Mathematical Models for Assessing Remediation of Radioactively Contaminated Sites

IAEA TECDOC – under development

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CHAPTER 2 – CONCEPTUAL MODELS

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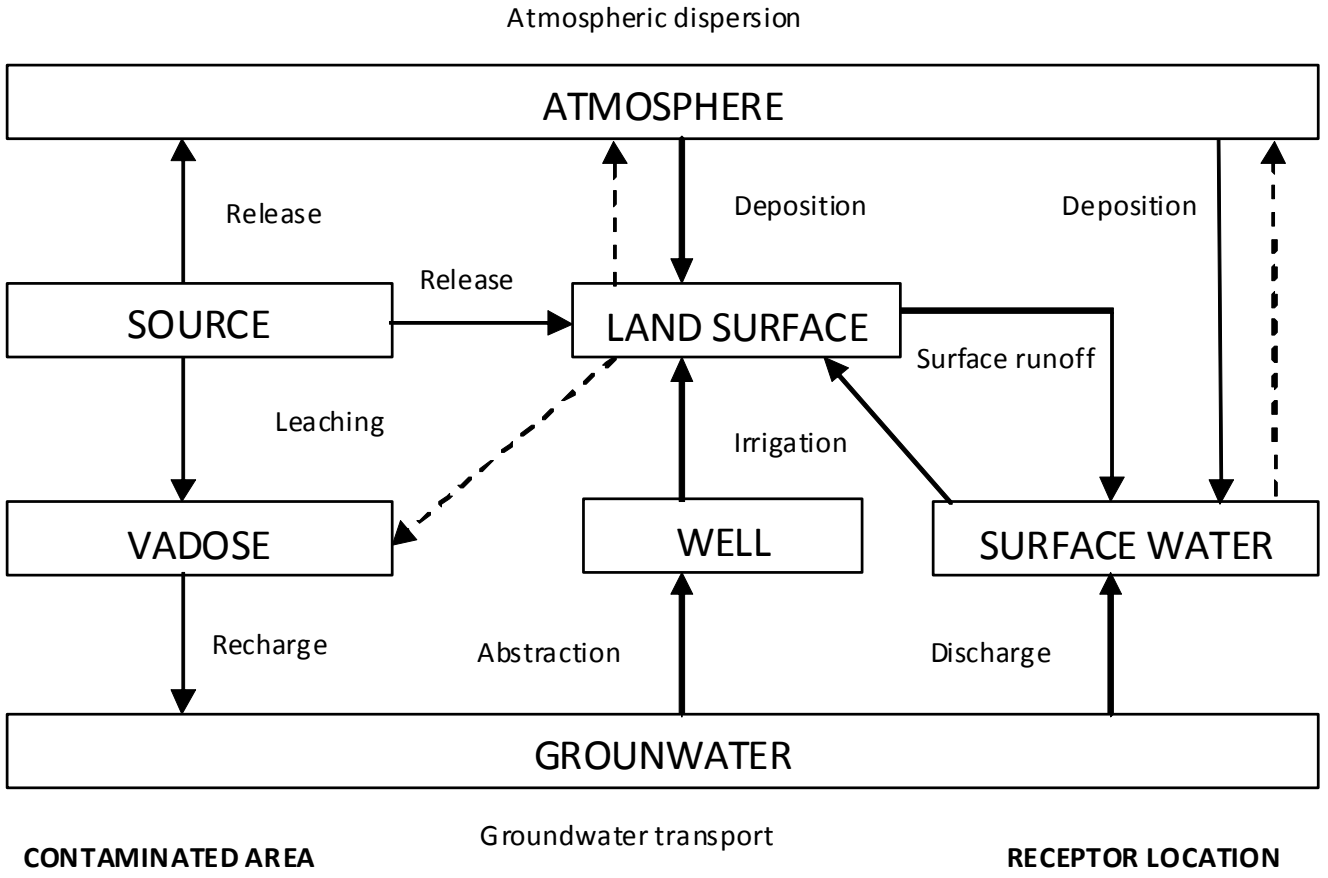
Main transport pathways



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Processes influencing the radionuclide transport

ATMOSPH	Rainfall Dry deposition Gas uptake			Rainfall Dry deposition Gas uptake	Rainfall Dry deposition Gas uptake	
Resuspension Volatilization/ Emanation Evaporation Transpiration	Source	Percolation Advection Diffusion Dispersion Colloid transp.		Erosion Surface runoff Sedimentation		
		Vadose	Recharge Advection Diffusion Dispersion Colloid transp.			
		Capillary rise Advection Diffusion Colloid transp.	GW		Discharge/Seepage	Pumping
Resuspension Volatilization/ Emanation Evaporation Transpiration		Inflitration Advection Diffusion Dispersion Colloid transp.		LAND SURFACE	Surface runoff	
			Recharge	Irrigation Flooding	SURFACE WATER	
				Irrigation		Well

