1}): from a minimum 0.34 in Germany (farmland) to a maximum of 160000 in China (horticultural cultivations) and many intermediate values reported in-between (Kim et al. 2021). Characteristic cases of mulched soils are presented in Figure 2. The big variations are attributed to the defined cut-off particles size (0.02, 0.05, 0.1, 1.0 mm), sampling protocols, morphological characteristics, analytical identification methods (e.g., visual observation, microscopy, FTIR, μ-FTIR, Raman-based spectroscopy), cultivations, agricultural practice, soil types, environmental conditions etc. The estimated MNP abundance in farmland soil is also the result of a coupled effect of various internal and external AP sources, industrial and domestic sources, input pathways and environmental fate dependent removal rates through surface runoff and/or infiltration and wind erosion. The discrepancy observed between MP and NP abundance in soil confirms a non-steady state MP fragmentation process (Kim et al. 2021). MP concentration is reported to be positively related to AP application period (e.g., mulching film). A continuous degradation with time, and AP remains micro-fragmentation into MP under open field conditions has been shown. MP abundance and size was shown to decrease with soil depth. Climatic conditions and cultivations are important parameters.

In most cases, MP composition was found to vary widely (PP, PE, PA, PES, PET, rayon, etc.), along with the MP prevailing forms (fibres, films, fragments), suggesting additional to AP multiple sources of MP origin in agricultural soil. In all cases studied, it was confirmed that biosolids (compost, treated wastewater, sewage sludge), fertilisers, textiles, wind, runoff etc. play a dominant role (Figure 2). Likewise, MP in greenhouse soil was shown to originate from AP products used in greenhouses (e.g., twines, clips, mulching films, containers of agrochemicals, pipes, fertilisers, etc.) but also external sources (biosolids, domestic and industrial plastics etc.).

The solution to the problem of soil contamination by MNP does not depend entirely on the use and characteristics of AP and APW mismanagement. MP deliberately released into the soil (through polymers coated fertilisers, coated seeds, and capsule suspension-based plant protection products) play significant role. MP entering soil indirectly through biosolids, fertilisers, wind, and runoff have a dominant role in soil pollution by MNP.

The solution sought should come from an integrated approach of innovative design of AP products, including AP certified as biodegradable in soil or compostable, APW material recirculation, in combination with restriction of primary MNP presence in fertilisers and biosolids.

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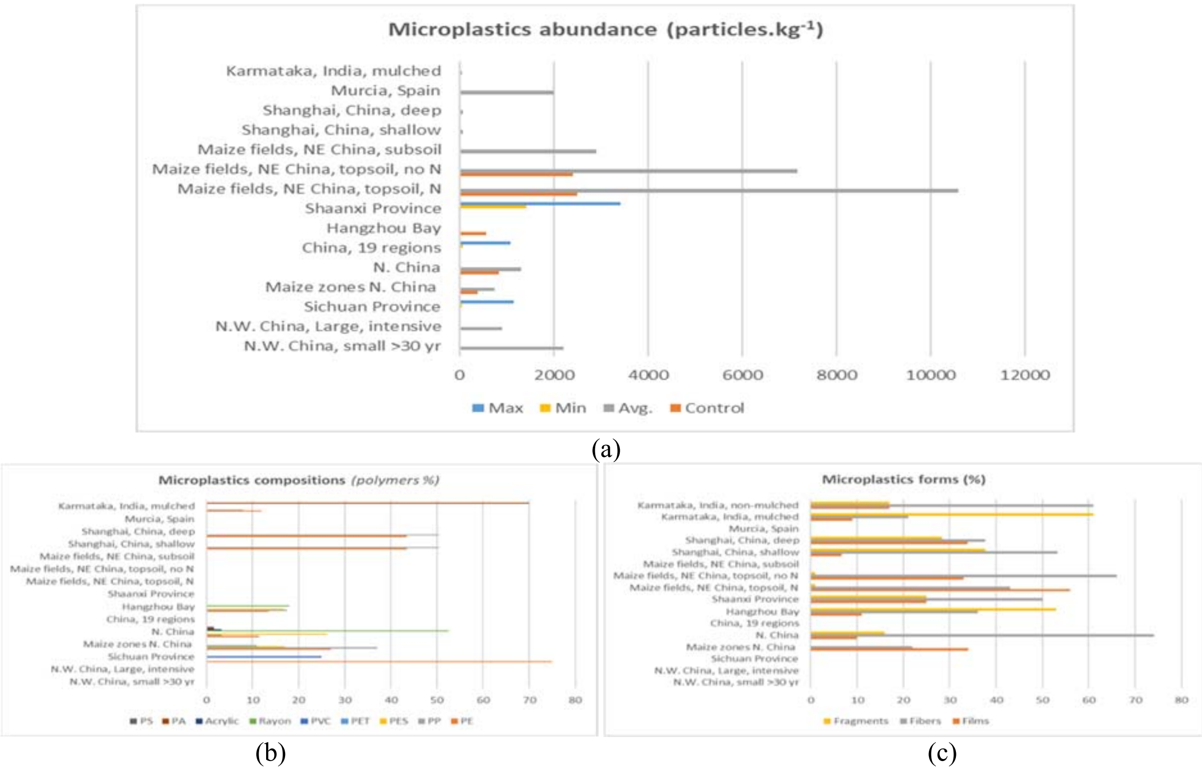

Figure 2. MP abundance (a), composition (b), and forms (c) reported for farmland cases with extensive use of mulching films

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