Vysus Group

A STATE-OF-THE-ART CALCULATION TOOL FOR PUBLIC AND WORKER DOSES

Vysus Dose Calculation Tool

Ingenuity.
Imagination.
Insight.

PSAM18, Pittsburgh

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Why a New Dose Calculation Tool?

Challenges

- Increasing complexity of accident analyses
- Regulatory dose assessments
- Emergency preparedness
- Manual calculations are time-consuming
- Need for faster and traceable analyses

Integrated automation improves efficiency, consistency and confidence.

Objectives

The development objectives of the new dose calculation tool were to

- automate many steps, and reduce the large number of manual actions needed to obtain the final results,
- reduce the susceptibility to manual errors,
- increase user-friendliness using an intuitive interface,
- improve the computational time to obtain results,
- facilitate calculations,
- facilitate traceability, and
- support licensing and emergency planning.

Novel Modelling Approach

Inputs:

- flows, volumes, source inventories, weather data, exposure cases.

Outputs:

- doses to the public,
- doses to workers,
- doses from iodine to the thyroid gland for a 1-year-old child,
- external source terms.

Modelling Framework

- Doses are calculated for a representative person of the public, which is an adult and a one-year-old child living on a farm approximately **300 m from the main stack of the facility**.
- The **exposure paths include inhalation**, **external radiation** from the radioactive cloud passing the representative person (cloud shine), external radiation from **the activity deposited on the ground** when the radioactive cloud passes (ground shine), and **ingestion of food and water contaminated** by the emitted radioactivity.
- To calculate the doses is the **activity concentration at the position** of the representative person.
- Calculation for each nuclide by multiplying the emitted integrated activity of the nuclide with the relative concentration.
- Doses are calculated for four different **emission heights**, e.g., 10 m, 20 m, 30 m, and 45 m (main stack height), and
- Two **different weather situations**, i.e., median weather, being the 50 % percentile weather (P50%), as well as the 95 % percentile weather (P95%).

Analysis Principles

Analysis prerequisites:

- Results from thermodynamic analyses of the accident sequence:
  - activity release dynamics from the activity source (or sources),
  - gas flows between the rooms and spaces in the emission path of the activity, and
  - other quantities such as the volumes of the affected rooms.

Calculation Method – Main steps

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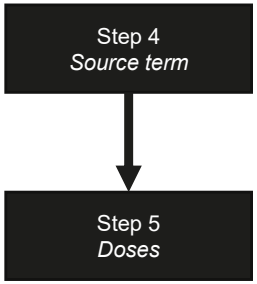
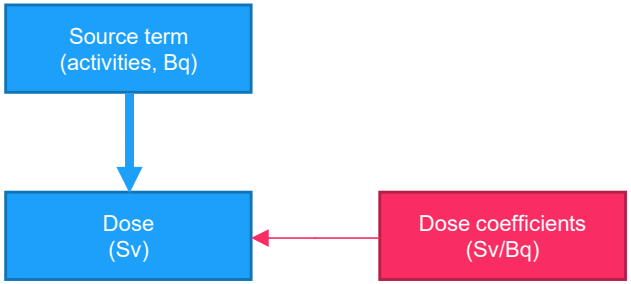
Step 5
Doses

Goal → Dose (Sv)

Public or worker

Calculation Method – Main steps





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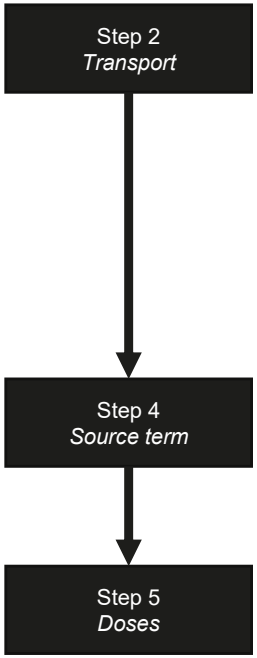

