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Fate and occurrence of micro(nano)plastics in soils: Knowledge gaps and possible risks

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Abstract

The majority of micro(nano)plastic research has been concentrated on the marine environment. Whilst the ocean represents an ultimate sink for contamination, this focus overlooked key processes and pathways of micro(nano)plastics in the terrestrial environment that are of critical importance for their global environmental budget and exposure of humans and biota. Lack of robust analytical methods for the isolation of these materials from complex, organic-rich soil matrices represent a major hindrance. Regardless, soils in agricultural and urban areas are expected to represent major environmental reservoirs of micro(nano)plastics, possibly comprehensively larger than the marine one. Additionally, soils exhibit several potential exposure pathways for micro(nano)plastics to organism and human health, including contamination of groundwater aquifers.

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Microplastic, Nanoplastic, Soil, Sewage sludge, Groundwater.

Introduction

Microplastics research is a rapidly evolving domain. Traditionally, studies have focused on the marine environment; however, recent research has identified the significance of microplastics in terrestrial ecosystems [1]. This has included work on freshwater systems, such as rivers and lakes, and has recorded high microplastic concentrations [2–5]. Very little work has dealt with the presence, fate, or impact of microplastics in soils [6–8]. Despite recent efforts to establish effective analytical procedures [e.g. [9,10]], detection of nanoplastic in environmental substrates is not yet possible. Hence, no studies have thus far investigated the occurrence or fate of nanoplastics in soil systems. This review brings together the existing research on soil micro(nano) plastics and draws upon wider material to infer potential sources and fate of small plastic particles within soils. We focus primarily on research published in the last two years with the purpose of identifying recent advances relevant to the soil micro(nano)plastics research domain.

Existing research

Early studies identified synthetic fibres in soils treated with sewage sludge [11,12] and the potential for soil microplastic contamination was first reviewed by Rillig [6]. Recently, a large portion of soil microplastic research has concentrated on interactions with biota. Several studies have investigated the effects on soil organism health and behaviour [13*–19*]. Key findings reveal variable responses to microplastic ingestion by earthworms, where histological damage in the gut trait was related to exposure [13*,14]. Fauna are capable of moving microplastic within soil systems, including vertical transfer [18,19*]. However, thus far, no studies have recorded this under environmental conditions and realistic exposure scenarios.