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Processes in the source, the vadoze, the groundwater and the surface land compartments

INPUT						
	AQUEOUS	Adsorption / Surface complexation Ion exchange	Precipitation	Volatilization Heterogeneous reaction Diffusion Decay (Rn, Tn)		
	Desorption Ion exchange	SOLID	Co-precipitation	Decay (Rn, Tn)		
	Dissolution	Co-precipitation	SUSPENDED	Decay (Rn, Tn)		
	Condensation Diffusion Decay (Rn, Tn)	Decay (Rn, Tn)	Decay (Rn, Tn)	GASEOUS		
					MICROBES	
						OUTPUT

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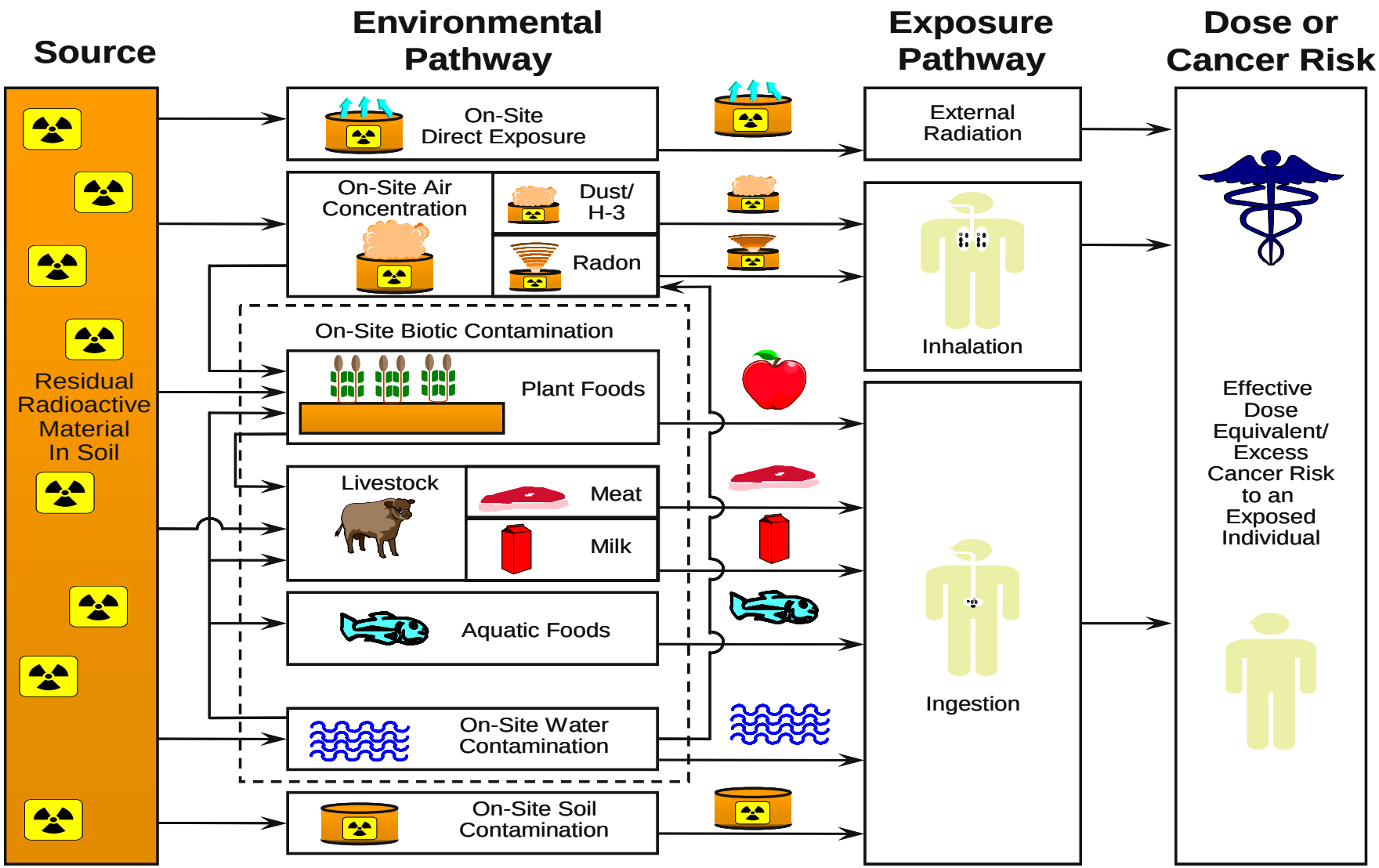
Exposure pathways