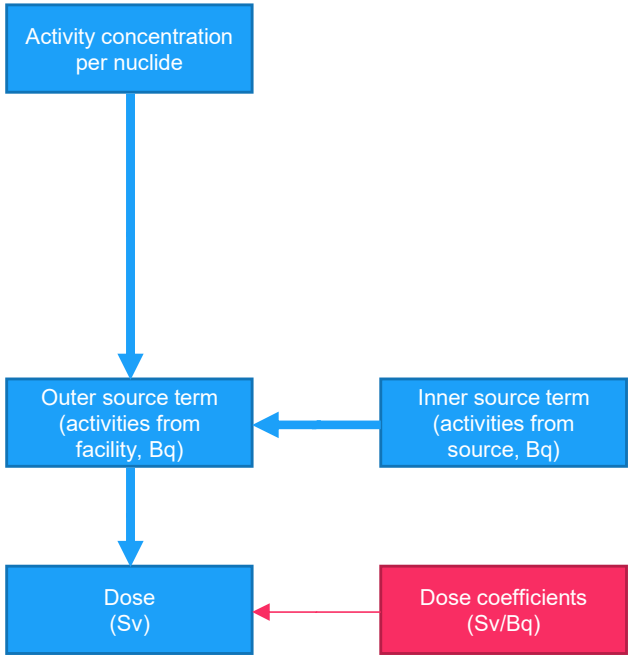

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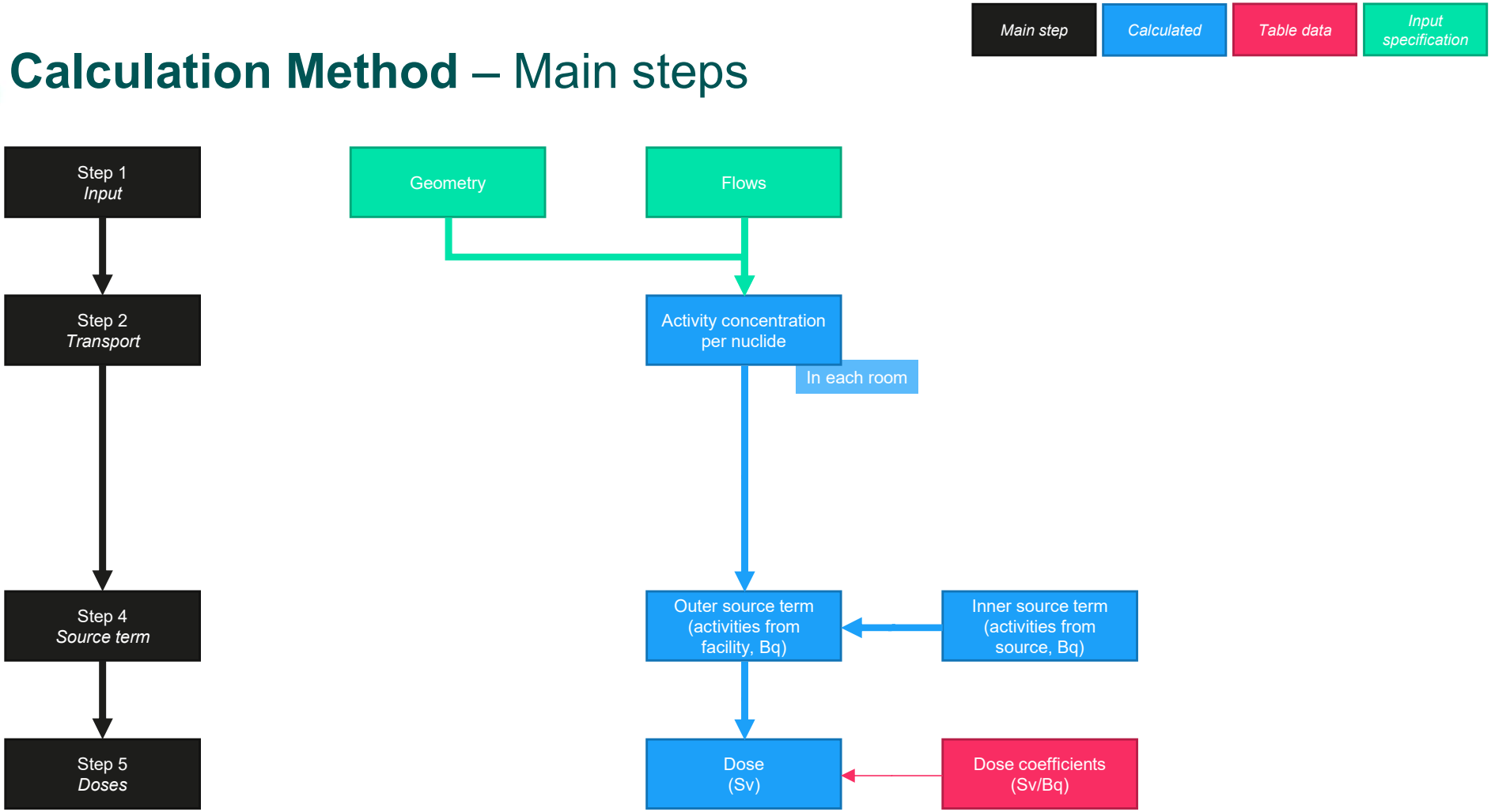

