Pesticide fate and climate: how are they linked?

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Enviresearch

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Outline

- What is fate?
- What is climate?
- Basic processes
- Indirect effects
- Modelling the link
- What really matters
FOCUS leaching scenarios

- **Substance**: FOCUS A
  - $K_{oc} = 103 \text{ L/kg}$
  - $DT_{50} = 60 \text{ d}$

- **Crop**: winter wheat

- **App date**: 1 April

- **Soil**: Okehampton
Scope
Weather or climate

**Weather**
- Rain this year
- Rainstorm today
- Barbeque summer
- Weather here or there

**Climate**
- Annual average rain
- Distribution of storm events
- Likelihood of a barbeque summer
- Weather patterns across the world
Climate in the context of agroecology

Basic processes

• Partitioning

• Chemical transformation

• Flow
Partitioning

- Solids
- Chemical Substance
- Gas phase
- Water
Temperature effects on solid-liquid partitioning

Cold = More adsorption

Hot = Less adsorption

Sorption and leaching and temperature

- 4 pairs of simulations
  - MV1 = baseline
  - MV3 = temperature-dependent sorption

- 3 show that inclusion of temperature – sorption gives lower leaching losses

Steffens et al., 2013. Agriculture, Ecosystems and Environment 172, pp. 24-34
## Percentage of pesticides in phases of soil

<table>
<thead>
<tr>
<th>Substance</th>
<th>Air</th>
<th>Liquid</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene dibromide</td>
<td>0.66</td>
<td>28.4</td>
<td>70.9</td>
</tr>
<tr>
<td>Dichlobenil</td>
<td>0.0013</td>
<td>4.6</td>
<td>95.4</td>
</tr>
<tr>
<td>Simazine</td>
<td>$1.3 \times 10^{-7}$</td>
<td>9.5</td>
<td>90.5</td>
</tr>
<tr>
<td>Lindane</td>
<td>$4.1 \times 10^{-5}$</td>
<td>0.8</td>
<td>99.2</td>
</tr>
<tr>
<td>DDT</td>
<td>$1.2 \times 10^{-6}$</td>
<td>$4 \times 10^{-4}$</td>
<td>~100</td>
</tr>
</tbody>
</table>

The effect of temperature on solubility and vapour pressure

- **Solubility (Van't Hoff)**
- **Vapour pressure (Clausius-Clapeyron)**
Summer and winter temperature in Europe

**Winter**
- ~ -15°C

**Summer**
- ~ 8°C
- ~ 30°C

Climate Research Unit, Univ. of East Anglia.
Soil moisture status across Europe

30 January 2016

>40%

28 August 2016

<10%

NASA Worldview (SMAP L-Band Radiometer)
Soil moisture at 10 cm depth in Okehampton soil

Days from start of simulation

Soil moisture (%)

Okehampton climate

Sevilla climate
Factors affecting chemical transformation in surface water

Arenas-Sanchez et al., 2016. Science of The Total Environment 572, pp. 390–403
Contaminant travel time as a function of aridity and storminess

Key climatic variables as determined by MACRO simulations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean April to June temperature (°C)</td>
<td></td>
</tr>
<tr>
<td>Mean September to November temperature (°C)</td>
<td></td>
</tr>
<tr>
<td>Mean October to March precipitation (mm)</td>
<td></td>
</tr>
<tr>
<td>Mean annual precipitation (mm)</td>
<td></td>
</tr>
<tr>
<td>Number of days (April to June) where total precipitation &gt; 2 mm</td>
<td></td>
</tr>
<tr>
<td>Number of days (April to June) where total precipitation &gt; 20 mm</td>
<td></td>
</tr>
<tr>
<td>Number of days (April to June) where total precipitation &gt; 50 mm</td>
<td></td>
</tr>
<tr>
<td>Number of days (September to November) where total precipitation &gt; 20 mm</td>
<td></td>
</tr>
</tbody>
</table>

Nolan et al., 2008. Pest Management Science 64. pp. 933-944
Rainfall R-factors across Europe

Global runoff

Major physical pathways (wind, rivers and ocean currents) that transport contaminants to the Arctic

Macdonald et al., 2005. Science of the Total Environment 342, pp. 5-86
Delivery routes of contaminants to the arctic and subsequent fate

Macdonald et al., 2005. Science of the Total Environment 342, pp. 5-86
Indirect impacts of climate

**Main impacts**
- The decision to cultivate a piece of land
- The crop species
- The cultivar
- Irrigation
- Selection of pesticide
- Rate, timing and frequency of pesticide use.

**A collection of references**
- Chen & McCarl, 2001
- Bloomfield et al., 2006
- Boxall et al., 2009
- Noyes et al., 2009
- Tu, 2009
- Kattwinkel et al., 2011
- Wilson & Weng, 2011
- Visser et al., 2012
- Delcourt et al., 2015
- Gagnon et al., 2015
- Steffens et al., 2015
Climate change

Projected change in winter temperature (°C)

Projected change in consecutive summer dry days (d)

Ciscar et al., 2014. Climate Impacts in Europe. The JRC PESETA II Project. JRC Scientific and Policy Reports, EUR 26586EN.
Impact of climate change on pesticide fate

- **Partitioning**
  - Lower sorption
  - More volatilisation

- **Chemical transformation**
  - Faster reactions due to high temperature
  - Slower reactions due to dry soils
  - More phototransformation

- **Flow**
  - More leaching
  - Faster contaminant movement in rivers
  - More pesticide runoff, erosion and macropore flow
  - More atmospheric transport
  - Changing oceanic pattern of global redistribution

- **Indirect effects**
  - Increased arable area will mean pesticides will be used in new areas
  - Higher pest pressure will lead to an increase of pesticide use overall
  - Regulatory and technological change: effects uncertain
Conclusion: What is important?

“In the long-term, land-use change driven by changes in climate may have a more significant effect on pesticides in the environment than the direct impacts of climate change on specific pesticide fate and transport processes.”

Bloomfield et al., 2006. Science of the Total Environment 369, pp. 163-177