Kinetic Evaluation of Field Dissipation Studies: Applying MCMC Simulator DREAM for Parameter Inference and Uncertainty Analysis

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Introduction and Objective

In legacy field dissipation studies, plant protection products (PPP) were applied to soil surface or to cropped plots. Consequently, surface processes other than (microbial) degradation might contribute to the overall dissipation of PPP mass in a soil profile. The properties of the compound as well as agro-climatic conditions will influence degradation, plant uptake and leaching below the lowest sampling depth, particularly if the depth of sampling is limited. A recent EFSA guidance document[1] provides criteria to be followed to determine a true DegT50 from those field trials. The guidance lacks some information about the detailed procedure to derive DegT50 of metabolites, particularly if global solvers or inverse modelling approaches are to be considered. A novel approach is presented, which allows a comprehensive evaluation of such legacy field dissipation studies in order to derive suitable model input for exposure assessment of parent and metabolites. The approach combines the mechanistic model (PEARL) and the Bayesian statistical methodology (DREAM_ZS as global solver).

Materials and Methods

- 16 field degradation studies (6 uncropped) for the duration of approx. 1 year
- Dynamics of residues of parent substance and metabolite summed up for the first 30 cm of the soil profiles (3 trials not evaluated as no metabolite detected)
- EFSA 10 mm rainfall criteria considered to exclude surface processes
- Parent test substance non-volatile and photolytically stable
- Masses compared to simulations using FOCUS PEARL 4.4.4., coupled with the Markov chain Monte Carlo simulator DREAM[2] for parameter inference, using MATLAB[3]. Figure 1 shows a schematic of the overall modelling process
- In total, 4 parameters estimated: applied mass (M0), DegT50 for both parent substance and metabolite, and formation fraction (*ff*) of the metabolite
- Description of the goodness of fit: 95-% confidence intervals for the parameter values, error criterion based on a χ^2-significnce test (ε), t-test (see box below)
- Fractions of masses leached and taken up quantified. Correlations between *ff* and DegT50meta found in most cases
- The set of field trials was also evaluated using the regular FOCUS assessment
- Other (fixed) input parameters: *K*om(parent) = 124 L kg^{-1}, *K*om(meta) = 5.8 L kg^{-1}; plant uptake factor (both species) = 0.5; dispersion length (whole profile) = 5 cm

