MATHEMATICAL MODELLING OF RADIONUCLIDE BEHAVIOUR IN THE VIENNE RIVER DURING ROUTINE RELEASES OF THE CIVAUX NUCLEAR POWER PLANT

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INTRODUCTION

The Civaux nuclear plant, currently under construction, is located on the Vienne river in west centre of France, a river with a minimal monthly average flow rate of 23 m^3/s. Special attention was given to the prediction of radioactive contamination of the river due to the routine discharge of liquid wastes at low flow during summer. To address this issue, a one-dimensional unsteady model, named CALIDO, was developed to simulate radionuclide transport along the 120 km stretch of the Vienne river, from Civaux to the confluence with the Loire river. It takes into account the processes governing sediment transport and radionuclide exchange between water and suspended matter. The model's aim is to assess the radiocontamination of the three main compartments of an hydraulic ecosystem, the water, the suspended matter and the bottom sediments.

THE CALIDO MODEL

CALIDO is a one dimensional non stationary model taking into account longitudinal dispersion. It calculates the distribution of activity concentration in water, suspended matter and bottom sediments as a function of time and space. With this aim in view, the river is divided into longitudinal sections according to the flow stream. The model calculates both the interactions between the environmental compartments and the linkage of the successive river sections as shown in figure n° 1.

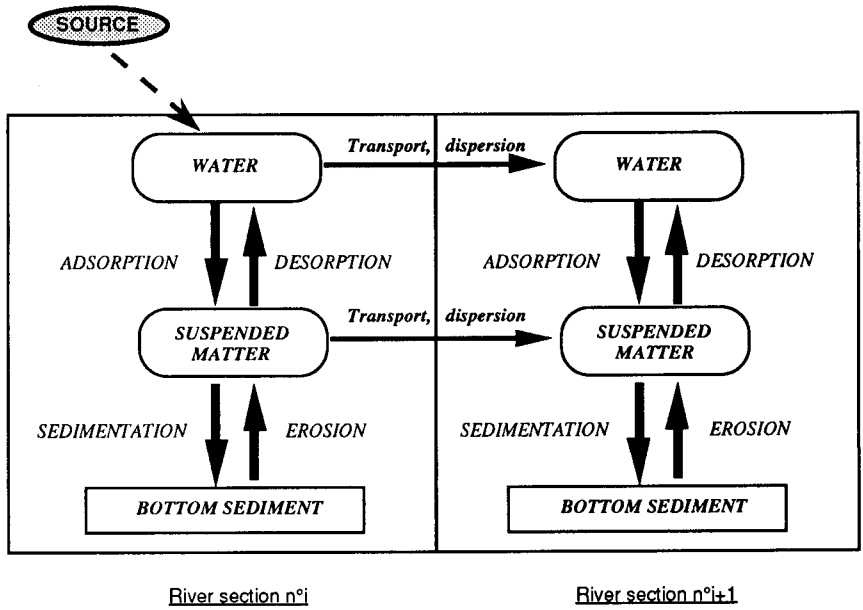

figure n°1 : Processes included in the model and linkage of successive river sections.

The global model is subdivided in three coupled submodels:
- The hydrodynamic submodel assesses river flow, depth and velocity in each section. We use a fully complete 1D hydraulic model named LIDO which solves free surface flow problems in rivers. LIDO requires a very accurate bathymetry to describe the natural form of the river. It calculates hydraulic parameters in sections of a few hundred meters long.
- The sediment model uses the results of the hydraulic model, it simulates the transport and the dispersion of suspended matter in water column. The processes of sedimentation and resuspension are modelized by the classical laws of Krones and Partheniades. Sedimentation and resuspension (which are regulated by two parameters: settling velocity and erosion rate) occur at constant critical shear stresses which have to be calibrated.

- The exchange model describes the exchanges of radionuclides between the dissolved and the particulate phases. The exchanges are modelized using a kinetic equation for a one step reversible reaction which leads to an equilibrium characterized by the distribution coefficient K_d.

CALIBRATION OF THE MODEL

The hydrodynamic submodel : the bathymetry of the Vienne river (data of main section profiles) was achieved and we performed several tracings of the river in order to calibrate the roughness coefficients of each river sections.

The sediment submodel : to obtain site-specific values of the four submodel parameters (settling velocity, erosion rate, critical deposition and erosion shear stress) a concentrated effort at field data collection downstream of Civaux was required :

- during the summer period, the concentration of the suspended matter in the river was measured every 8 hours at a few selected locations along the river. These measurements were used to calibrate the submodel by comparison between measured and calculated results. A field survey of bottom sediments was undertaken at low flow to gain information on the thickness and size distribution of the sediment layer. The vertical profile of the suspended matter was examined at a low velocity location of the river. It allowed us to calculate the settling velocity of particles. Samples were collected weekly for size distribution analysis (measured by laser beam diffraction, using a Coulter particle size analyser). Besides, the organic fraction of the suspended matter was distinguished from the mineral fraction. These analyses were undertaken in order to calibrate the submodel for different granulometric or qualitative classes of the suspended matter.

The exchange model : in order to determine K_d and kinetic parameters for each radionuclide values, we performed both in situ and laboratory experiments. The radioactivity associated with suspended matter was measured in the Loire river during scheduled discharges from low activity waste tanks of the Dampierre nuclear power plant. The obtained results were compared with laboratory experiments aiming at studying the behaviour of some selected radionuclides in Vienne river water.

EXAMPLES OF CALCULATIONS

The first example shows the evolution of activity in water and suspended matter after a constant release in stationary conditions. The term source is a constant release of ^{58}Co with a 100 Bq/m^3 activity over a period of 4 hours. The river flow rate is about 23 m^3/s and the contaminated wave is followed over a period of 3 days from the site of release, Civaux. The results are presented in figure 2.