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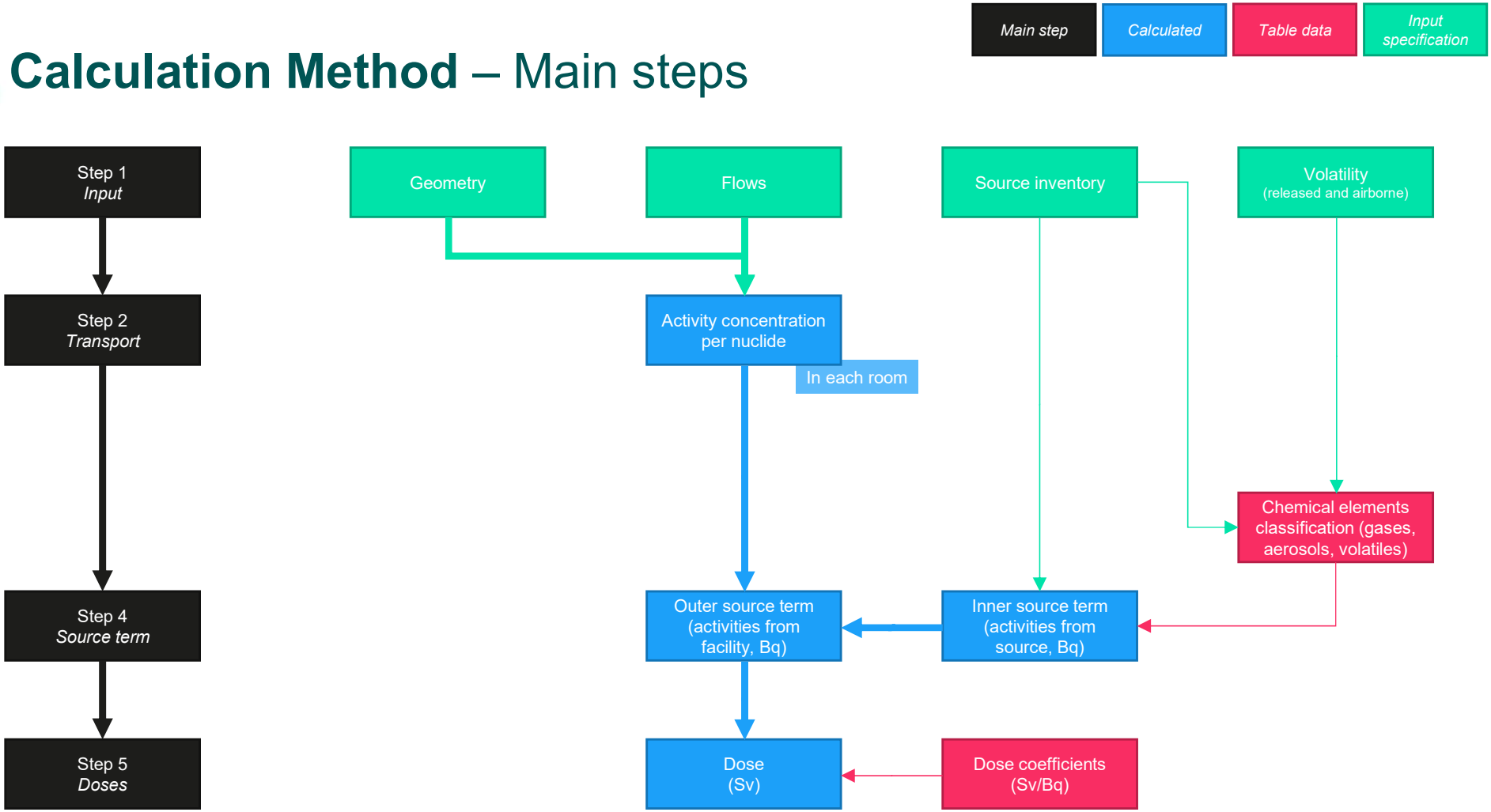