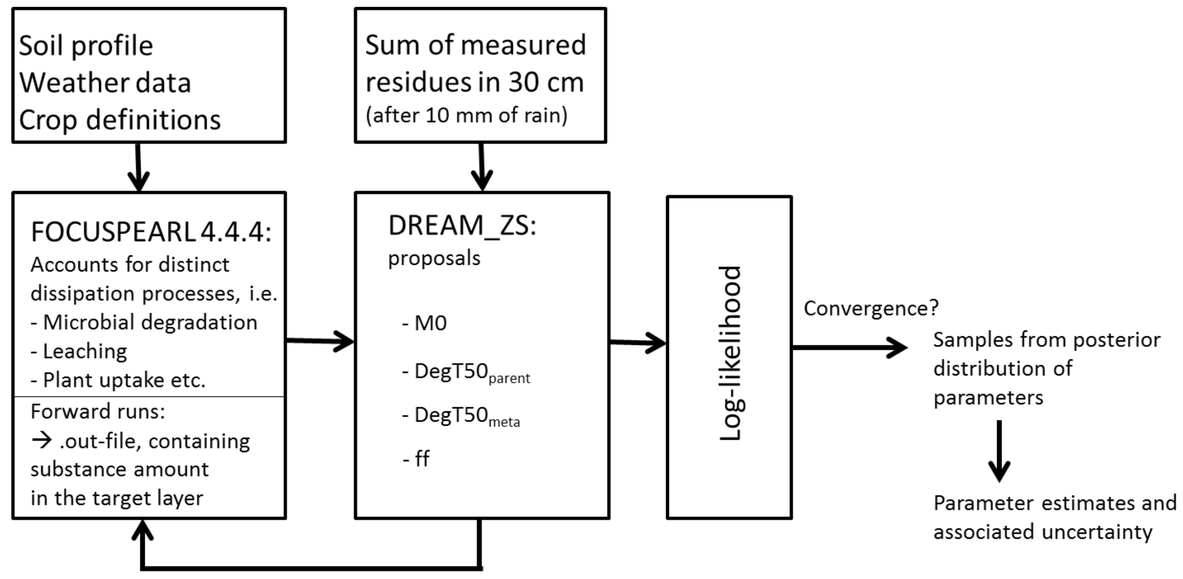


Figure 1: Inverse modelling process.

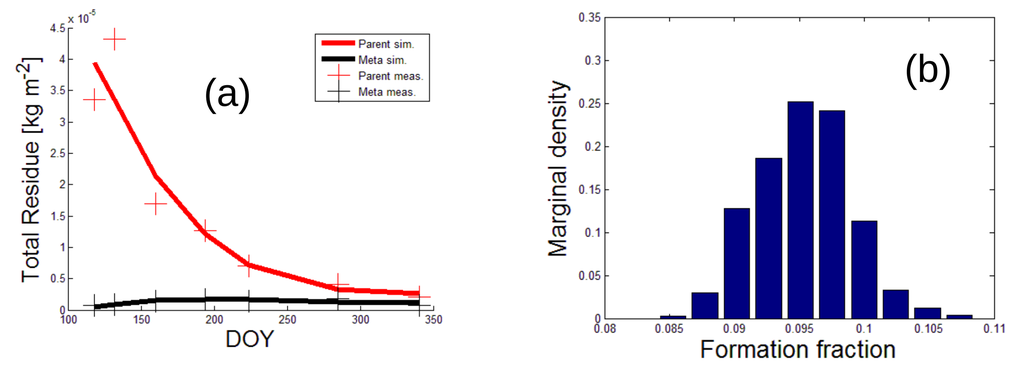
Results & Discussions

- Table 1 shows best parameter estimates, scaled errors (ε), the fractions of leached and uptaken masses of the metabolite. The estimation of the best parameters for the formation fraction was achieved with particularly small uncertainties
- Generally, the measurements were well reproduced by the parameter inference (example case 2 in Fig. 2 (a))
- Posterior distribution functions of the parameters: single, well defined maxima (bell-shaped) for both parent (not shown) and metabolite (Fig. 2 (b) and (c))
- Error surface plot of *ff* and DegT50meta (Fig. 2 (d)) demonstrates the high sensitivity besides the almost equivocal estimation for the DegT50meta
- In comparison with the regular evaluation following FOCUS, the number of valid cases increased from 4 (1 bare soil, 3 cropped trials) to 9
- In those cases where the sum of other processes than microbial degradation (i.e. leaching below the target depth of 30 cm and plant uptake) were high (74% up to 94%), and there was a low correlation between *ff* and DegT50meta (< 0.09), the assessment became not reliable in terms of confidence intervals (cases 6, 7, 11, and 13), since the upper boundaries tended toward the maximum of range

Table 1: Results of the parameter inference for the metabolite for all field trials, best estimates along with 90-% confidence intervals (lower (lb) and upper (ub) boundary) and scaled errors (ε). Leached and uptaken masses were related to the total mass of formed metabolite; linear correlation is given for *ff* vs. DegT50meta

