Herbicide transport in freezing soil

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Summary

In several separate Finnish studies, observed pesticide concentrations in soil tillage layer and in surface water have been higher in spring (during / soon after soil thawing) than before winter. This phenomenon might be explained by the effects of soil freezing on pesticide fate (see Fig.1).

None of the current pesticide fate models have a proper soil freezing description. A new model CROPWATN-P was created in order to study the effects of soil freezing on pesticide transport. The model first version was tested against measured herbicide fate data, and against MACRO simulation results. The current version of CROPWATN-P does not take into account all relevant processes related to freezing, but model development is going on.

Fig. 1 The physical effects of soil freezing on pesticide fate (hypothosis)

Data used for simulations

Field experiment was carried out in a flat plot (3500 m², medium-textured Glycic Podzol), which is equipped with water collecting systems for surface runoff and tile drainage (tiles at 1-m depth).

Ethofumesate and glufosinate-ammonium were sprayed on bare soil on 8th July; concentrations were observed in soil and in runoff waters until next May. Summer after application was dry and following frost heave equal to the combined thickness of all ice lenses within the profile

The difference in simulated distribution between 0-3 cm and 3-25 cm layer may be due to different number and thickness of ice lenses

In addition to effects on transport, freezing may release pesticide “bound” residues from soil, and increase the laboratory recoveries in soil samples.

CROPWATN-P is a new model.

• Start point: a 1-dim. model CROPWATN for water, solute and heat balance.

• Added: preferential flow. The main difference between the two flow domains is that the potential flow approaches of MACRO and CROPWATN-P, is the driving force for mass exchange between soil micro- and macropores. In CROPWATN-P, the pressure head is in pressure head, while moisture in MACRO. CROPWATN-P requires p-curves for macropore-domain.

• Added: preferential flow equations: application, sorption (Freundlich) and degradation (1st order kinetics, rate dependent on moisture, temperature and depth).

• Added soil freezing description: effects on heat balance; freezing as a drying process; hydraulic conductivity in frozen soil (Kice); Kice = Kwat (1 - P/F), where Kwat is hydraulic conductivity in non-frozen soil, a is constant and P/F is the volumetric fraction of ice in soil (Motovilov’s equation).

• Currently: thermodynamic equilibrium is not separated into the two flow domains; neither chemical exchange from ice crystals nor soil freezing / generation of new preferential pathways are taken into account.

Soil freezing

1. inhibits soil temperature changes
2. decreases the amount of liquid water
   ⇒ soil dries
3. decreases soil hydraulic conductivity
4. forms ice crystals from pure water
   ⇒ chemicals in soil solution are excluded
   ⇒ high chemical concentration in the soil solution at the freezing front
5. generates heaving
   ⇒ frost heave equal to the combined thickness of all ice lenses within the profile
   ⇒ may result new preferential pathways
6. First freezes the “free” water in the middle of large pores.
7. Freezing temperature depends on solute concentration.

References:


Results and conclusions

Simulation results (figures 2-16) obtained with MACRO 5.0 and CROPWATN-P did not differ remarkably from each other. Observed pesticide fate was not correctly simulated in either of the models. Simulated soil freezing effect on pesticide transport was negligible using the current version of CROPWATN-P and available dataset. Model development is going on.