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Assessment of exposure to NORM

Rodolfo Avila

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Assessment of doses for the current situation

Presentation of results derived from two main studies:

- **<u>Swedish Radiation Safety Authority:</u> Assessment of Risks to Human Health and the Environment from Uranium Tailings in Ukraine -** Phase 1 report. Facilia ENSURE Report: TR/SIUS/01.

- **<u>IAEA:</u>** "A**ssessment of doses from exposures to elevated levels of natural radionuclides in areas close to uranium tailings in Tajikistan and Uzbekistan**" in IAEA Report: Safe Management of Residues from Former Mining and Milling Activities in Central Asia. *Regional Technical Cooperation Project RER/9/086.*

Investigated sites

Ukraine: Dniprodzerzhinsk

Tajikistan: Taboshar and Degmay

Uzbekistan: Charkesar

Contamination not spatially homogeneous with large variation of radionuclide levels in different areas within a given site.

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Dniprodzerzhinsk Site, Ukraine

42 M tonnes

3,2 x 10^{15} Bq

276 000 inhabitants

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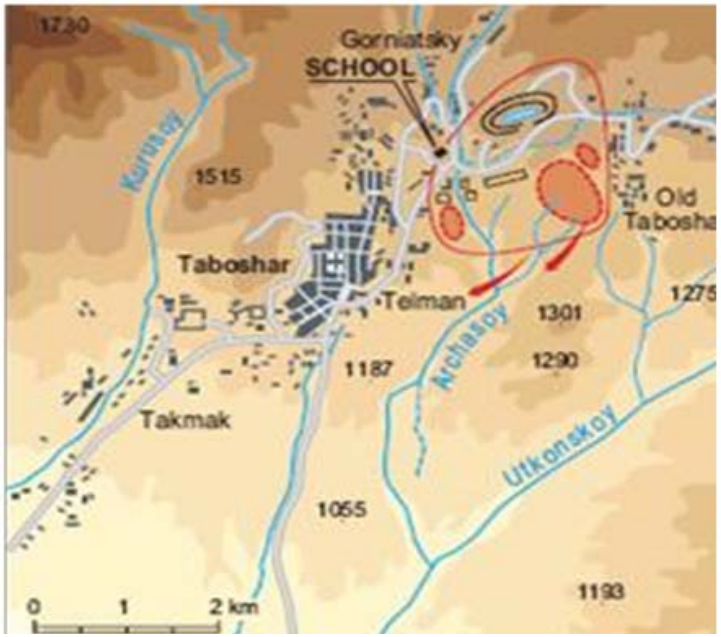
Two sites in Tajikistan

Taboshar tailing site



Degmay tailings near
Khudjand and Chkalovsk

7,6 M tonnes 12 000 inhabitants

salt covers with ^{238}U 10-20 Bq g^{-1}

20 M tonnes 16 000 GBq

164 000 & 22 000 inhabitants

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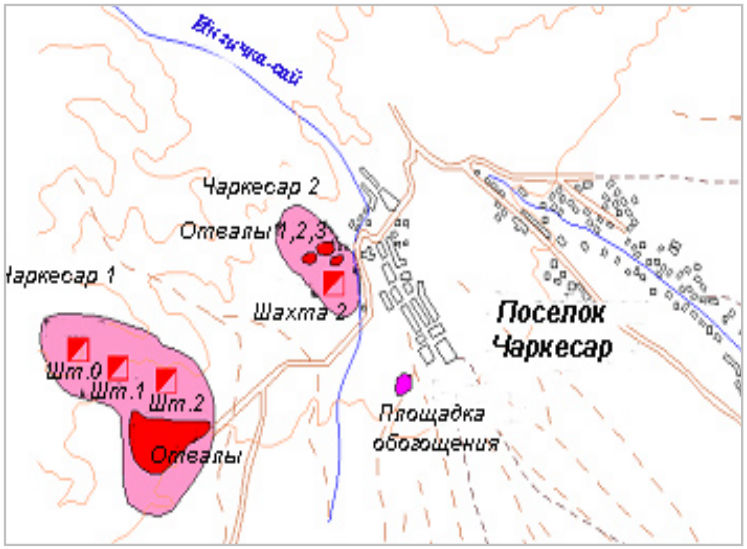
Mines and disposal areas near Charkesar village, Uzbekistan



482 000 m^3 3 x 10^{13} Bq 2 500 inhabitants

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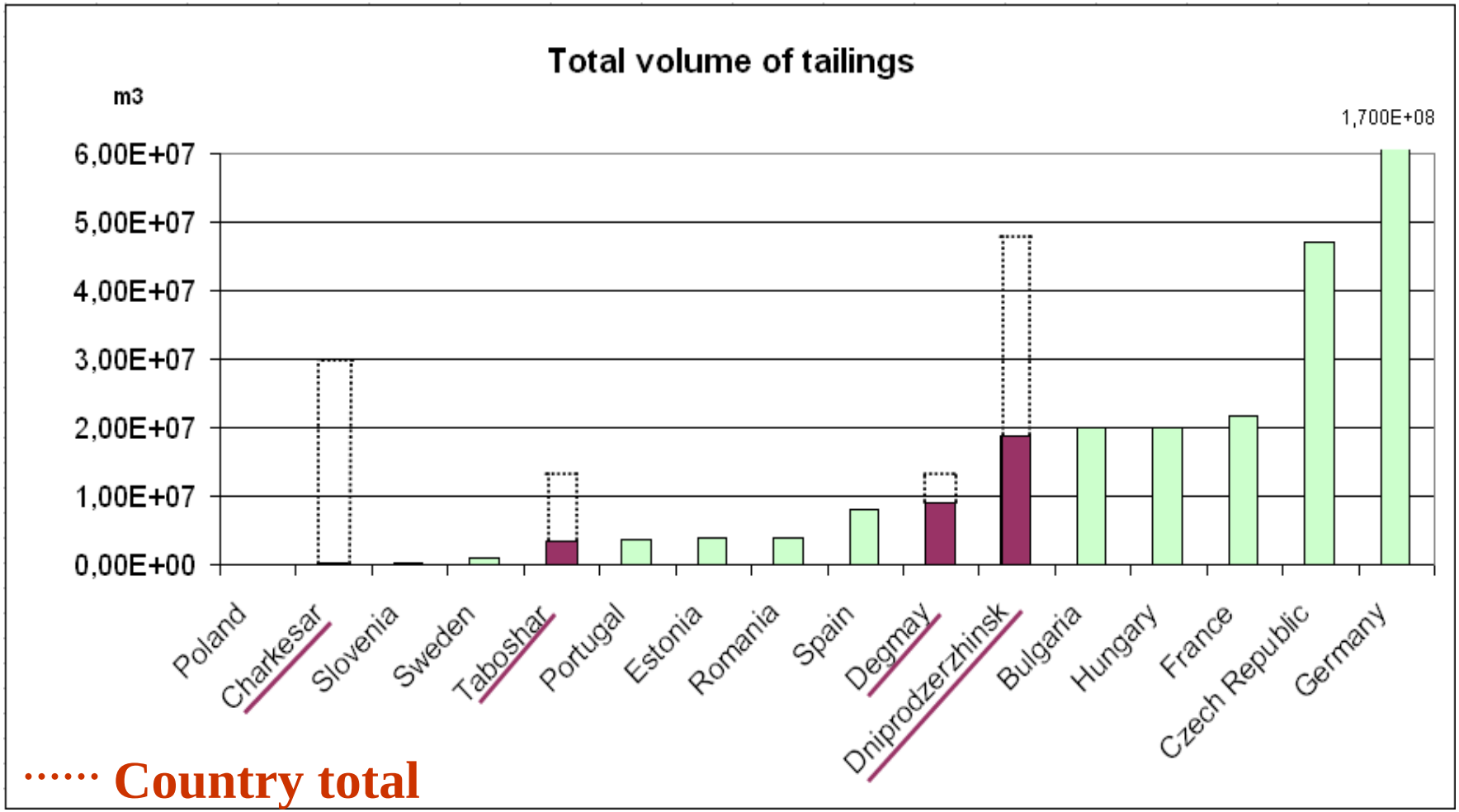