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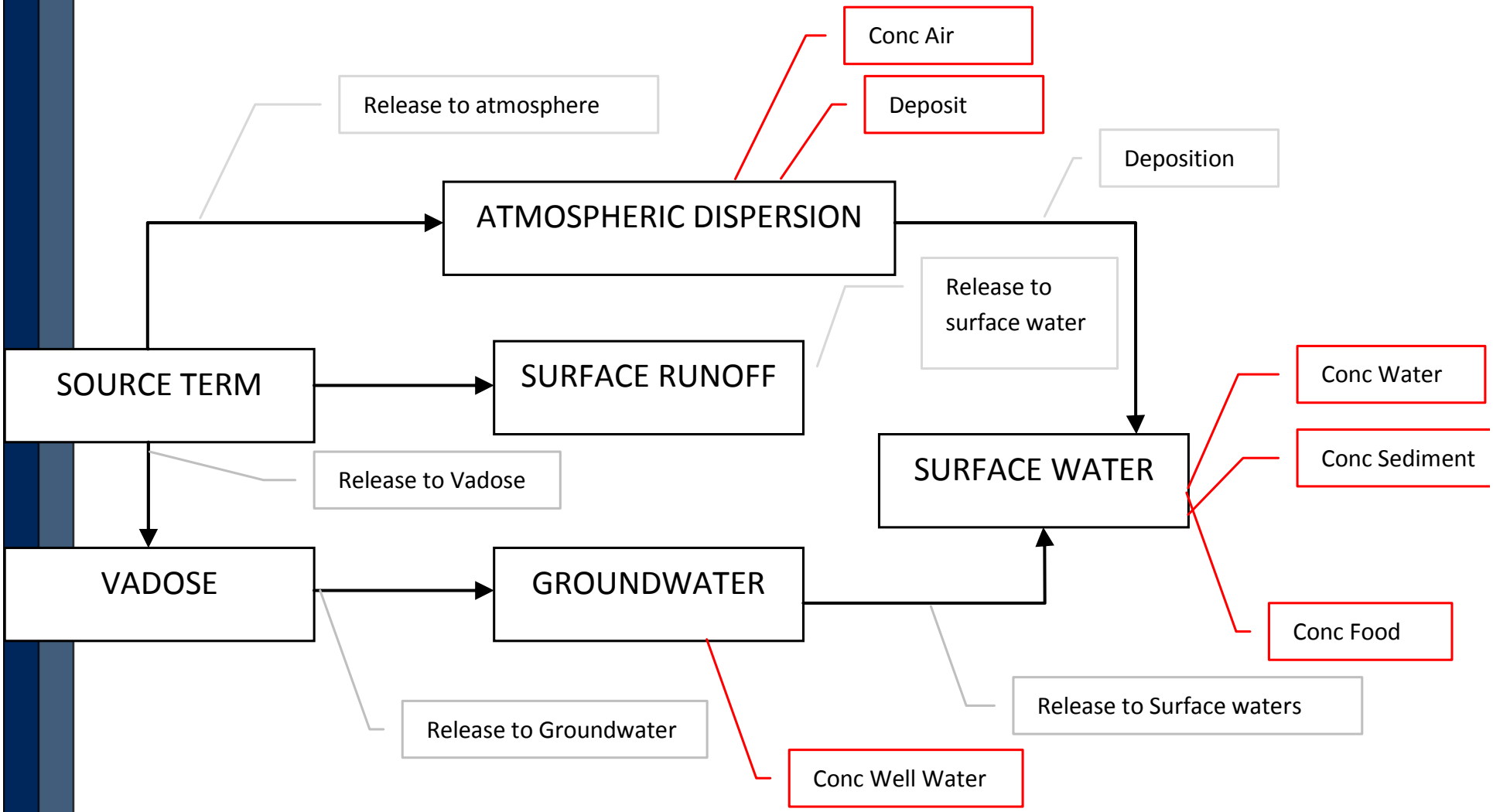
Interactions between models



CHAPTER 3 SOURCE TERM MODELS

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SOURCE TERM MODELS

3.1 Introduction

3.2 Simplified assessment (equilibrium) models

3.2.1 Release to the atmosphere

3.2.2 Release to the vadose zone/groundwater

3.2.3 Release to surface water bodies

3.2.4 Applicability of the models and information required

3.3 Biogeochemical models

All biogeochemical models are based on the principle of mole balances and principle of thermodynamics for fast/equilibrium reactions and chemical kinetics for slow/kinetic reactions.

