

Introduction to process-based models

'Process-based models represent and simulate physiological and biogeochemical processes and their interactions with the abiotic environment (water, climate, and nutrients) by using functional relationships'

[Larocque et al. 2016. Ecological forest management handbook. CRC press, Boca Raton. pp.223-267].

Models to predict radionuclide activity concentrations in human foodstuffs tend to use empirical soil-to-plant transfer factors (also known as soil-plant concentration ratios) to describe the transfer of radionuclides from soil to crops. Process-based soil-plant transfer models have existed for nearly two decades, but are rarely used in emergency planning. To date most consideration in the development of process-based soil-to-plant transfer models has been focussed on radiocaesium.



CONFIDENCE Workshop: Do process-based models have a role in human food chain assessments?

CIEMAT, Madrid, Spain, 9th -11th September 2019

The aim of this CONFIDENCE workshop was to discuss soil-plant process-based models with a range of stakeholders (industry, regulators, scientists and representatives from international organisations) to gain opinion on if stakeholders saw benefit in process-based model use and development. In part, this was motivated by the priority given to process-based models by scientists (e.g. in the ALLIANCE Strategic Research Agenda) versus a perceived lack of uptake of process-based models by end-users. A number of presentations were given to aid discussion, including: 'conventional' food chain models (e.g. the FDMT module of JRodas and FARMLAND); an overview of process-based soil-plant models for Cs; application of process-based soil-plant models for Cs post Fukushima in Japan; a regulators perspective of process-based models; CONFIDENCE activities on Cs and Sr process-based soil-plant models. Presentations were followed by facilitated 'breakout' sessions to discuss process-based models and their use. To prompt discussion the following questions were posed:

- 1) What is stopping 'you' from using process-based models?
- 2) Do process-based models have a use in post-accident management?
- 3) When should process-based models be used/when are they useful?
- 4) Are we confident that process-based models have been sufficiently parameterised/tested?
- 5) Are process-based models useful in communicating information?

The cases 'for' and 'against' process-based models

A number of workshop participants expressed some doubts about process-based models:

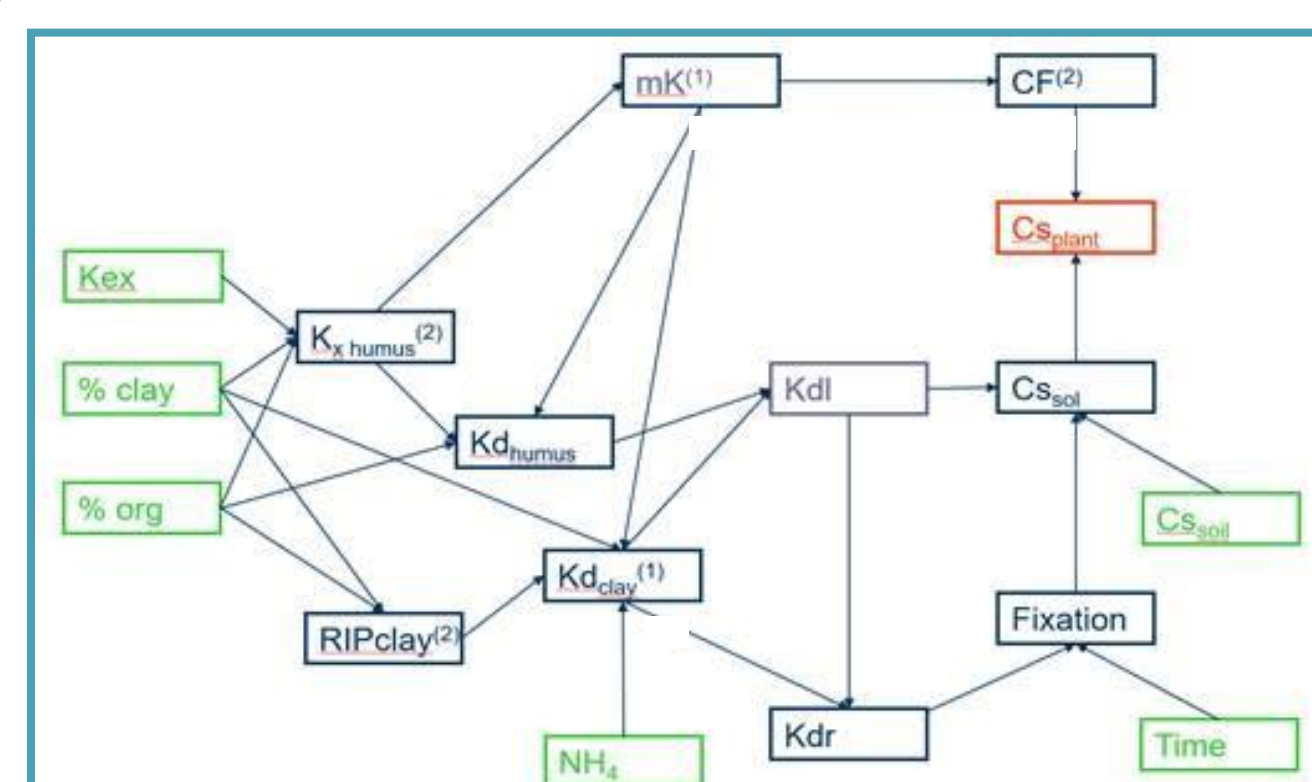
- Process-based models are too complicated requiring a considerable amount of data to implement them
- As a consequence of their complexity process-based models are difficult to communicate to stakeholders including the public
- Process-based models have not been sufficiently tested and hence end users are not confident in their use
- Scientists have not 'made the case' for process-based models
- Change to an established system (i.e. modelling approach) has financial and time implications