European data extracted from TREN report “Situation concerning uranium mine and mill tailings in an enlarged EU” (2006)

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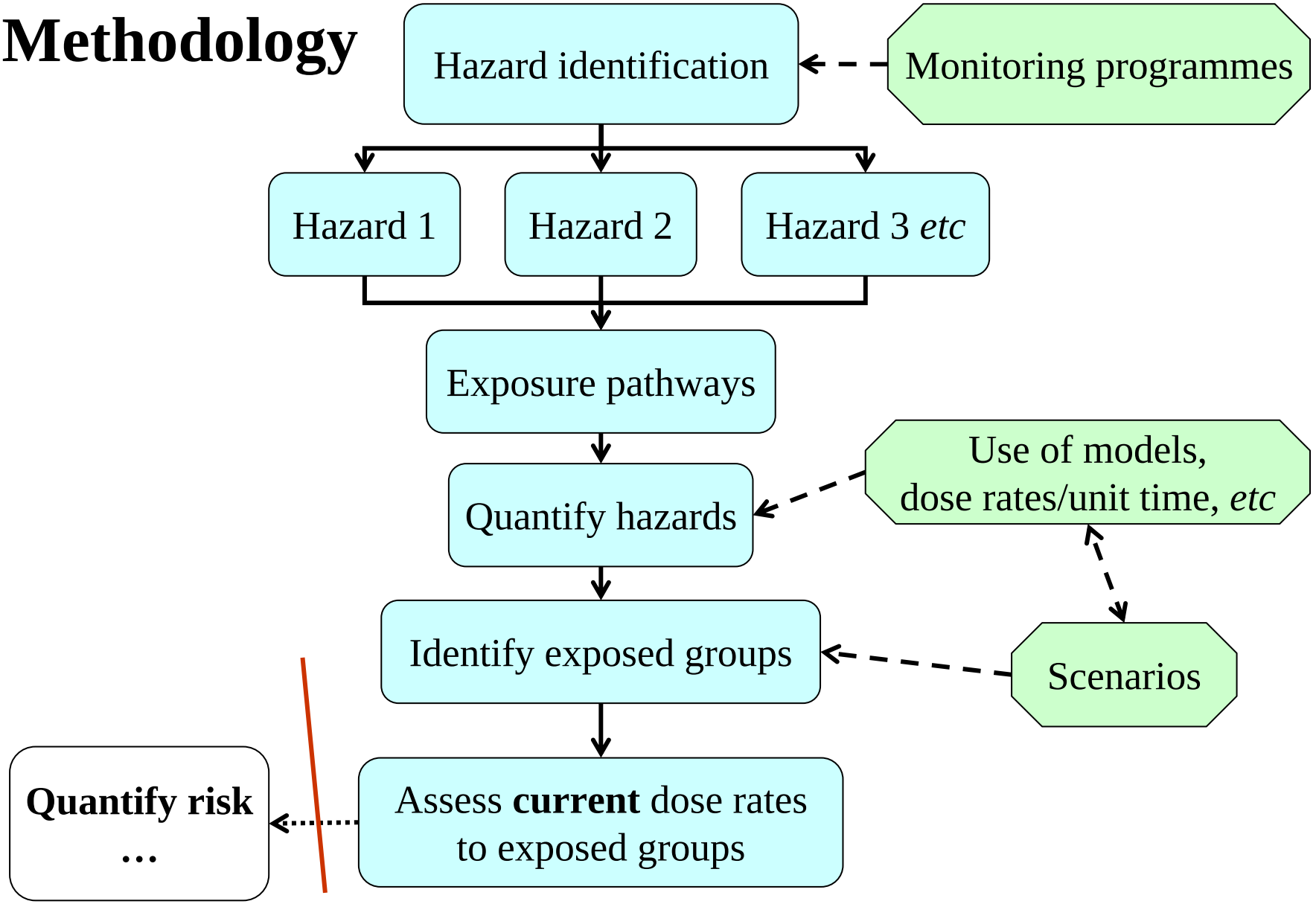
Methodology



Identification of hazards

Hazards is the potential to cause harm whereas risk is the probability of harm

We define hazard as an area or object (ex. a water body with elevated (above background) radionuclide levels)

Monitoring:

- Gamma dose rates outside and inside of buildings
- Radionuclide concentrations
  - aerosols, soils and tailing materials
  - in water and food products
- Radon concentrations outside and inside buildings

