Soil Sorption-Desorption Characteristics of Imidacloprid in Croatian Coastal Regions

Dalibor BROZNIĆ, Ćedomila MILIN

Medical Faculty, University of Rijeka, Braće Branchetta 20, 51000 Rijeka, Croatia; dbroznic@medri.hr

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SUMMARY

Sorption and desorption of insecticides are important processes that influence the amount of insecticide retained by the soil and that which is susceptible to runoff or movement in the soil profile. In this study, we examined the sorption and desorption characteristics of imidacloprid [1-(6-chloro-3-pyridylmethyl)-N-nitroimidazolidin-2-ylideneamine] in ten coastal Croatian soils. In Croatia, imidacloprid is most commonly used in olive growing areas against olive fruit fly. Understanding variabilities in pesticide sorption than can occur among and within the regions can improve imidacloprid applicability. Therefore, the relationship between selected soil properties (particle size, organic carbon content, acidity), imidacloprid concentration and soil sorption coefficients ($K_f$ and $K_d$) for soils among and within the regions, were analyzed. Additionally, applicability of the pseudo-first-order, pseudo-second-order, Bangham and intraparticle diffusion kinetic models to predict imidacloprid kinetics of sorption and desorption processes was tested. Adsorption equilibrium data were analyzed by Langmuir, Freundlich and Temkin isotherm equation. The standard batch equilibrium method was used for quantifying imidacloprid in a soil + pesticide solution (1 + 5 by mass) for a wide range of initial concentrations and reaction times (48 h). After sorption of the imidacloprid, five consecutive desorption steps (5 day) were carried out. The aqueous phase was analyzed by HPLC using a UV/VIS detector (270 nm). All analyses were performed on reverse phase $C_{18}$ column (150 x 4.6 mm, 5 µm particle size). The mobile phase of acetonitrile + water (1 + 4 by volume) was used under isocratic conditions at a flow rate of 0.8 mL min$^{-1}$. Higher sorption was observed in soils with higher organic carbon and clay content. $K_f$ and $K_d$ correlated significantly with the organic carbon ($R^2=0.994; P<0.01$) and clay content ($R^2=0.987; P<0.01$), but according to the multiple regression the organic carbon content predominantly influenced imidacloprid sorption. $K_d$ statistically differed among and within the regions. In all soils, a greater sorption occurred at lower concentrations of imidacloprid. According to the calculated $K_{OC}$ value (250 L kg$^{-1}$), imidacloprid can be categorized as a medium mobility pesticide. Imidacloprid sorption data described well according to Freundlich ($R^2=0.96$), Langmuir ($R^2=0.89$) and Temkin ($R^2=0.90$) isotherms. Imidacloprid sorption and desorption results were strongly kinetic for all soils. Pseudo-first order kinetic model found to best represent the data for imidacloprid sorption onto soil particle. After the five desorption steps, the percentage of desorbed amount of imidacloprid was decreased with the increase of the initial adsorbed concentration in all tested soils. Desorption data exhibited hysteresis phenomena. These results emphasize the importance of sorption-desorption measurements for increasing the accuracy of models that attempt to predict the frequency of groundwater contamination by pesticides and expected pesticide concentrations in the subsurface. Understanding the variability of soil properties and processes as a function of soil profile is necessary for accurate prediction of pesticide dissipation.