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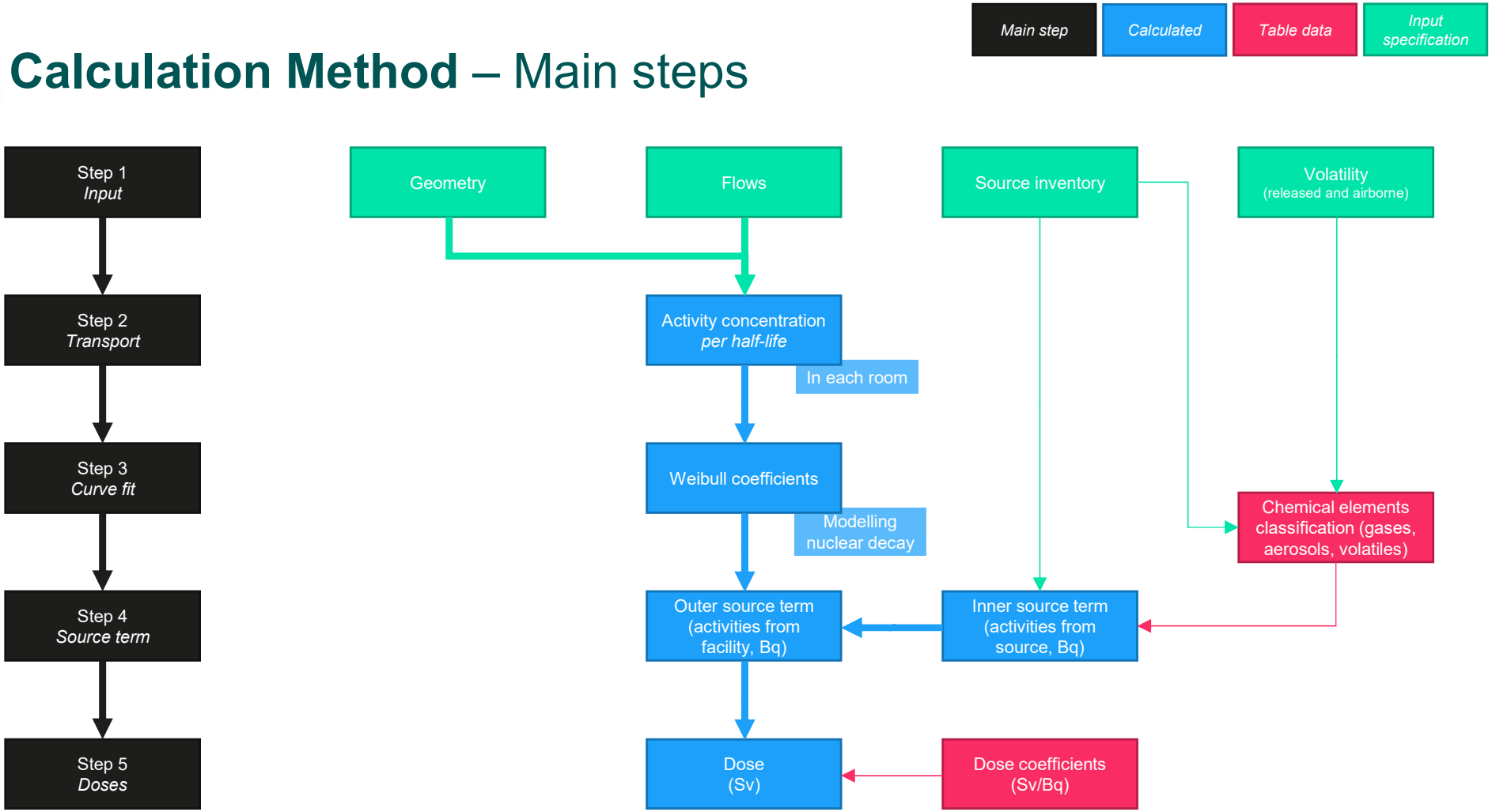
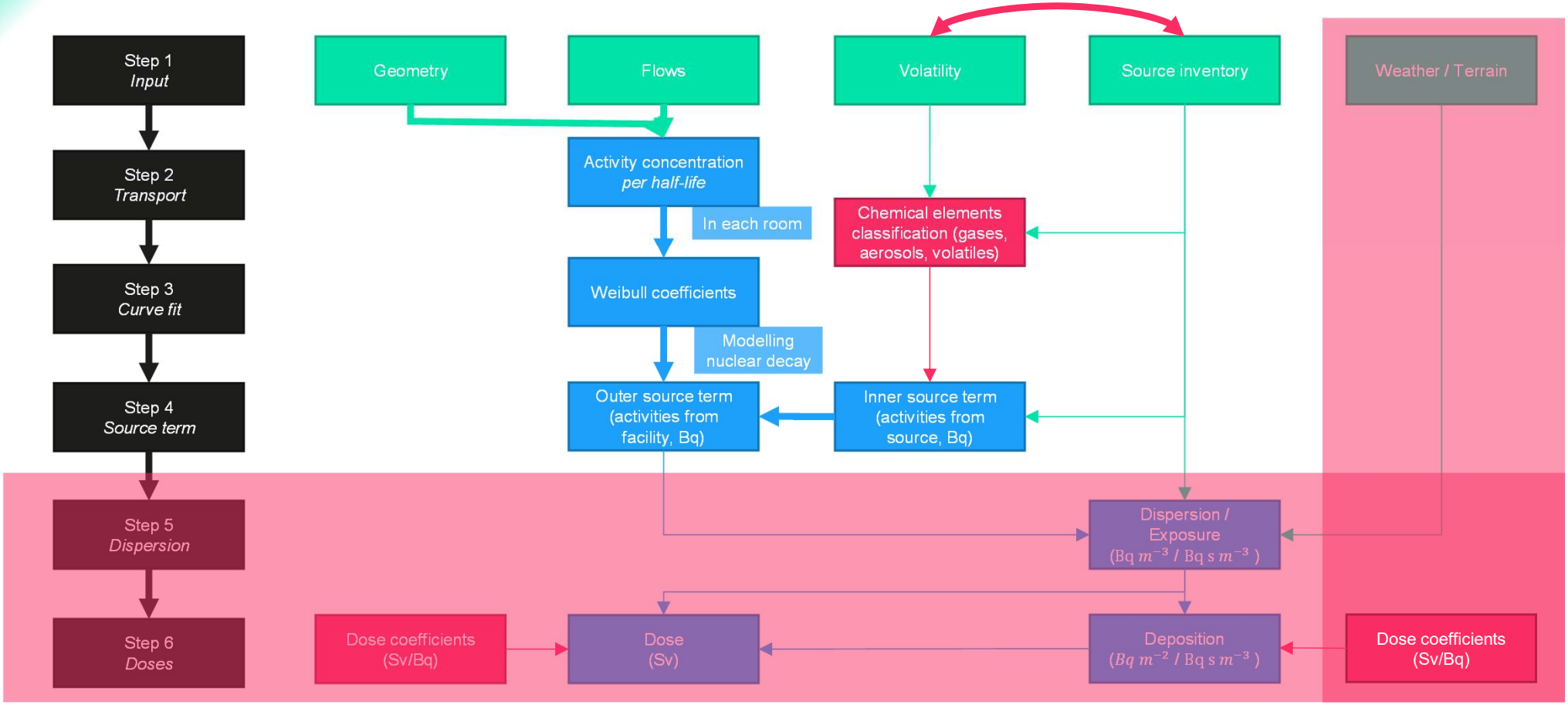


Adding Dispersion Step



Public Dose – Definitions

Mathematical Modeling of:

- **Dispersion/Deposition:** Distribution of radioactive material in the atmosphere.
- **Deposition:** Settling of radioactive material on the surface.
- **Exposure:** Effect of radiation on a person.