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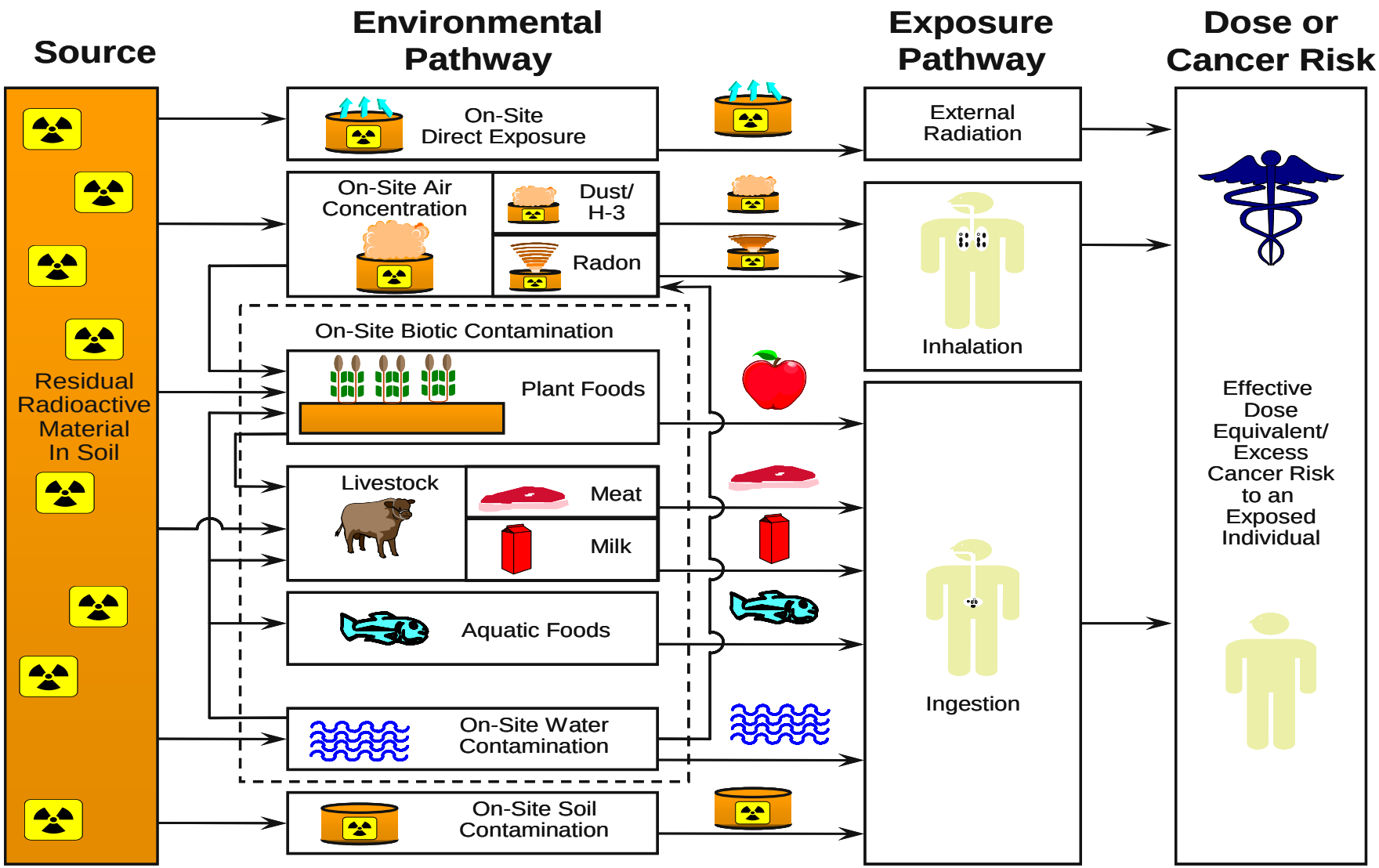
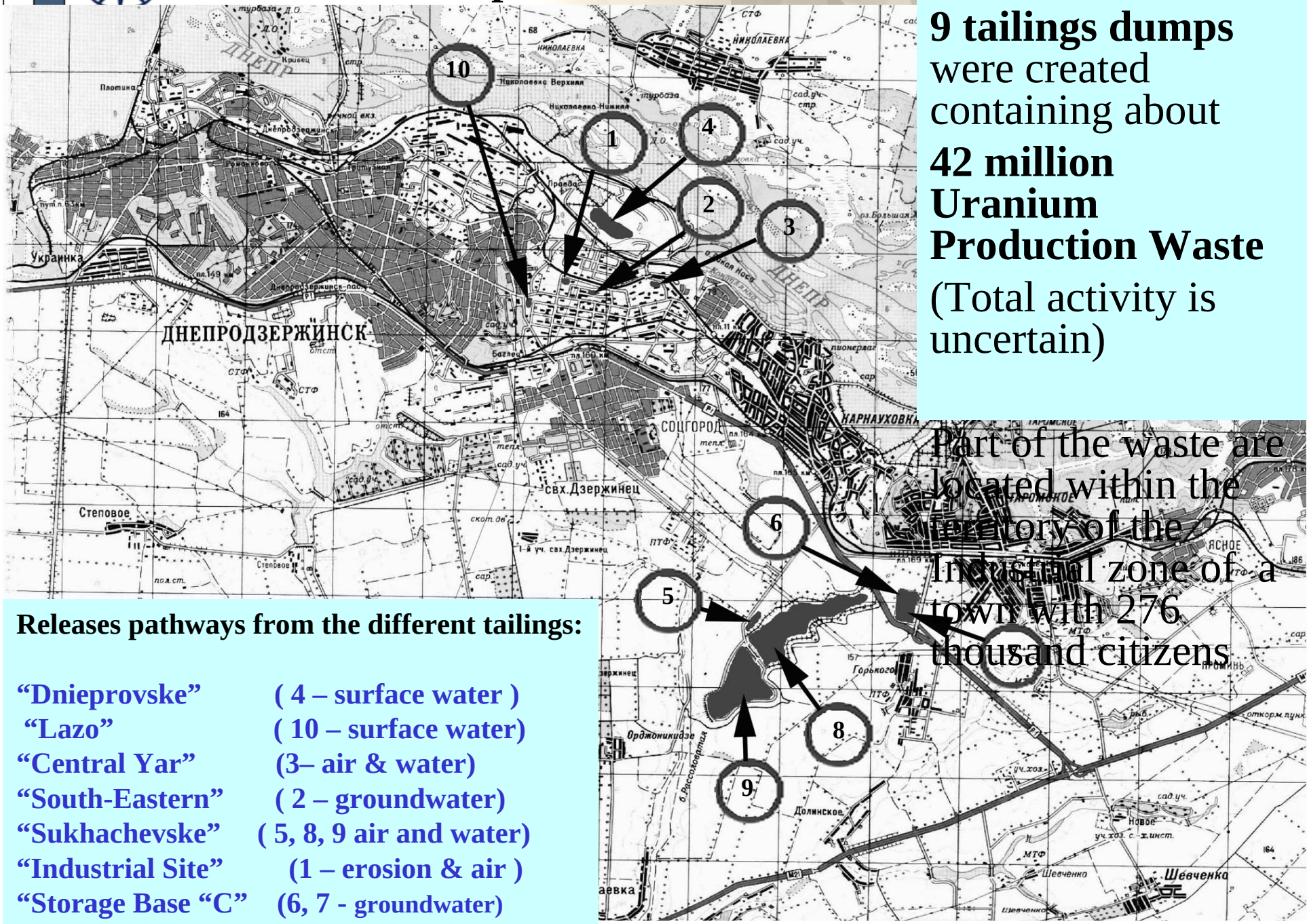
Exposure pathways



Dniprodzerzhinsk



9 tailings dumps were created containing about **42 million Uranium Production Waste** (Total activity is uncertain)

Part of the waste are located within the territory of the Industrial zone of a town with 276 thousand citizens

Releases pathways from the different tailings:

"Dnieprovske"	**(4 – surface water)**
"Lazo"	**(10 – surface water)**
"Central Yar"	**(3– air & water)**
"South-Eastern"	**(2 – groundwater)**
"Sukhachevske"	**(5, 8, 9 air and water)**
"Industrial Site"	**(1 – erosion & air)**
"Storage Base "C"	**(6, 7 - groundwater)**

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Degmay

Largest tailing in Central Asia

Located very close to inhabitant areas

Risk of water pollution – no protective cover

High radon exhalation (36-65 Bq/m^2/s)

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Taboshar

Milled ore materials with relatively low Uranium content

Cover partially damaged

Highly contaminated drainage and seepage water, which is migrating into surface water and the shallow ground water table

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Charkesar

local population has used tailing materials for construction of their houses. Indoor Rn-222 concentrations exceeding 1000 Bq m^{-3} High gamma dose rates in local hospital and school

Identified hazards

Dniprodzerzhinsk	• Workers on the site get the highest radiation doses • Elevated radionuclide and radiation levels: a) inside and outside polluted buildings b) Hot Spots in the forest c) in the different tailing sites
Taboshar	• Elevated radionuclide and radiation levels: a) indoors and outdoors at settlement b) at tailings, locals go and animals graze c) at pits, locals visit and swim d) in waters contaminated by tailings or/and pits
Degmay	• External exposure to gamma radiation and radon • Elevated radionuclide and radiation levels: a) in the Degmay settlement b) at the uranium tailings c) in groundwater (water from local wells)
Charkesar	• Tailing materials used for house construction • Elevated radionuclide and radiation levels: a) areas close to and away from the industrial site b) at the industrial site c) in water bodies, e.g. springs, mine waters, rivers

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Derivation of doses

To provide a basis for necessary exposure assessments at these sites, we used the methodology (and models) highlighted by the German Federal Ministry for the Environment (BMU), Nature Conservation and Reactor Safety (1999):

