Radioprotection 51(HS2), S141-S143 (2016)

DOI: 10.1051/radiopro/2016051

Enhancing of the existing decision support systems with capabilities of importance – *Aquatic dispersion and consequence modelling*

Available online at:
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ARTICLE

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 (^{137}Cs and ^{90}Sr) 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 ^{137}Cs and ^{90}Sr 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).

[1] MOIRA-PLUS is available at the web-site https://sites.google.com/site/moirasoftware/.

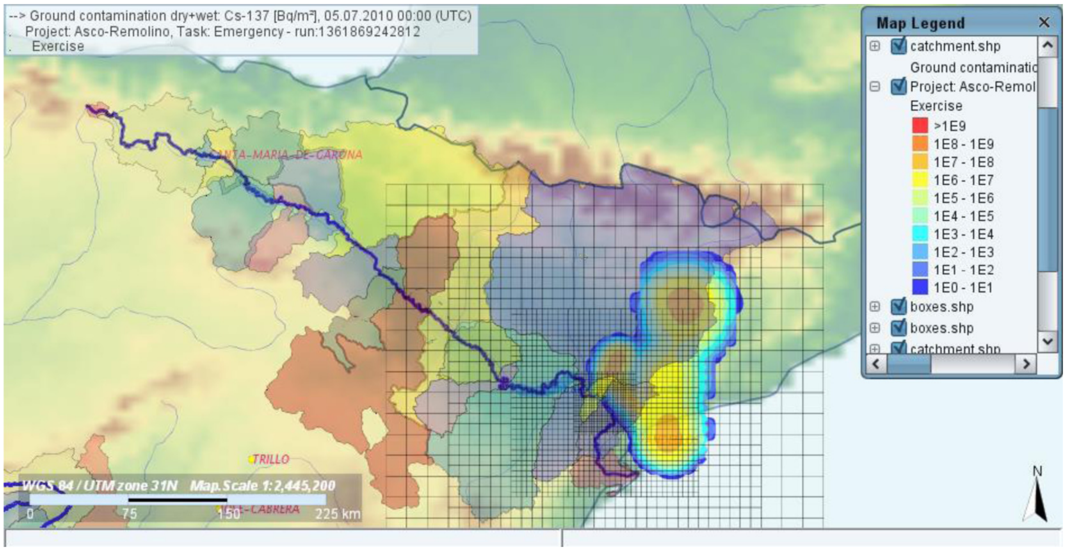

Figure 1. Display of the JRODOS MOIRA River screen with a test scenario based on a release at Ascó NPP (Spain), showing the JRODOS atmospheric dispersion calculation grid and the Ebro river structure of the catchment (20 boxes).

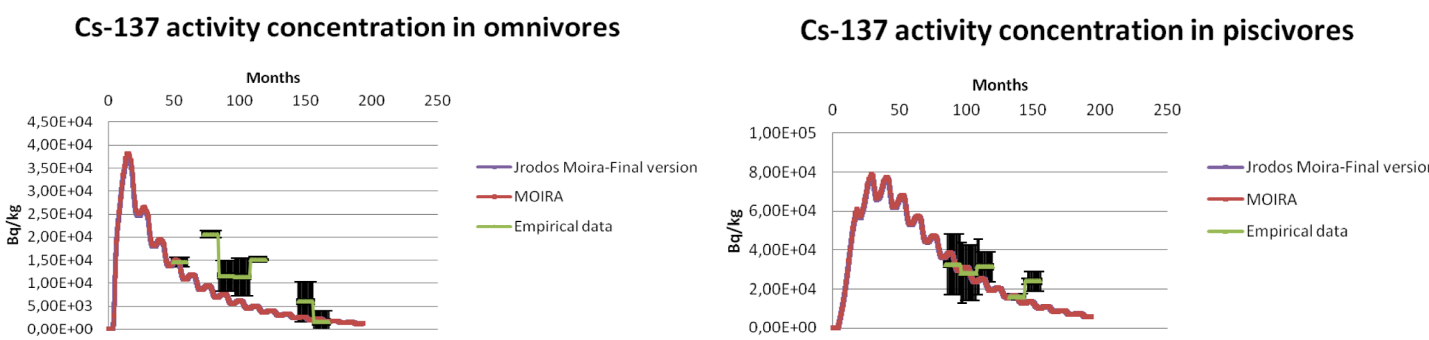

Figure 2. Predicted and empirical data for ^{137}Cs activity concentration in fishes (piscivores and omnivores). The results obtained with both the original MOIRA DSS and the JRODOS DSS are identical.

Table 1. Countermeasures available for simulation in the new MOIRA-JRODOS modules.

Application of chemical agents (only in lakes) (time dependent)	Application of physical measures (time dependent)	Application of social restrictions (in FDMA) (in user defined periods)
• Potash treatment • Direct liming • Wetland liming • Fertilisation	• Removal of sediments (lakes and rivers) • Removal of snow and ice (lakes) • Water flow diversion between segments (rivers)	• Bans on fish consumption • Bans on water ingestion • Bans on irrigation

– Radionuclide dispersion and transformation in lakes or in 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),

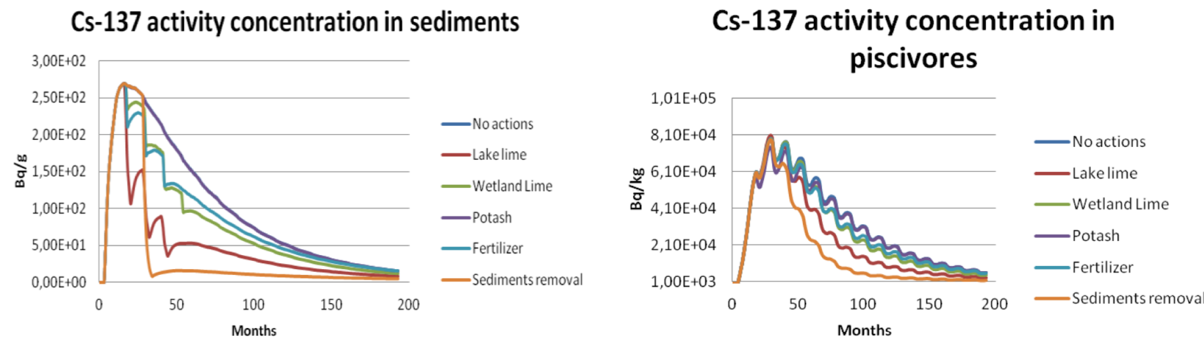

Figure 3. Predicted effect of some countermeasures on the evolution of ^{137}Cs activity concentration in sediments and fishes (piscivores). Only results obtained with the new JRODOS DSS modules are displayed, but are identical to those with MOIRA DSS.

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).