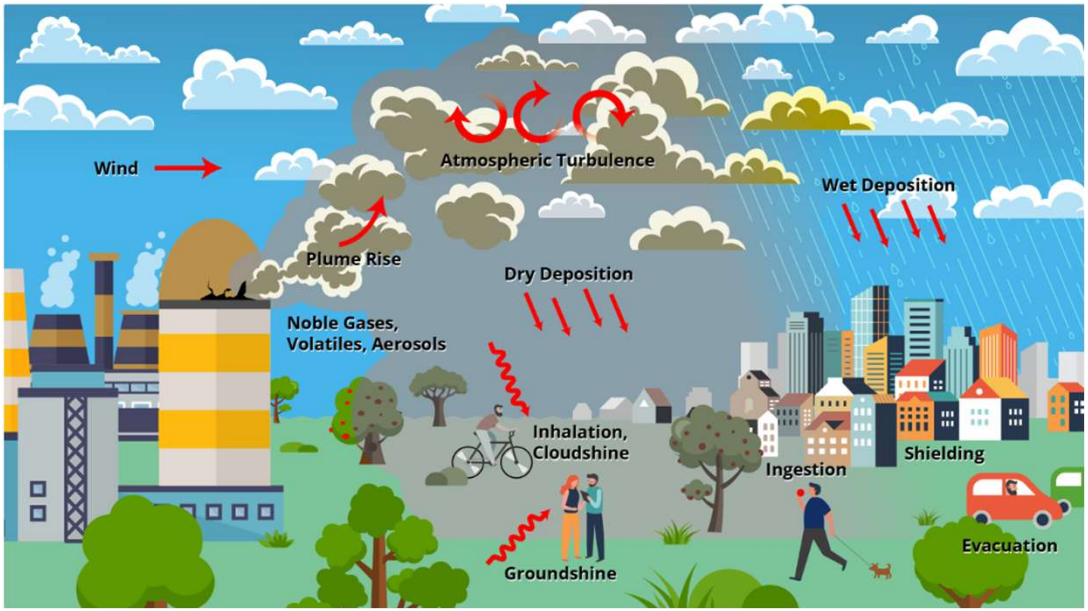
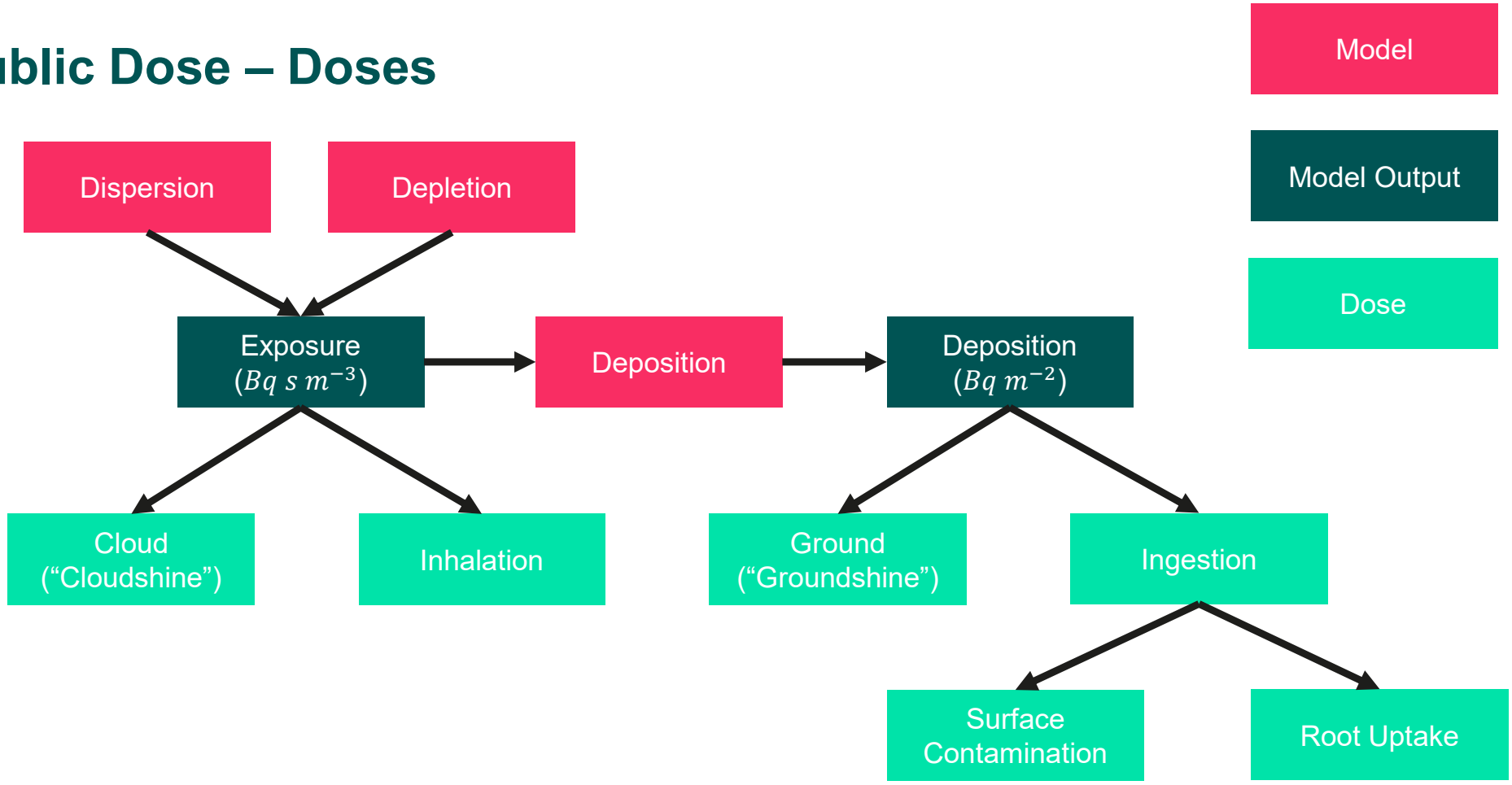