Other workshop participants (including regulator/industry end-users) were of the opinion that process-based models could be useful:

- Process-based models offer an approach to understand/address the high degree of variability in empirical plant-soil concentration ratios and provide predictions more relevant to a given site
- Process-based models (if not too complex) may be easier to explain to the public than a 'black-box' model as they better reflect reality (e.g. a model that bases predictions on easily understandable soil parameters such as percentage clay, organic matter content and/or soil potassium is easier to explain than a 'black-box' model with ratios and rate constants).
- Process-based models may be useful for site-specific assessments of existing exposure scenarios
- Process-based models may be useful in emergency planning (though the required data (e.g. soil properties) would be needed for sites)
- Process-based models may help to justify and guide model simplifications



'Take home' messages for CONFIDENCE



A diagrammatic representation of the soil-to-plant transfer Cs model as proposed by Tarsitano et al. (2011) (courtesy of Prof. N.M.J. Crout, University of Nottingham)



There are clearly some issues we need to address before process-based soil-to-plant transfer models become more widely accepted. **For Cs**, although we appear to be able to make **relatively good predictions** of activity concentrations in grass, predictions for other crops are currently relatively poor. **CONFIDENCE has made good progress in developing process-based soil-to-plant transfer models for Sr** although these models currently can only make equilibrium predictions of Sr activity concentrations in crops. We acknowledge the **need to validate available process-based soil-to-plant transfer models for a wider range of scenarios** (soil types and crops). Once this is done, then **uptake of process-based models would benefit from some well-designed training provision** aimed at different stakeholders with demonstrations of the comparative predictions of process-based and conventional empirical concentration ratio based models.

When communicating process-based models to regulators and other stakeholders **we need to make it clear that process-based models are not necessarily complicated and/or resource intensive** (for example in the case of Sr, the simplest model proposed by CONFIDENCE requires only calcium concentrations in soil and plants). **End users need to have confidence in the outputs of models** which stresses the importance of **communication** and of **model validation and inter-comparison** exercises. Models should be **optimised to those few key parameters that really matter** (the development of models for Sr in CONFIDENCE is an example of such parameter optimisation/model reduction). Model complexity may change depending upon need, but it would be **useful to have one modelling package** from which different components could be selected. The implementation of FDMT, the 'Absalom' model and a model for 'hot particles' into the EGOLEGO package within CONFIDENCE is a step to meeting this recommendation.

With respect to post-accident response, the majority of workshop participants agreed that the application of process-based models would become more relevant as time progressed and when more specific questions with regard to contaminated areas needed to be answered. In the earlier stages after an accidental release, many considered that conventional models (e.g. FDMT, FARMLAND etc.) would be adequate. However, **if process-based models were sufficiently validated and spatially implemented, they could also play an early role in identifying areas where food chain issues may persist into the longer-term**. The comment (made a number of times) that, conventional models would be sufficient in the short-term but perhaps not optimal in the longer-term, implies that **long-term predictions from conventional models should be communicated with care**. It was also suggested that process-based models may be of relevance to other scenarios, and radionuclides, including long-term assessments of waste disposal facilities.