" **Berechnungsgrundlagen zur Ermittlung der Strahlenexposition infolge bergbaubedingter Umweltradioaktivität (Berechnungsgrundlagen - Bergbau)"**

[Assessment principles for estimation of radiation exposures resulting from mining-related radioactivity in the environment (Assessment principles for mining)]

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Exposure pathways

- soil contamination for reference persons inside and outside buildings
- aerosols inside and outside buildings
- in, and exposure to, locally grown foodstuff (not yet included in the Ukraine project)
- exposure through the direct ingestion of soil
- inhalation of ^{222}Rn and its short lived progeny

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Studied radionuclides

1. $^{238}U \rightarrow {}^{234}U \rightarrow {}^{230}Th \rightarrow {}^{226}Ra \rightarrow {}^{210}Po \rightarrow {}^{210}Pb$

2. $^{235}U \rightarrow {}^{231}Pa \rightarrow {}^{227}Ac$

3. $^{232}Th \rightarrow {}^{228}Ra \rightarrow {}^{228}Th$

This may lead to slight underestimation of the total doses

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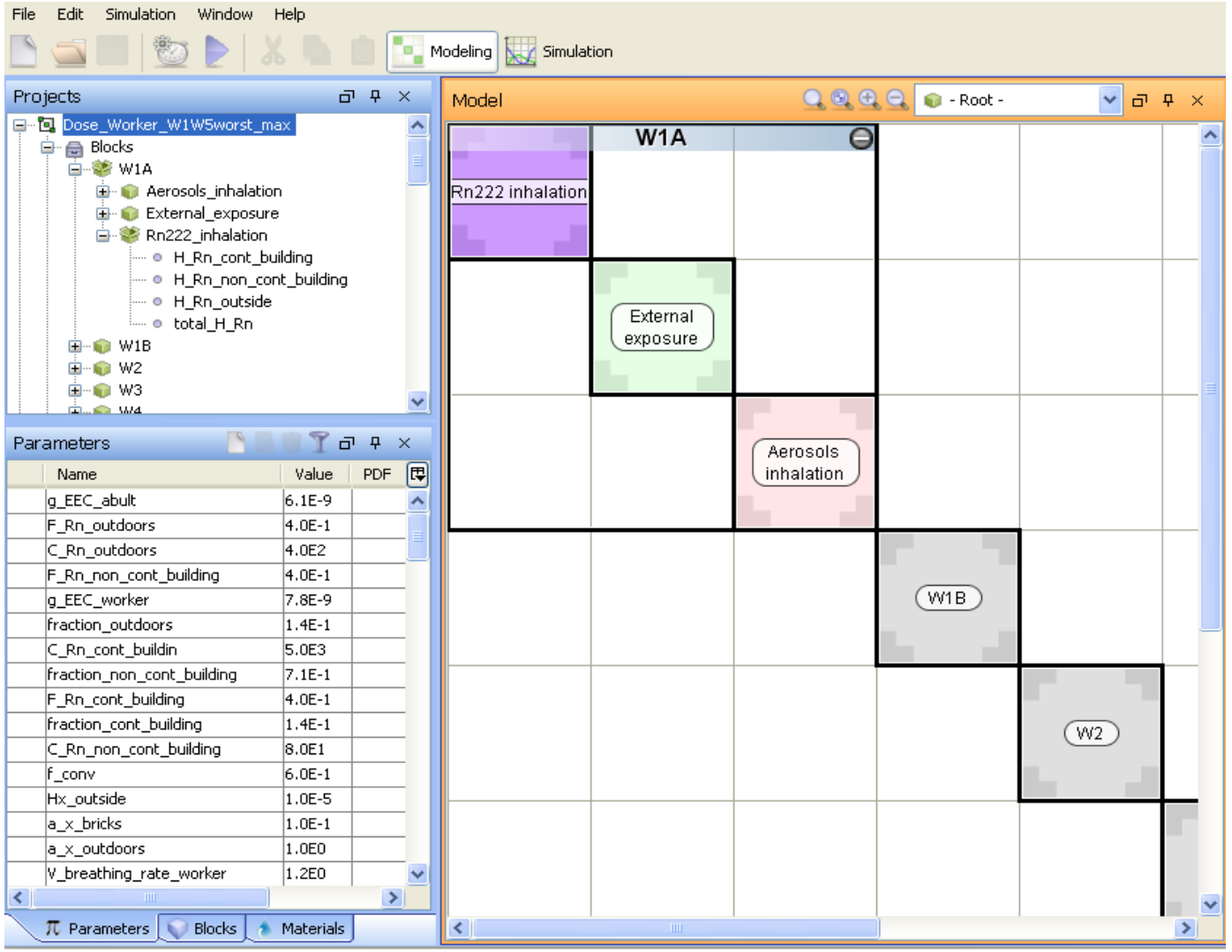
Screening models placed in Ecolego



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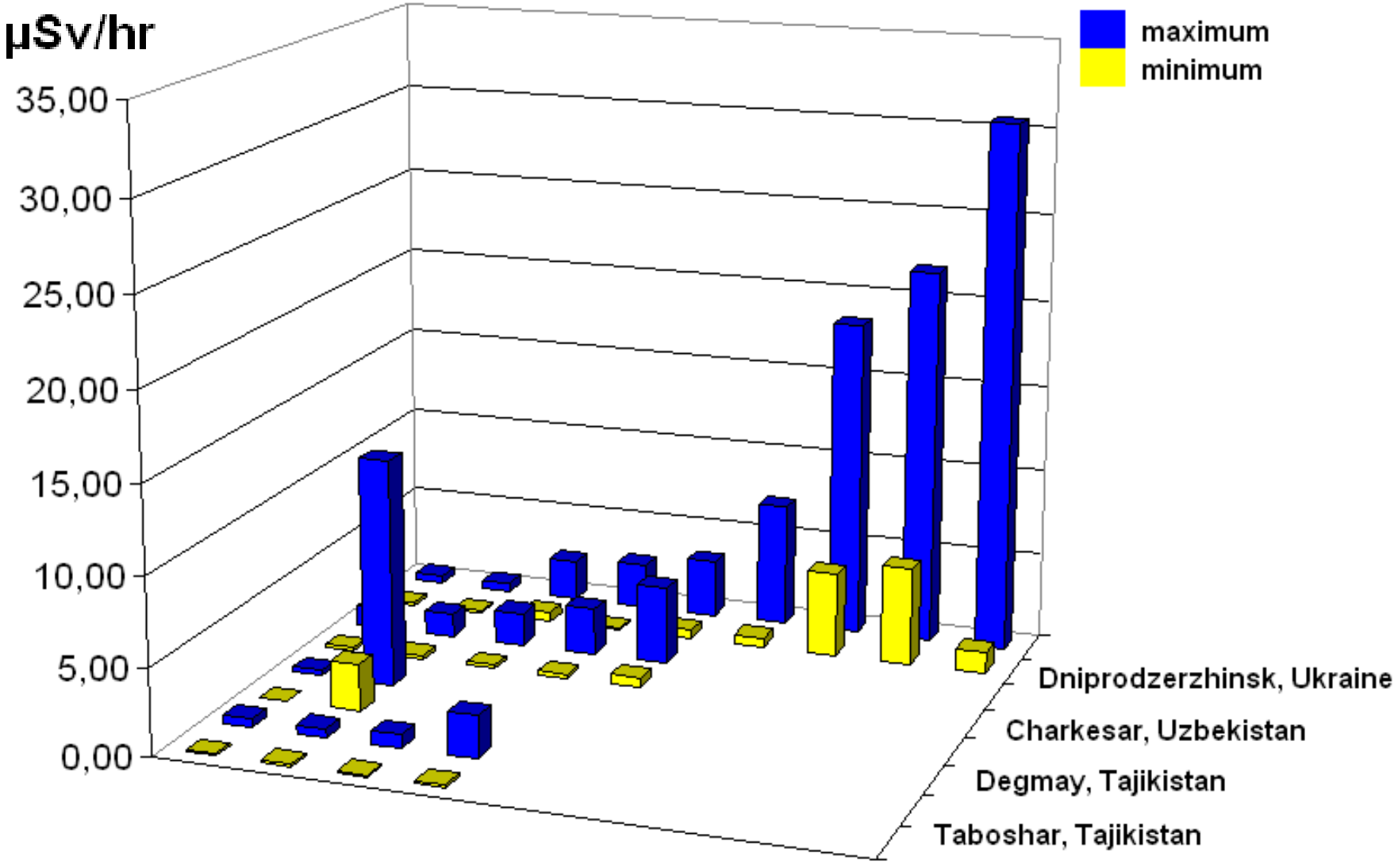
Comparison of dose rates between the four sites