Figure: https://maccs.sandia.gov/software/maccs (accessed 2025-09-10)

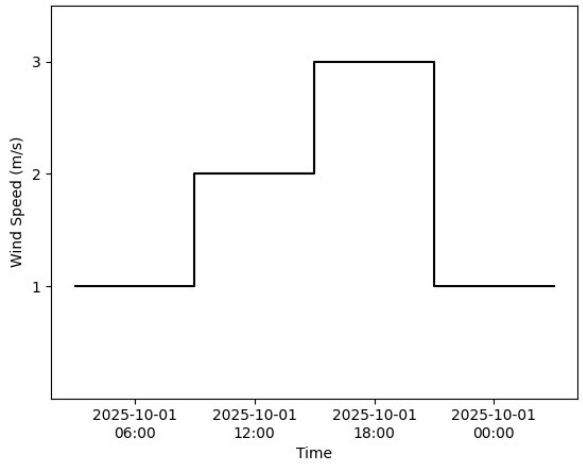
Public Dose – Doses



Weather Data I/II

Date	Time	Wind Speed (m/s)
2025-10-01	06:00:00	1.0
2025-10-01	12:00:00	2.0
2025-10-01	18:00:00	3.0
2025-10-02	00:00:00	1.0

Conversion
Filtering
Stepwise Interpolation



Weather Data

- Tabular format, Date-Time-Value
  - Wind Speed and Wind Direction
  - Cloud Cover
  - Precipitation

Weather in the Vysus tool

- Interpolation to nearest measurement
- Data processing:
  - Artificial minimum wind speed
  - Replace NaN
  - Unit conversion
  - Inter/extrapolation (mm/<time unit> to mm/h)

Model Assumptions

Overestimated Dose
Simplified (bio)chemistry
No particle-size distribution

Scenario-dependent Effect on Dose
No plume rise/fall
Simplified building/terrain effect
Semi-infinite approximation
Constant Weather Parameters
Wind-speed Profile

Underestimated Dose
No daughter nuclides
No resuspension

Probably large overestimation, compensates for other simplifications

Tailored to situation at facility

Often considered “small corrections”

Vysus Dose Calculation Workflow

Accident Scenario

→ Source Term

→ **Compartment Modelling**

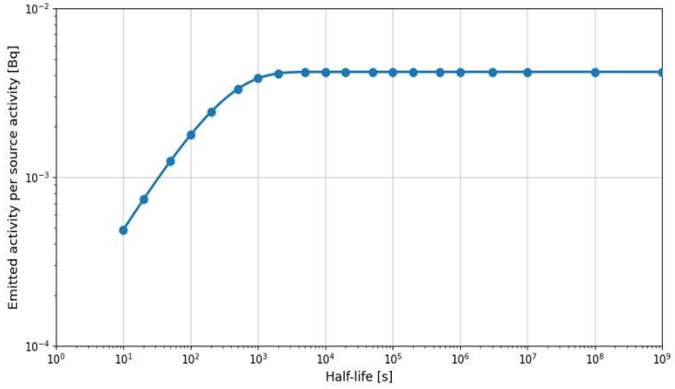
→ Atmospheric Dispersion

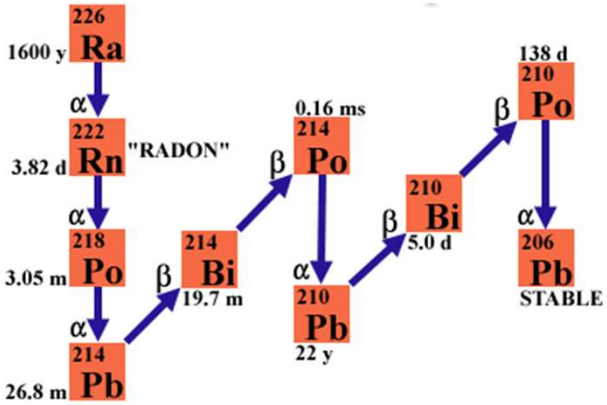
→ Dose Assessment

Compartment Transport Modelling

Features

- Flexible room network
- Multiple release sources
- Bidirectional flows
- Individual radionuclides
- Dynamic inventories





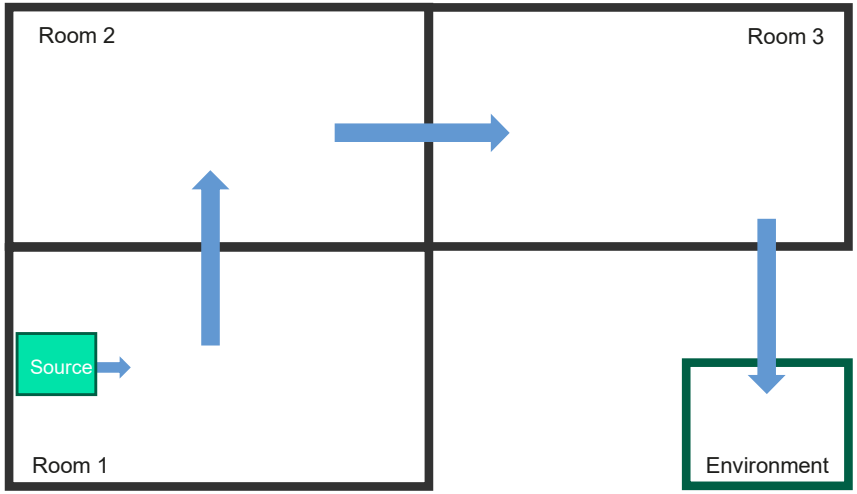
Improved realism for complex facilities

- ❑ Peviously considered decay of the nuclides, no daughter products
- ❑ Calculates for 20 pre-determined half-lives
- ❑ Usually takes >30 minutes with repeated user input required

