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Glyphosate transport modeling in soil and its relationship with groundwater contamination in a rural area of the Pampean Plain of Córdoba, Argentina

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The study area (3,000 km2) is located in the center of the Córdoba province (Argentina), in the fluvio-aeolian Pampean-plain. The climate is sub-humid, with small water excesses and an average annual precipitation of 761 mm (80% in spring-summer).
The agriculture is the main activity, with soybean, corn, wheat and, subordinated, peanut and alfalfa. The area is characterized by no-till-farming and intensive use of agrochemicals. glyphosate (N-phosphono-methylglycine) is the most commonly used herbicide in transgenic soybeans (RR) whose main metabolite, due to microbial degradation, is aminomethyl-phosphonic-acid (AMPA). Thus, the objective of this work was to evaluate the dynamic of glyphosate in the unsaturated zone (UZ) and its relationship with the detection in groundwater.
A groundwater sampling from 19 wells was carried out in spring (2017) and monitored in winter (2018). In both seasons 3 samples from typical soils were obtained: A: in fluvial sediments a Typic Ustorthent, loam texture, organic matter (OM) 1%, B: in aeolian sediments, a Entic Haplustoll, silty, OM 1.9% and C: in aeolian sediments, a Typic Natracualf, silty, OM 1.7%.
The studied unconfined aquifer, formed by the above-mentioned aeolian-fluvial sediments, contains groundwater with a general flow of NW-SE direction. The UZ thickness decreases in the same way, from 58 to 0 m, outcropping in low areas and lagoons.
In the sampled soils, the spring glyphosate-AMPA values (μg/Kg) were respectively 4.0/193.5 (A), 76.8/470.5 (B), and 8.1/390.2 (C). In the winter were: 2.7/111.5 (A), 11.5/151.2 (B) and 31.2/3,801.7 (C). Glyphosate has greater affinity with fine sediments (clays and silts) and higher OM percentage: minor glyphosate /AMPA in A and higher glyphosate-AMPA in silty soils with more OM (B and C). The values decrease during the winter season, except for C, which is the unique farm that reported mechanical fallow, an unexpected result to be monitored.
In the spring season 15.8% of groundwater samples showed glyphosate (1.3 to 2.0 μg/L) and also AMPA, in those places where the water table is shallow (< 4 m). In winter, only one sample presented glyphosate (< 0.1 ug/L) and none presented AMPA. More glyphosate reached the groundwater in humid periods and in areas with greater intrinsic aquifer vulnerability which are, thin UZ zone, very low hydraulic gradient (0.16%), moderate-low hydraulic conductivity (K = 1.5 m/d) and low flow velocity (0.02 m/d), preventing dilution of the solutes by hydrodynamic dispersion processes.
The numerical model of water flow and solute transport (software MACRO 5.0), calibrated with field data in soil C, indicates DT50 of 20 days and DT90 of 70 days for glyphosate in soil. At this point the model shows that the glyphosate concentration in the soil is very variable and does not exceed the first 10 cm. Also it evidences that the solute transport is controlled mainly by micropores and not so much by macropores. For the modeled scenario, the result indicates that there is no transport and leaching of glyphosate to the aquifer, which coincides with the measured values, since for the modeled site no glyphosate was detected in the groundwater.