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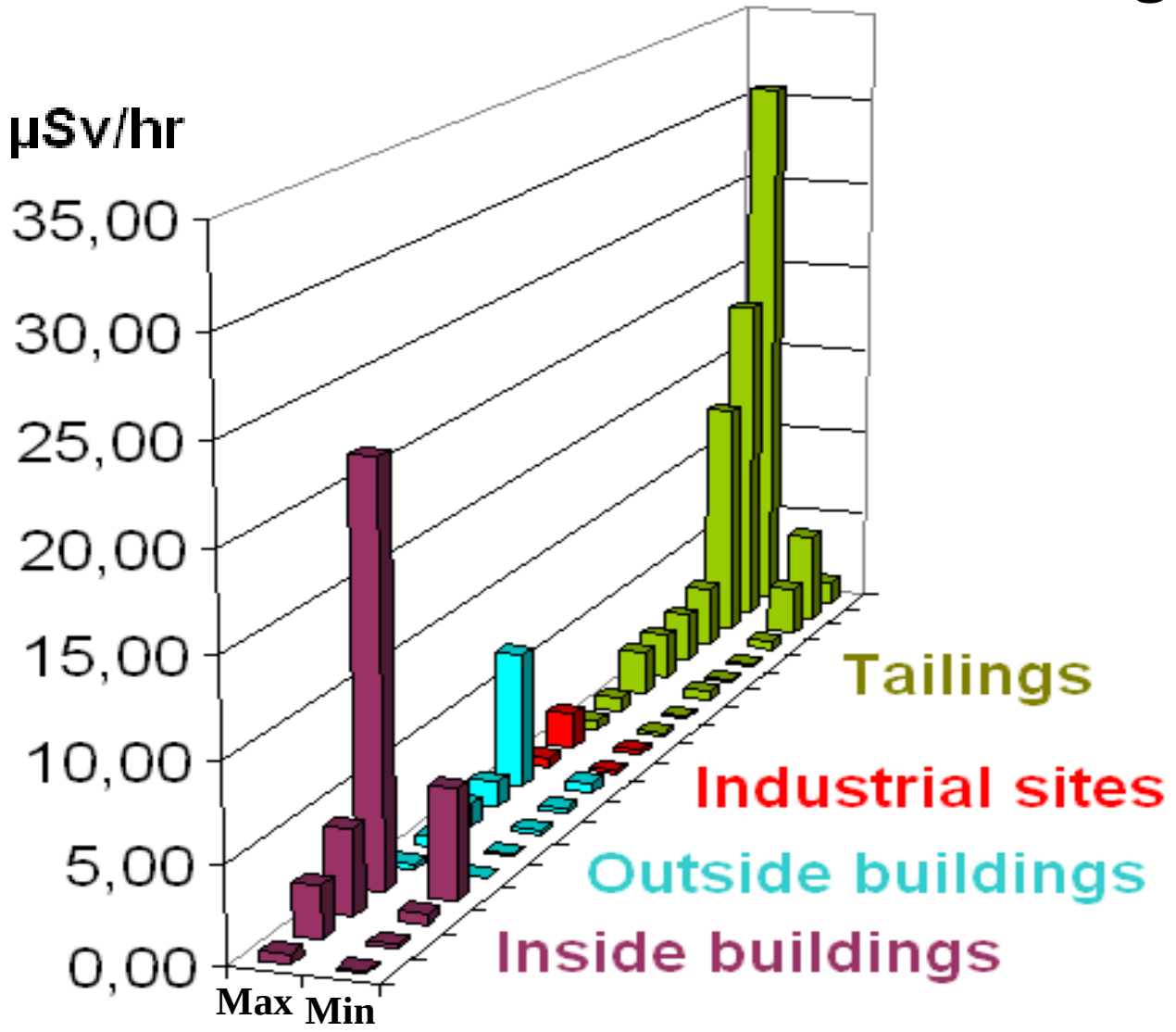
Comparison of dose rates between hazard categories



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Example: current doses at Taboshar

Exposure scenarios:

Group	Exposure (hr/y) to different hazards				Fraction of annual consumption		
	Outdoor at tailing	Outdoor at waste rock piles	Indoor in houses	Outdoor at the town	Meat and milk (water from tailing)	Irrigation of vegetables (water from mine)	Drinking water from mine
1	0	0	5840	2920	0 %	0 %	0 %
2	0	0	5840	2920	0 %	30 %	30 %
3	0	730	5110	2920	0 %	30 %	30 %
4	1460	730	5110	1460	30 %	30 %	30 %
5	0	1380	5110	2270	0 %	0 %	0 %