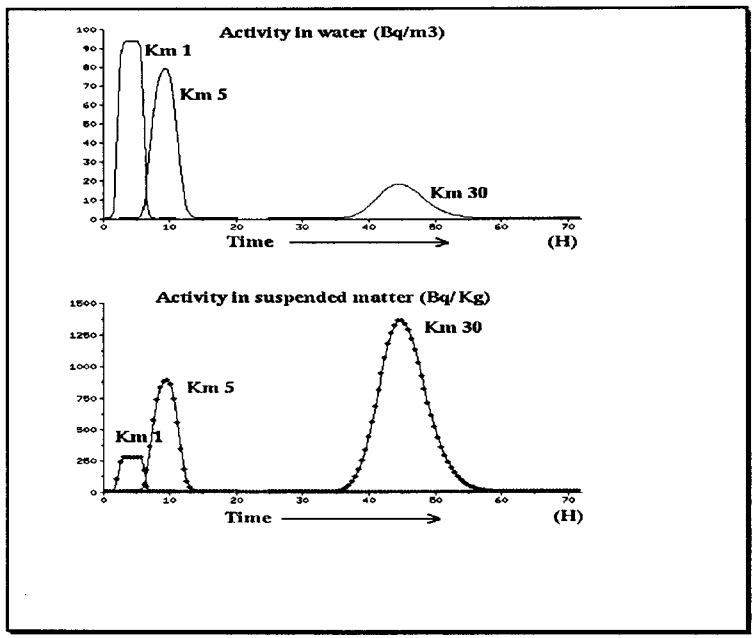

figure n°2: Calculated activities in water and suspended matter as a function of time presented at different distances from the site of release.

As a result of dispersion and adsorption, the concentration in water decreases and, simultaneously, the concentration in suspended matter increases.

The second example is the simulation of the routine functioning of the Civaux nuclear plant over the 1987 hydrologic conditions. Based on the daily river flow rate, a power plant effluent model simulates the daily release of radionuclides. The suspended matter concentrations at Civaux are also computed as a function of the daily river flow rate. Taking the example of ^{58}Co, one of the main released radionuclides, CALIDO model simulates its behaviour in the three compartments of the river during all the 1987 period. With such a kind of non stationary model integrating all the variability of meteorological conditions, it is possible to assess the radiocontamination of the river taking into account all the successive passings of contaminated waves. Figure n°3 focuses on the contamination of the bottom sediments at the end of summer 1987 between Civaux and the confluence of Creuse river. Expressed in Bq/m^2, the main contaminated areas are located just in front of major dams.

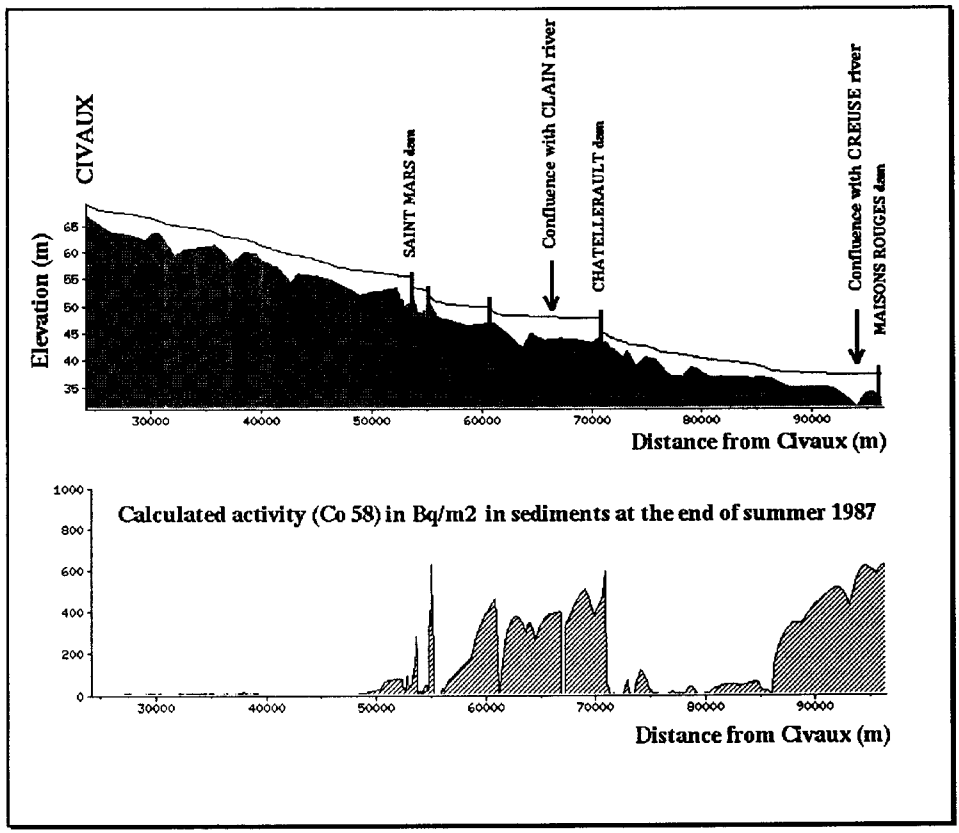

figure n° 3 : Calculated activity in sediments as a function of space at the end of summer 1987, after 9 months of simulated routine functioning of Civaux nuclear plant.

PROSPECTS

CALIDO is currently used with a single class of sediment. We are working at including different classes to integrate all the results of experiments.

The model will be coupled with other biological transfer models (transfers to biomasses) to assess the contamination of the upper level of the river food chain. The radiocontamination of the different compartments is a pathway to the contamination of man.