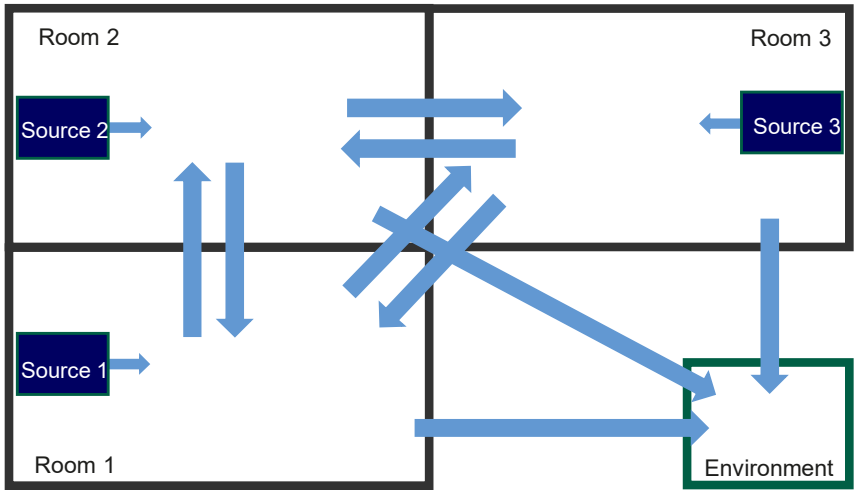
Vysus Dose Calculation Tool

- ❑ Includes decay products
- ❑ Solves for each individual nuclide
- ❑ One big system -> automatic solving