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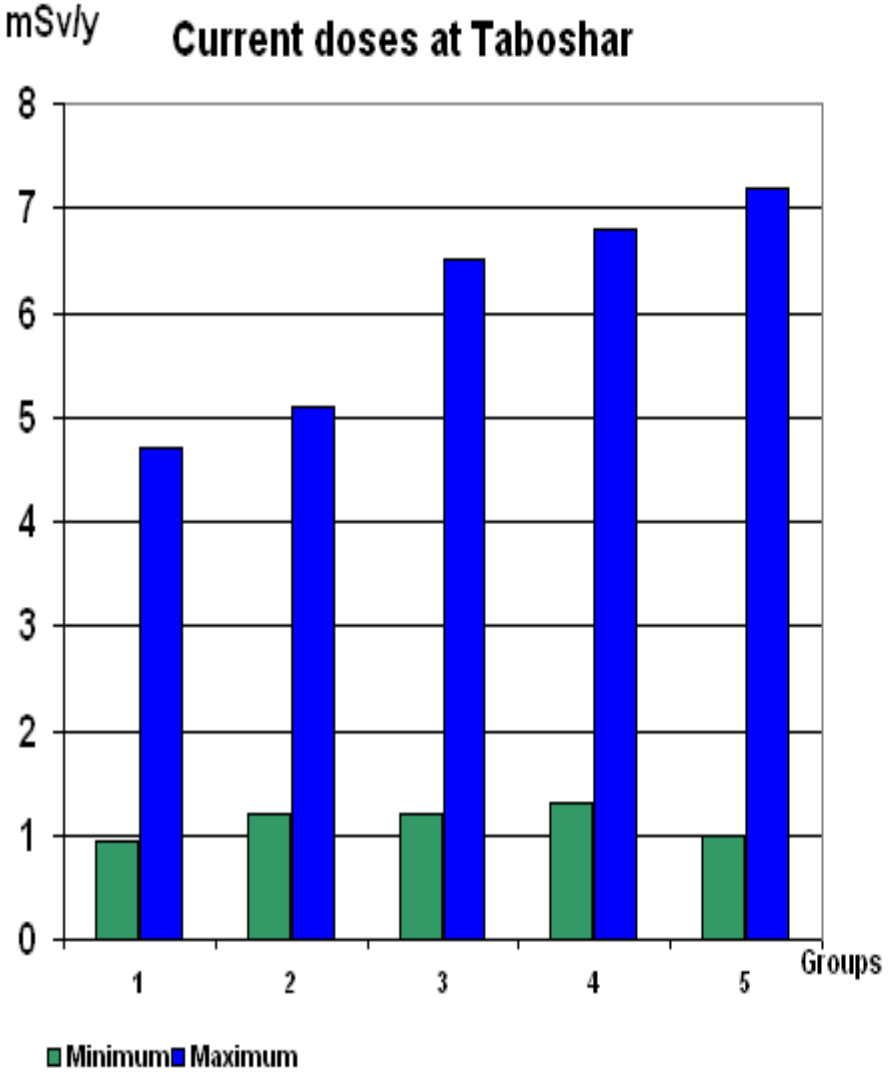
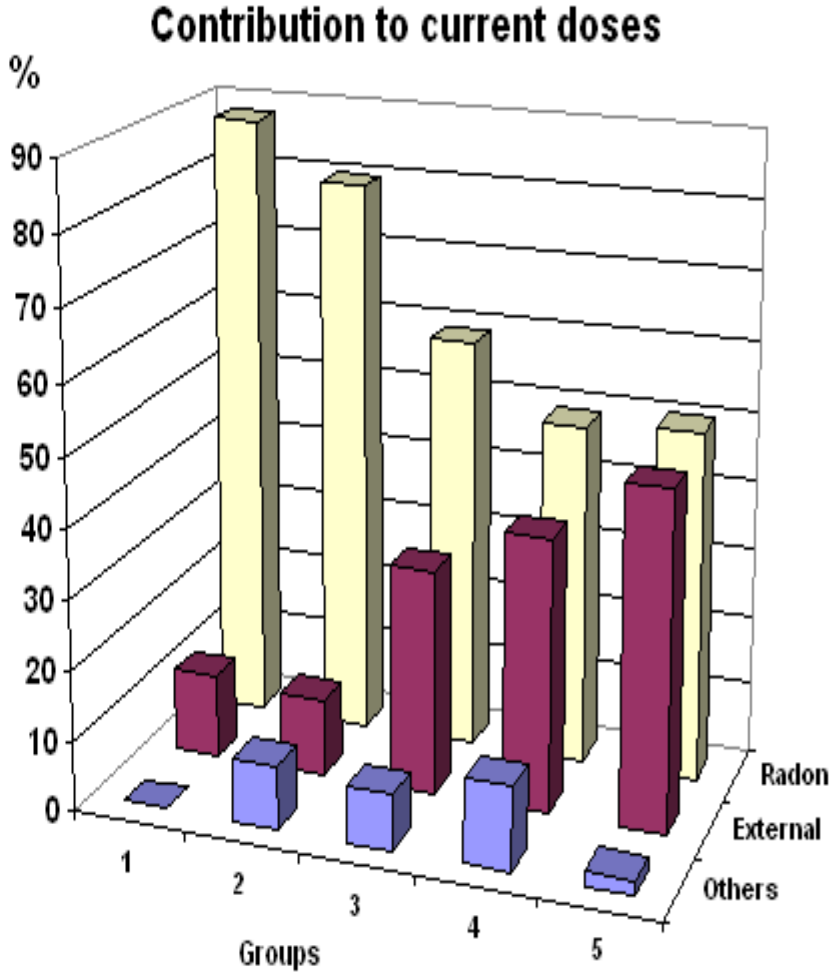

mSv/y
Current doses at Taboshar
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Groups
Minimum
Maximum


Contribution to current doses
%
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Groups
Radon
External
Others

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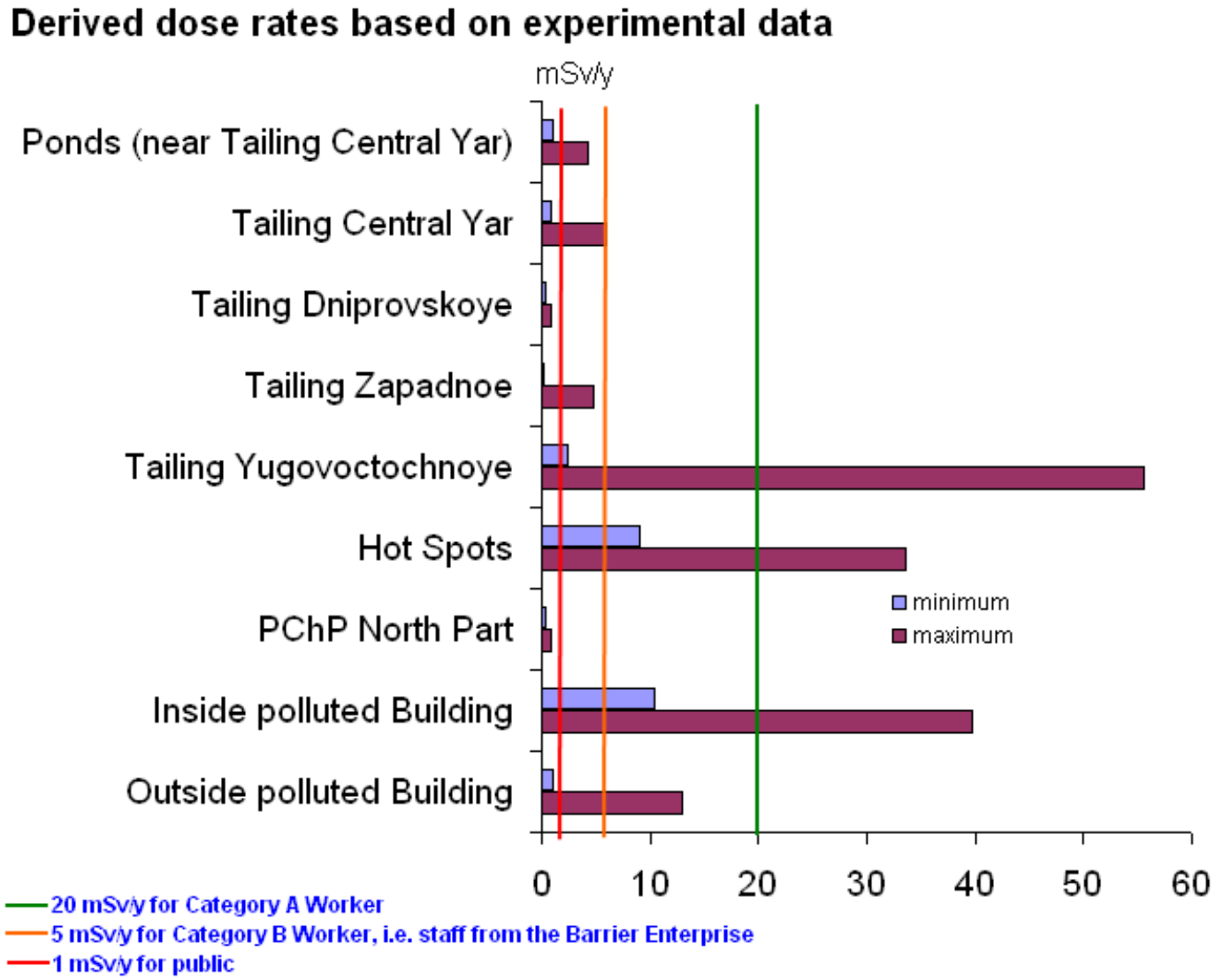
Dniprodzerzhinsk