3.3.1 Release to the Atmosphere

3.3.2 Release to the vadose zone/groundwater

3.4 Uncertainties associated with these models

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CHAPTER 4 ATMOSPHERIC DISPERSION MODELS

The main focus of this Chapter will be on describing how to apply these models for the case of area sources. A simple approach, proposed in the IAEA SR 19, is to calculate a pseudo point source release rate by integrating over the entire area of the source and locating the release point at the edge of the area nearest to the location of the receptor of interest. A more sophisticated approach is to divide the area into several cells and perform calculations for each cell.

A Table with a description of available models will be included. An example is the Argonne model MILDOSE.

A description of how to estimate the concentrations needed for the exposure assessment will be also included.

4.1 Introduction

4.2 Continuous long-term releases

4.3 Short term releases

4.4 Application of the models and information required

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CHAPTER 5 VADOSE ZONE MODELS

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5.1 Introduction
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5.2.1 Applicability of the models and information required
5.3 Flow and transport models
5.3.1 Water flow
5.3.2 Solute transport
5.3.3 Soil hydraulic properties
5.3.3.1 Retention Curve
5.3.3.2 Hydraulic Conductivity
5.3.3.3 Pedo transfer Functions
5.3.4 Transport properties
5.3.5 Applicability of the models and information required

5.4 Biogeochemical models

Geochemical models: Wateq, Minteq, Geochemist Workbench, PHRE

-Geochemical transport models: PHREEQC, HP1, HydroBioGeoChem, others

5.5 Uncertainties associated with these models

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CHAPTER 6 GROUNDWATER MODELS

6.1 Introduction

6.2 Simplified assessment models

This section will include description of analytical equations and simple compartment models that can be used for estimating the transport of radionuclides with groundwater.

6.2.1 Applicability of the models and information required

6.3 Flow and transport models

6.3.1 Media hydraulic properties

6.3.2 Transport properties

6.3.3 Applicability of the models and information required

6.4 Biogeochemical models

Table of models (e.g., MODFLOW, RT3D, MT3D, MODFLOW Surfact, FeFlow, Porflow, HYDRUS)

6.5 Uncertainties associated with these models

CHAPTER 7 INTEGRATED SUB-SURFACE MODELS

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7.1 Introduction
7.2 Flow and transport models
7.3 Biogeochemical models
7.4 Applicability of the models and information required
7.5 Uncertainties associated with these models

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CHAPTER 8 SURFACE RUNOFF MODELS

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8.1 Introduction

8.2 Simplified assessment (equilibrium) models

Surface runoff using Universal Soil Loss Equation will be presented. The model to estimate radionuclide concentrations and dilution in surface water body will be presented.

8.2.1 Applicability of the models and information required

The data required in the model and the limitations of the model will be discussed.

8.3 Flow and water quality transport models

8.3.1 Applicability of the models and information required

8.4 Uncertainties associated with these models

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CHAPTER 9 SURFACE WATER MODELS

This section provides guidance on how estimate concentrations in surface waters from the releases obtained with the models described in the previous sections.
A full description of the models will not be included but rather advice will be provided on how to use the models in the IAEA SR 19.

9.1 Introduction
9.2 Simplified assessment models
9.2.1 Lakes
9.2.2 Rivers
9.2.3 Estuaries
9.2.4 Coastal areas
9.3. Uncertainties associated with these models

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10.2 External exposure
10.2 Inhalation
10.3 Ingestion
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CHAPTER 11 APPLICATION FOR DECISION MAKING IN ENVIRONMENTAL REMEDIATION

CHAPTER 12 ASSESSMENT OF REMEDIATION SOLUTIONS

CHAPTER 13
DEMONSTRATIVE EXAMPLES

13.1 Uranium Tailings

An uranium tailings simulation in the integrated subsurface media will be provided.

Assessment of remediation strategies of uranium tailing for a legacy site in Dnieprozerchinsk, Ukraine.

13.2 In situ leaching

An in-situ leaching (natural monitored attenuation) simulation in integrated subsurface media will be proved.

13.3 Acid drainage

An acid drainage example in integrated subsurface media will be provided. Application of a water flow and geochemical modeling to support the remediation activities of the acid rock drainage generation in the uranium mining and milling site of Pocos de Caldas Brazil

13.4 Application of isotope techniques