Geophysical Research Abstracts
Vol. 13, EGU2011-3361, 2011
EGU General Assembly 2011

Using high resolution rainfall data to identify critical source areas for runoff-related pesticides: luxury or necessity?

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The impact of climate drivers on contaminant transport has been largely neglected. Rainfall variability within a storm event can have a significant impact on the amount of contaminant transport especially surface applied chemicals such as pesticides, by triggering rapid flow processes as surface runoff. We seek to better understand how rainfall patterns impact contaminant transport depending upon pesticides characteristics. A Bounded Multiplicative Random Cascades approach is used to generate an ensemble of rain events with specific Intensity-Duration-Frequency characteristics. In addition to simulations with variable rainfall, constant rain intensities were also simulated. We explore the effects of the partitioning of rainfall and chemical between fast surface runoff and slow flow in the soil matrix. The hydraulic properties, i.e. effective porosity, suction head and saturated hydraulic conductivity, of a vineyard clay loam soil are investigated. Ten years of six minute resolution rainfall data, from the Alsatian vineyard in France, are used to derive the cascade and Intensity-Duration-Frequency relationships. Pesticide transport both by runoff and infiltration are modelled by a near-surface mixing model and Green-Ampt infiltration.
We show that using a constant intensity during the rainfall event is not adequate to assess the runoff and the risk of pesticide transport. Indeed rainfall variability can increase pesticide transport in surface runoff compared to steady rainfall. Moreover, the results show that variations in rainfall intensity within events have a significant effect on the triggering of point scale rapid flow and transport processes such as surface runoff and pesticide loading. Much smaller pesticide loading occurred for more weakly sorbing and more strongly sorbing pesticides. The patterns of rainfall generating large surface runoff did not necessarily associate to large pesticide loadings depending on pesticide sorption. Monte Carlo simulations investigating the role of within-storm rainfall variability during events suggested that the average amount of solute released to runoff pathways increases rapidly for weakly sorbing solutes, then decrease for more strongly solutes with increases in sorption. This result casts doubt on the utility of sorption capacity as a measure of the mobility of solute by runoff. The riskiest events in terms of runoff were end-of-event peaking while they are middle-of-event or end-of-event for pesticide loading depending of pesticide sorption characteristics. We show that potential shifts in rainfall patterns within storms dramatically impact the frequency of contamination events, even without changes to storm duration and mean intensity return intervals. The framework developed shows that using high resolution rainfall data is definitively a luxurious necessity to a better understanding of risk of pesticide transport by rapid flow processes.

Key words pesticides; rainfall; runoff; modelling; high resolution data