Case no.	DegT50meta [d]			Formation fraction *ff* [-]				% mass leached below 30 cm	% mass uptaken	Correlation *ff* vs. DegT50
	Best	lb	ub	Best	lb	ub	ε [%]			
1*	**113**	86.7	159	**0.088**	0.084	0.092	**30.7**	72	-	0.69
2*	**44.0**	39.7	50.1	**0.096**	0.089	0.101	**16.7**	6.6	-	0.79
3*	**37.9**	33.7	46.2	**0.115**	0.105	0.122	**27.9**	32	-	0.81
4*	**32.4**	29.2	37.7	**0.078**	0.071	0.081	**39.2**	29	-	0.65
5	**112**	70.7	239	**0.194**	0.177	0.205	**28.6**	66	12	0.72
6	**1424**†	910	1471	**0.108**	0.103	0.110	**23.0**	80	14	0.02
7	**348**†	336	348	**0.090**	0.087	0.092	**26.4**	63	23	0.05
8	**34.1**	30.5	37.6	**0.169**	0.161	0.178	**17.0**	22	16	0.72
9	**186**	133	326	**0.127**	0.118	0.135	**22.5**	57	13	0.72
10	**71.8**	61.2	89.0	**0.150**	0.142	0.156	**24.5**	17	18	0.95
11	**962**†	745	996	**0.082**	0.079	0.085	**45.7**	24	50	0.01
12	**45.7**	40.8	45.7	**0.102**	0.102	0.109	**13.9**	6.7	26	0.63
13*	**276**†	183	350	**0.218**	0.213	0.226	**24.0**	87	-	0.09

* Trials with bare soil
† less reliable results, i.e. upper boundary tends towards the maximum range



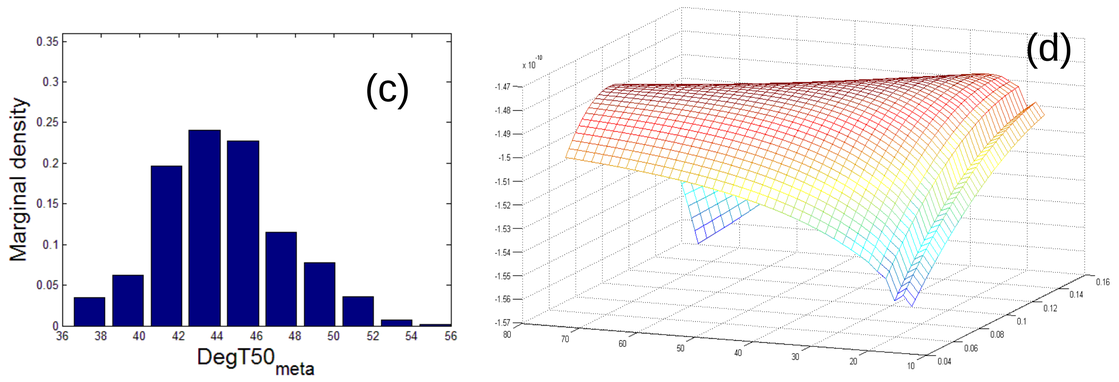


Figure 2: Example of the results of case 2: (a) measurements vs. simulations, posterior distribution for (b) the formation fraction, and (c) the DegT50 of the metabolite. A surface plot (d) shows the sensitivity in terms of formation fraction and DegT50.

T-Test using best posterior parameter samples

- Bayesian methods do not go together with a frequentist t-test
  → positive parameters with priors that reject all negative samples
- T-test that makes use of the best posterior parameter samples can be performed following FOCUS
- T-test proved a statistically valid parameter inference, e.g. resulting in p-values for case 2: DegT50meta: 0.00048, *ff*: 6.1E-05, DegT50parent: 0.00042, M0: 1.5E-05

Conclusions / Benefits of the proposed strategy

- ✓ Makes optimal use of largely available legacy field dissipation studies:
  - ✓ Increased number of statistically reliable evaluations
  - ✓ Evaluation of real degradation times (DegT50) instead of dissipation times (DT50), based on inclusion of all processes, i.e. plant uptake, leaching, degradation
  - ✓ Simultaneous estimation of metabolite formation fraction and degradation rate
  - ✓ Consideration of all EFSA and FOCUS kinetics criteria possible
- ✓ Robust estimation of best parameter values; statistically sound 90-% confidence intervals using a global optimisation strategy
- ✓ Global optimization avoids dependency on initial values for the parameters

Acknowledgement

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References

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