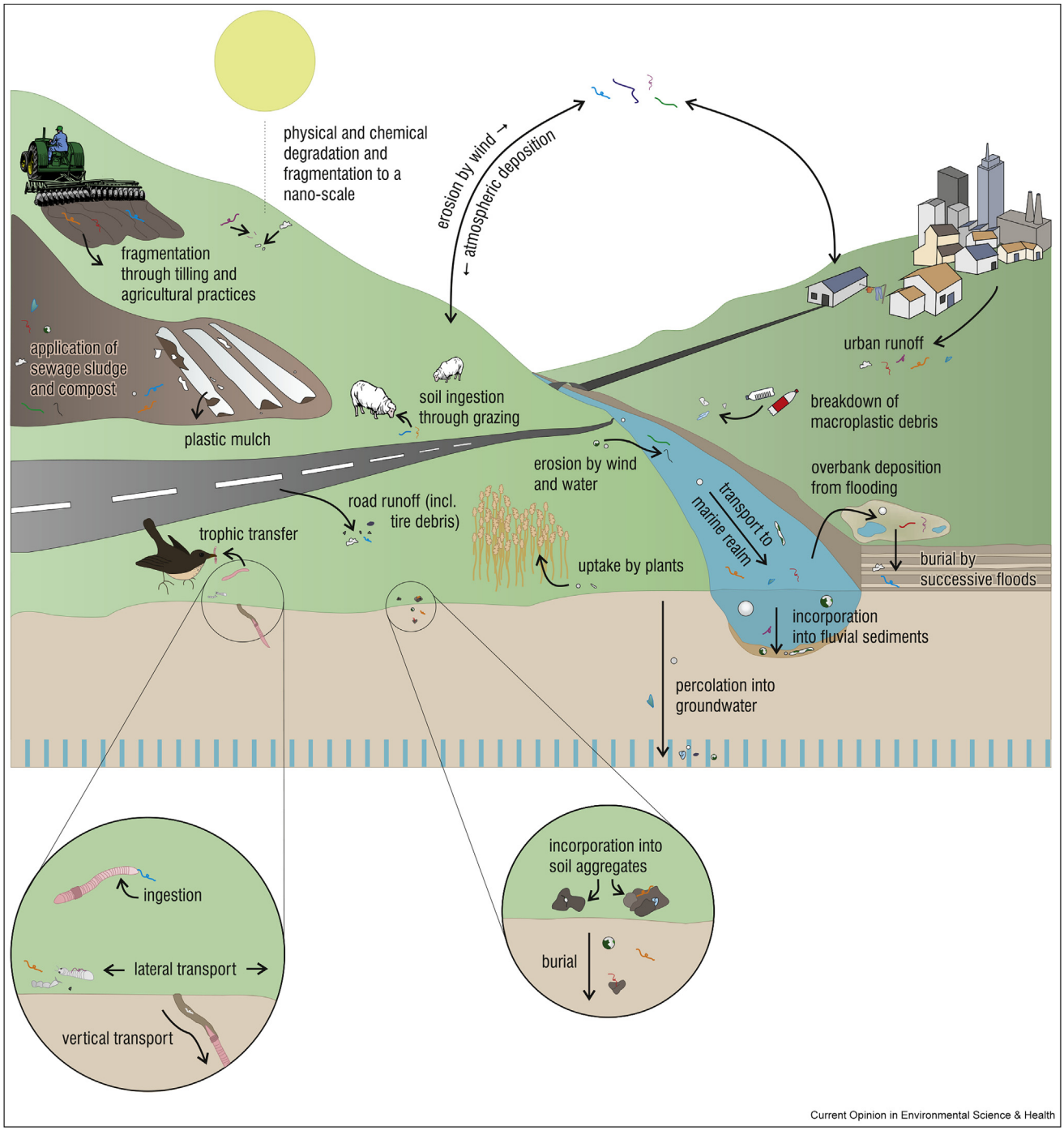
Agricultural practices are relevant to soil microplastic contamination. The application of sewage sludge on farm soils has been theoretically estimated as one of the largest sources of microplastics to the environment [20**,21]. It is proposed that 125–850 tons of microplastic per million inhabitants are added each year to agricultural soils in Europe, with an annual total of 63,000–430,000 and 44,000–300,000 tons of microplastic added to European and North American farmlands respectively [20**]. The broad confidence intervals of these estimates stem from the uncertainties regarding the fate of microplastics derived from car tire debris and surface runoff, for which efficiency of sewer collection and fate in wastewater treatment plants (WWTPs) are unknown. These figures suggest that soil systems may represent a larger environmental reservoir than the global ocean. Very little data are available on the ecological implications of such an exposure. One study has linked the effect of microplastic debris from plastic mulching to changes in organic matter cycling and nutrient dynamics in Chinese loess soils [22]. However, the influence of soil type is unknown. Several studies have examined methodologies for microplastic analysis in soils and other complex organic-rich environmental matrices such as sewage sludge [23,24*]. Although, no standardised approach has yet emerged.

Finally, urban soils are contaminated by microplastics. Soils close to industrial areas in Sydney were found to be composed of 0.03–6.7% microplastic [24*]. However, details of the type of microplastic contamination observed were not presented.

Sources of micro(nano)plastics to soils

The sources of micro(nano)plastics to soil have recently been reviewed by Bläsing and Amelung [25**]. The key sources can be separated into three categories: inputs from agricultural practices, the influence of runoff and

Fig. 1



Processes that potentially affect the concentration of micro(nano)plastics in soil systems, including sources and fate processes.