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A new general mechanistic river model for radionuclides from single pulse fallouts which can be run by readily accessible driving variables

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Abstract

This paper presents a new general, process-based river model for substances such as radionuclides from single pulse fallouts. The new model has been critically tested using data from 13 European rivers contaminated by radiocesium from the Chernobyl accident. This modelling approach gives radionuclide concentrations in water (total, dissolved and particulate phases; and also concentrations in sediments and fish, but the latter aspects are not discussed in this paper) at defined river sites. The model is based on processes in the upstream river stretch and in the upstream catchment area. The catchment area is differentiated into inflow (≈dry land) areas and outflow (≈wetland) areas. The model also accounts for time-dependent fixation of substances in the catchment. The catchment area sub-model is based on a previous catchment model, which has been tested with very good results for radiocesium, radiostrontium and Ca-concentrations (from liming operations). The new river model is simple to apply in practice since all driving variables may be readily accessed from maps and standard monitoring programs. The driving variables are: latitude, altitude, continentality, catchment area, mean annual precipitation, soil type (percentages or organic and sandy soils), fallout and month of fallout. Modelled values have been compared to

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independent empirical data from 10 rivers sites (91 data on radiocesium in water) covering a wide domain (catchment areas from 4000 to 180 000 km^2, precipitation from 500 to 960 mm/yr and fallout from 1700 to 660 000 Bq/m^2). The new model predicts very well – when modelled values are compared to empirical data, the slope is perfect (1.0) and the r^2-value is 0.90. This is good giving the fact that there are also uncertainties in the empirical data, which set a limit to the achieved predictive power, as expressed by the r^2-value.

Keywords: River; Model; Catchment; Fixation; Chernobyl; Runoff; Radionuclides; Validations; Predictive power

1. Introduction and aim

In radioecology, it is important to model, understand and predict the "peak and the tail" concerning radionuclide concentrations in rivers related to a given accidental fallout (IAEA, 2000; Sansone and Voitsekhovitch, 1996; Strand et al., 1996; Smith et al., 2004). Quantifying the monthly transport of radionuclides in rivers from an accidental fallout is the focus of this paper.

In modelling, one must often find a balance between answering interesting, often important, questions of understanding and delivering a practical tool to society. In a strict sense, there is no such thing as a general ecosystem model, which works equally well for all ecosystems (of a give type) and at all scales because all models need to be tested against reliable, independent empirical data. The data used in such validations must of necessity belong to a restricted domain. At any modelling scale, the complexities of natural ecosystems always exceed the complexity and size of any model. Simplifications are always needed, and this entails problems. The ultimate obstacle in achieving predictive power and general validity for a model is to find the most appropriate simplifications, and/or omit small and irrelevant processes related to the given target variables to be predicted (Monte, 1995, 1996; Monte et al., 1997; Peters, 1991; Håkanson and Peters, 1995).

The new river model presented here is meant to predict monthly concentrations in water based on processes and mechanistic principles. At the same time, it should be as small as possible and the obligatory driving variables should be readily accessed. The actual tests of the model will use empirical data from 13 European rivers (Table 1). The model is partly based on a lake model which has been validated with very good results for radiocesium (Håkanson, 2000), radiostrontium (Håkanson et al., 2002) and Ca from liming (Håkanson, 2003). The first step of this work was to make the transformation of the lake model to a river model, the second step to calibrate the new river model, the third to validate the model against independent data and the fourth to demonstrate the practical use of the model. Radiocesium is used as a type substance but the basic idea is to develop a generic model that could be applied to all radionuclides (and metals, organics and nutrients as well).