Rhizosphere–plant–microbial system under polycyclic aromatic hydrocarbons-induced stress

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The rhizosphere–plant–microbial association is a complex and intricate system susceptible to various organic pollutants, including polycyclic aromatic hydrocarbons (PAH). Since the soil acts as a sink of PAH, their accumulation shifts the delicate rhizosphere–plant–microbe equilibrium and enters the food chain through plants. How the presence of PAH in the rhizosphere affects the rhizosphere–plant–microbial system is still unclear. This study aims to understand the effects of PAH on rhizosphere–plant–microbial interactions. It also explores the potential use of microbes to alleviate PAH-induced stress in the soil for effective and sustainable management.

Keywords: Bioaccumulation, microbe-mediated remediation, persistent organic pollutants, polycyclic aromatic hydrocarbons.

POLYCYCLIC aromatic hydrocarbons (PAH) are among the most notorious, cosmopolitan, toxic and persistent organic pollutants. They are ubiquitous in nature, and in the last five decades, their global burden has increased by around 45% (ref. 1). In 2007, the average global PAH emission was estimated to be 504 Gg/year, with major contributions from the developing Asian countries[2]. Africa, Europe, North America, Oceania and South America contribute 18.8%, 9.5%, 8.0%, 1.5% and 6.0% respectively, to worldwide PAH emissions[3]. The distribution and accumulation of PAH are not uniform and show significant regional variation. India (90 Gg) and China (114 Gg) are the major contributors of PAH annually[4]. This is due to rapid industrialization, fossil–fuel-dependent transportation and other anthropogenic activities. Sources of PAH can be broadly classified as petrogenic (petroleum as the source) and pyrogenic (incomplete combustion of fossil fuels and biomass). Most PAH are potential carcinogens, and their exposure or indirect consumption leads to serious health effects. They are considered priority pollutants due to their 'three disease-causing' effects (carcinogenic, teratogenic and mutagenic) on humans[5]. In spite of being volatile and present in the air, the presence of PAH in the soil is of concern as they tend to accumulate in it.

Due to their hydrophobicity, around 90% of the global PAH is adsorbed in the soil, which not only makes it a major sink but also drastically changes the physico-chemical properties of the soil, thereby altering its structure and function[6]. Rhizosphere, the zone of interaction between the soil and roots, is a diverse and intricate habitat hosting a wide range of algae, protozoa, arthropods, nematodes, bacteria and fungi. Among these, microorganisms play a significant role in regulating essential biogeochemical processes and facilitating xenobiotic degradation. Biodegradation of soil pollutants such as pesticides, insecticides, and PAH is a critical ecosystem service provided by rhizospheric microbes[7]. The presence of PAH in the rhizosphere enhances their risk of entering the food chain as well as influences soil microbial diversity and dynamics[8].

Plants are key players that influence the entry, accumulation and movement of PAH in the food chain. They take up PAH directly through the roots or indirectly through the cuticle[9]. The higher the PAH concentration in the soil, the greater the risk of their bioaccumulation and subsequent magnification in the plants. Excess PAH accumulation in plants is responsible for acute, chronic, and latent injuries that eventually disrupt their primary metabolic functions, such as photosynthesis[10]. As plants regulate the growth and diversity of microbial communities through root exudates, when grown in high PAH, the diversity of rhizospheric microbes, as well as their endophytes is observed to be modified[11]. Therefore, the interaction among soil microbes, plants and PAH is a tripartite process; any change in one of them significantly affects not only the other two, but also the food chain.

The interactions among rhizosphere–plant–microbe are delicate and sensitive to the presence of PAH. However, no study has addressed the effect of PAH toxicity on this complex yet important system. This study summarizes the multifaceted interactions among rhizosphere–plant–microbes

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