Integration of long-term radionuclide transport models
MOIRA-LAKE and MOIRA-RIVER into Hydrological Dispersion Module of JRODOS

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Abstract – The integration of the lake and river MOIRA models into the JRODOS Hydrological Dispersion Module (HDM) modelling framework, that originally only predicted short-term radionuclide dispersion in river systems, was a key objective of the PREPARE project. Thanks to it, the capabilities of JRODOS-HDM have been increased with regard to modelling the long-term fate of radionuclides (137Cs and 90Sr) in freshwater systems and to predicting the radiation doses via aquatic exposure pathways, as well as the efficiency of countermeasures to improve the radiological impact. Validated models have been implemented and exhaustive verification tests have been performed for both lake and river scenarios.

Keywords: freshwater long-term contamination / decision support / JRODOS/MOIRA

1 Introduction

MOIRA (“A MOdel-based computerised system for management support to Identify optimal Remedial strategies for restoring radionuclide contaminated Aquatic ecosystem and drainage areas”) (Monte et al., 2009) is a decision support system (DSS) designed to address the mid- and long-term management issues in the years or decades after the post-accidental contamination of freshwater bodies and catchments with radionuclides. It was developed and tested during the 4th–6th Euratom Framework Programme (FP4–FP6) projects MOIRA (Monte et al., 2000), COMETES (Monte et al., 2002), EVANET-HYDRA (Monte et al., 2005) and EURANOS (Gallego et al., 2010). The latest version, MOIRA-PLUS,1 incorporates many features derived from user’s experience and feedbacks (Monte et al., 2009).

The main components of MOIRA are validated models for predicting the dynamic behaviour of 137Cs and 90Sr in lakes, rivers and drainage areas and well as the effect of selected countermeasures to reduce the contamination levels. The models have been validated against historical data from several lakes and rivers, including post-Chernobyl contamination scenarios (Monte et al., 2009). The MOIRA DSS also has models to assess doses to man and biota (fish) and to evaluate the residual dose after implementing countermeasures affecting the direct human exposure to contaminated elements.

The integration of the lake and river MOIRA models into the JRODOS Hydrological Dispersion Module (HDM) modelling framework – that originally was a tool for the prediction of short-term radionuclide dispersion in river systems (Zheleznyak et al., 2010), was an objective of the PREPARE project, responding to suggestions made by users of both DSS.

2 Integration methodology

Several new elements have been developed, as for example, – all the MOIRA Models as Fortran modules, the model-specific JRODOS User Interface, the tools for data exchange between models and user interface, transfer of the GIS data available in the MOIRA DSS into the JRODOS GIS, and integration into the overall JRODOS structure to facilitate interconnection between the implicated modules and adequate presentation of results.

The new MOIRA model chains comprise the following sequence of processes which are required for a proper assessment:

– Atmospheric fallout to on the water body and its catchment and further migration in the mid- and long-term (months up to years or decades) after an accident. Manually input or read from previous calculation with the atmospheric dispersion and deposition modules of JRODOS DSS. This is particularly important for complex catchments like those in rivers (Figure 1).
– Radionuclide dispersion and transformation in lakes or in complex river/catchments (both in the abiotic and biotic part) in the mid- and long-term (months up to years or decades) after an accident. As additional features, the doses to aquatic biota (pelagic and benthic fishes) are incorporated into the MOIRA Lake and River Models.
– Doses to biota and people via aquatic exposure pathways.
– Flexible definition of management strategies by combining countermeasures (chemical, physical, and social).
– Analysis of the impact of countermeasures/strategies, in terms of reduction of contamination (a cycle of simulations can be initiated depending on the specification of countermeasures to analyse (Table 1)).

3 Verification and applications

In order to verify the correct implementation of MOIRA models into JRODOS, the developed new modules have been carefully tested against previously well-studied cases with MOIRA-PLUS.

Three lake scenarios were chosen: Lake Palancoso (Spain), Lake Kozhanovskoe (Russia) and Lake Svyatoye (Belarus),
the last two seriously contaminated after the Chernobyl accident; and two river scenarios in Spain: Ebro–Ascó NPP and Tagus–Almaraz NPP (Gallego and Montero, 2016).

To illustrate features of the MOIRA Lake model, Figure 2 displays the $^{137}$Cs concentration in omnivore and piscivore fishes for the post-Chernobyl contamination produced in Lake Kozhanovskoe in Bryansk region in Russia (Monte et al., 2002). For the same scenario, Figure 3 shows the capacity of the new model to simulate different countermeasures in lakes, by decreasing the activity in sediments and fishes.

4 Conclusions

After the PREPARE project, JRODOS DSS has increased its capabilities by incorporating new modules from MOIRA DSS, which allow to model the long-term fate of radionuclides ($^{137}$Cs and $^{90}$Sr) in freshwater systems: lakes and rivers. The new models also estimate the effectiveness of countermeasures to reduce radionuclide concentrations in water, sediments and fish. These new modules, integrated with the food and dose model FDMA, also assess radiation dose to people and livestock, as well as the impact of bans to reduce doses. All test cases show a correct integration of the MOIRA Lake and River models, as well as the GIS and the fallout distribution tools.

Acknowledgement. The research leading to these results has received funding from the European Atomic Energy Community Seventh Framework Programme FP7/2012-2013 under grant agreement 323287.

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Cite this article as: E. Gallego, L. Papush, I. Ievdin, A. García-Ramos, R. Pato-Martínez, L. Monte. Integration of long-term radionuclide transport models MOIRA-LAKE and MOIRA-RIVER into Hydrological Dispersion Module of JRODOS. Radioprotection 51(HS2), S141-S143 (2016).