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Assessments for future situations

- Start with an assessment for the current situation
- Identify new hazards that may appear in the future and how existing hazards can change
- Indentify potential new exposure pathways
- Characterize the hazards with the help of models
- Estimate exposure to different groups

Mathematical Models for Assessing Remediation of Radioactively Contaminated Sites

IAEA TECDOC – under development

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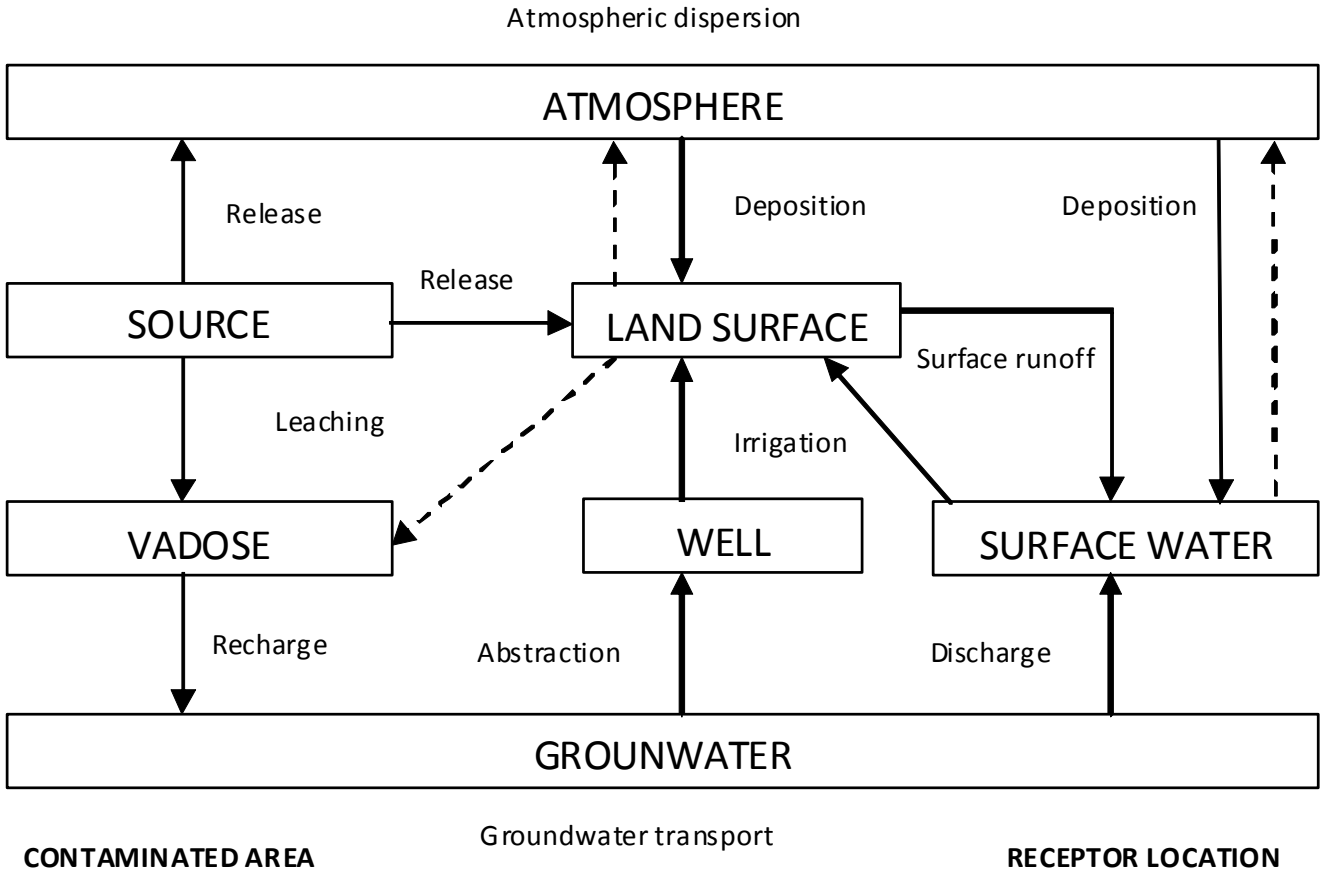
Main transport pathways



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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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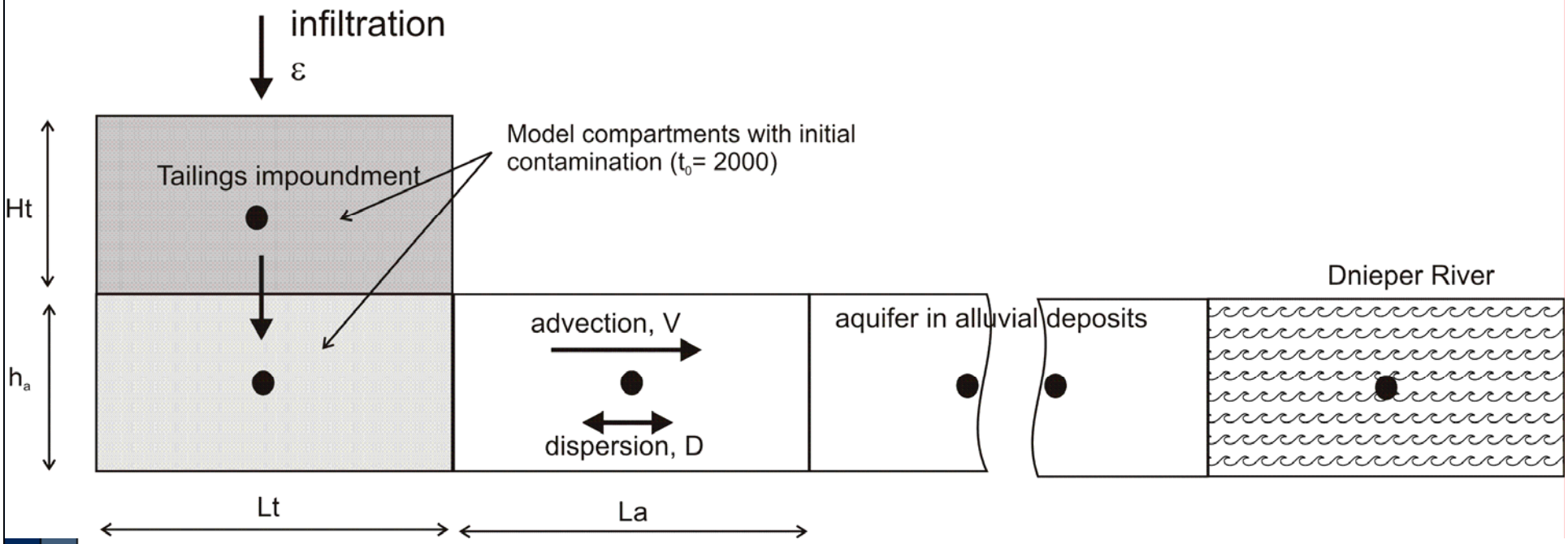
Migration from the tailings
ISAM methodology

