Interactions of triclosan, gemfibrozil and galaxolide with biosolid-amended soils: Effects of the level and nature of organic matter

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Pharmaceuticals and Personal Care Products (PPCPs) can often be accumulated in sewage sludge during wastewater treatment. Further, following land application of sewage sludge-originating biosolids, the PPCPs may reach agricultural environments, enter into the food chain and leach to groundwater. Since PPCPs are biologically active, there is a general interest in their environmental fate that is strongly influenced by sorption interactions at soil–water interfaces. Hence, the factors and mechanisms controlling the soil sorption of PPCPs are of great interest. The studies examining sorption of PPCPs on soils amended with sewage sludge-originating biosolids have been relatively limited, and, in particular, little work has been done under basic soil pH conditions, which are relevant for multiple environmental scenarios, for example, when soils contain natural or added calcium carbonate.

This paper reports the sorption study of three PPCPs, i.e., triclosan (an antibacterial and antifungal agent), gemfibrozil (a lipid-regulating agent) and galaxolide (a synthetic polycyclic musk). All three compounds are found at meaningful concentrations in sewage sludge from wastewater treatment facilities, demonstrate variable biological effects such as phytotoxicity and toxicity to aquatic microorganisms, accumulate in edible parts of plants, soil organisms and aquatic biota. Importantly, widespread use of triclosan is thought to lead to the development of microbial resistance to antibiotics. The three PPCPs selected all include large hydrophobic moieties, but differ dramatically in their ability to undergo ionization in aqueous solutions; thus they represent both non-ionized (galaxolide) and variously ionized (gemfibrozil and triclosan) PPCPs. Both of these factors (i.e., the presence of a hydrophobic backbone and the ability to ionize in aqueous solutions) are of significance in the mechanisms controlling organic compound–soil interactions.

Sorption of three organic compounds from aqueous solutions was studied in sand, loess and clay soils and mixtures of these media with three different sewage sludge-originating biosolids that were incubated under aerobic conditions for 6 months. For each compound, 15 sorption equilibrium isotherms were examined at pH 7.8-8.0. Increased soil organic carbon (OC) content due to the soil–biosolid incubation was associated with enhanced organic compound–soil interactions. However, at least for triclosan and galaxolide, there were no single relations between the Freundlich constants K_F characterizing the aqueous soil sorption of a compound and the OC content of the biosolid–amended soils. Notably, for a given OC content, the sand-containing sorbents tend to demonstrate enhanced interactions with triclosan and galaxolide, as compared with loess- and clay soil-containing sorbents. This sorption enhancement was related to more hydrophobic and/or less rigid soil organic matter (SOM) as compared with the clay-containing soils, which may imply indirect effects of soil minerals. Direct organic compound–soil mineral interactions were most likely of minor importance.

The soil OC-normalized Freundlich constants of a given organic compound are generally sorbent-dependent and, for a given soil, may vary significantly among different biosolids added, as well as among various soil–biosolid combinations. This dependence is not necessarily caused by the differences in the composition and properties of SOM; so, the non-zero intercepts of the linear K_F vs. soil OC content regressions also result in variable OC-normalized Freundlich constants. The non-zero (negative) intercepts suggest that a “critical” OC content may be needed in order to promote organic compound sorption in some soil systems. Based on sorption measurements carried out on sand-based sorbents at lower pHs, it is suggested that interactions of molecular and anionic forms of triclosan with a sand-containing sorbent may be comparable, but interactions involving gemfibrozil molecules could be stronger than interactions involving its anion. Despite the fact that sewage sludge-originating amendments may become additional sources of these PPCPs in the field, the release of organic contaminants to the environment should be mitigated by increased compound–soil (SOM) interactions.