Conceptual model of radionuclide migration from the “D” tailings



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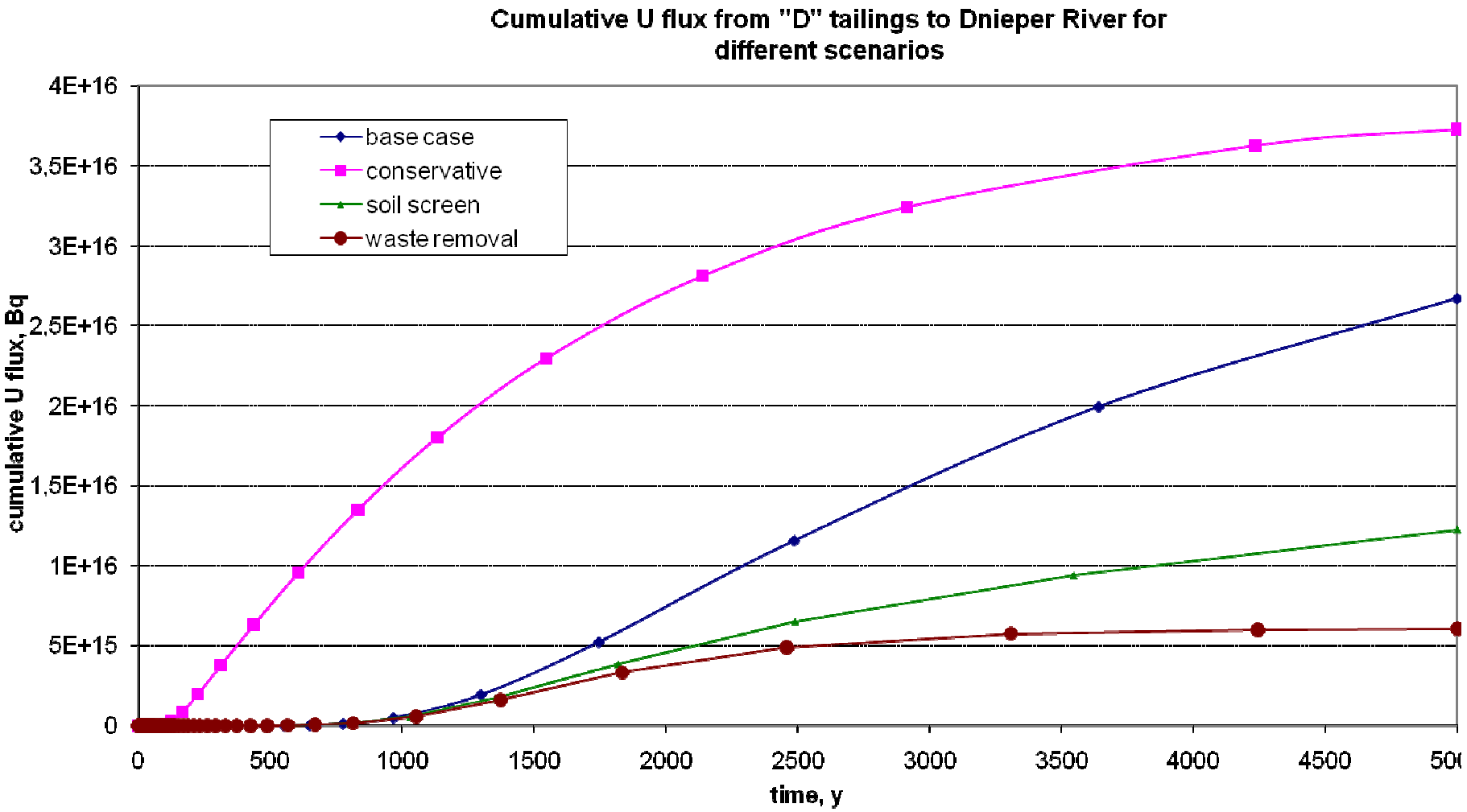
Prognoses for different remediation alternatives



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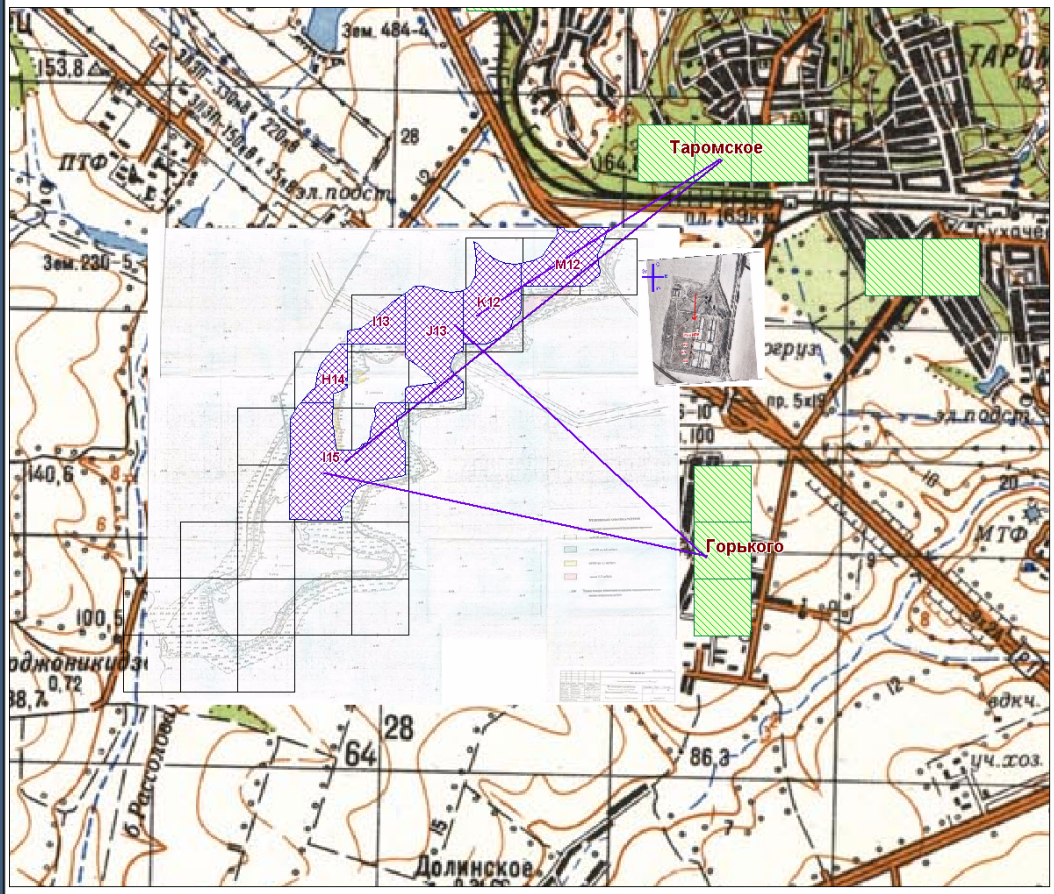
Results of simulations of atmospheric transport of dust

SR-19 used for chronic releases



More advance models for other situations

Example:
Study of the impact on nearby town of dust releases in a situation with dry weather and high wind speed (12 m/s)

Estimated doses 80-100 µSv

Near the source the concentrations are one order of magnitude higher

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Conclusions

- Models and methods for assessments of exposure to NORM are available
- A methodological approach to the integration and use of the models is missing
- One single model that can be used in all NORM situations is not possible
- People doing the assessments should have a good understanding of processes and the models – need to involve several experts