Advanced Numerical Solver



- Previous version

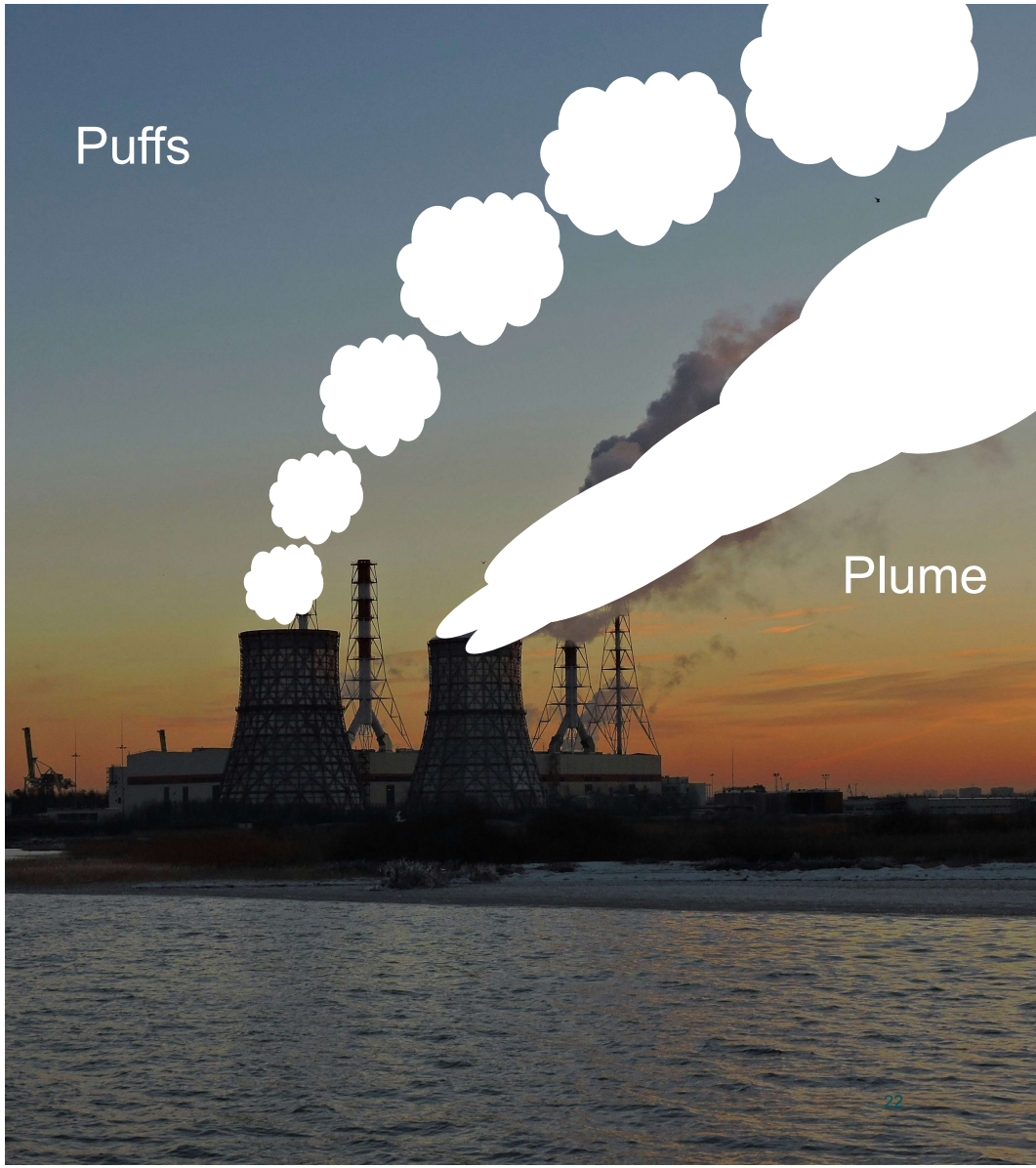


- Current Vysus Dose Calculation Tool

Gaussian Dispersion Modeling

Improved Physics

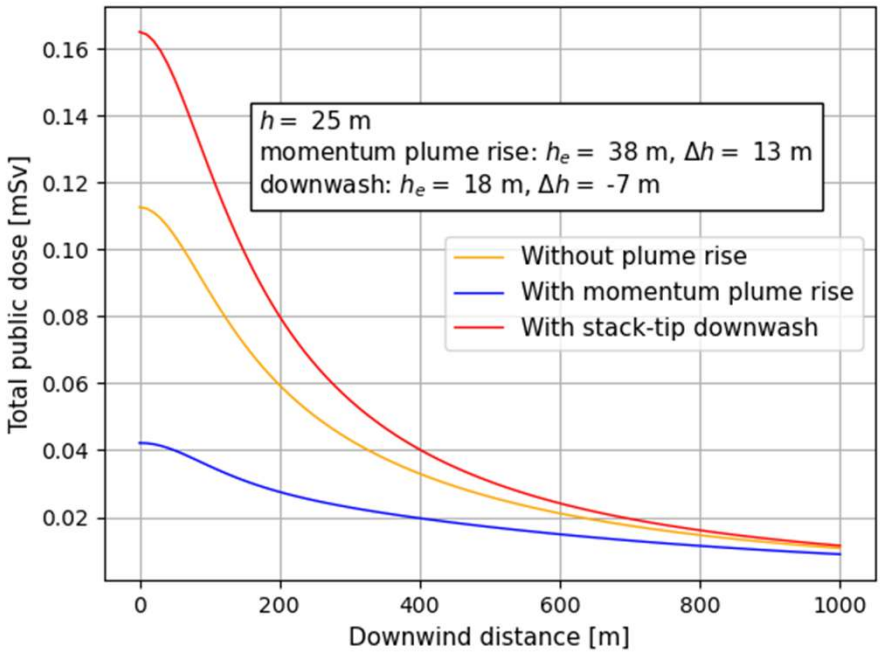
- Plume rise
- Puff rise
- Stack-tip downwash
- Improved release height
- Better atmospheric representation

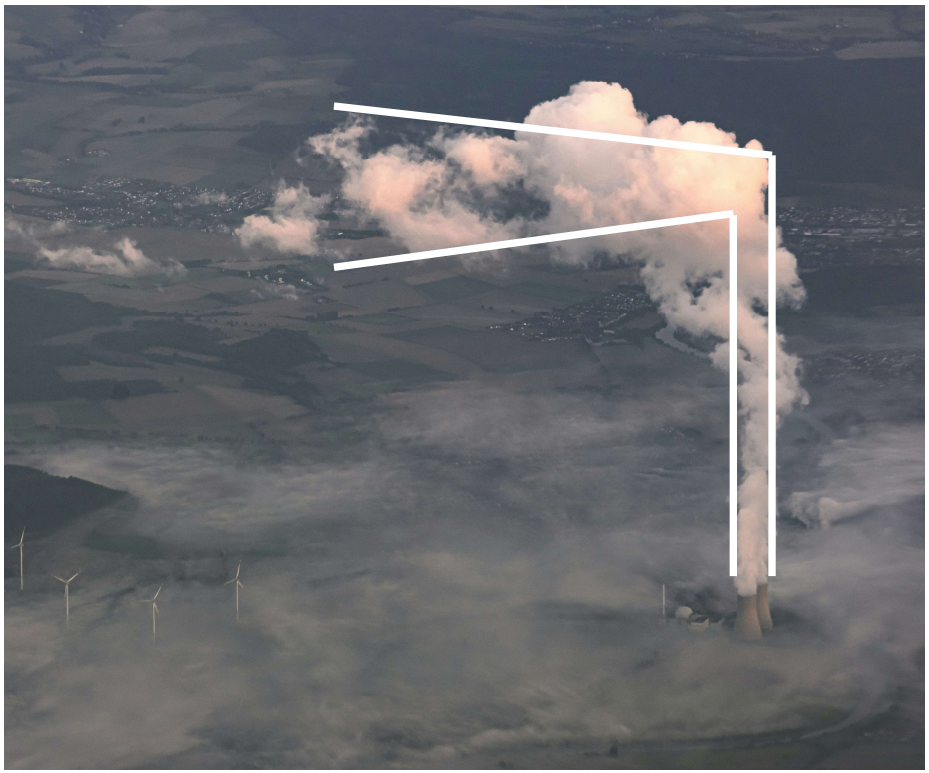


Results

Plume Rise

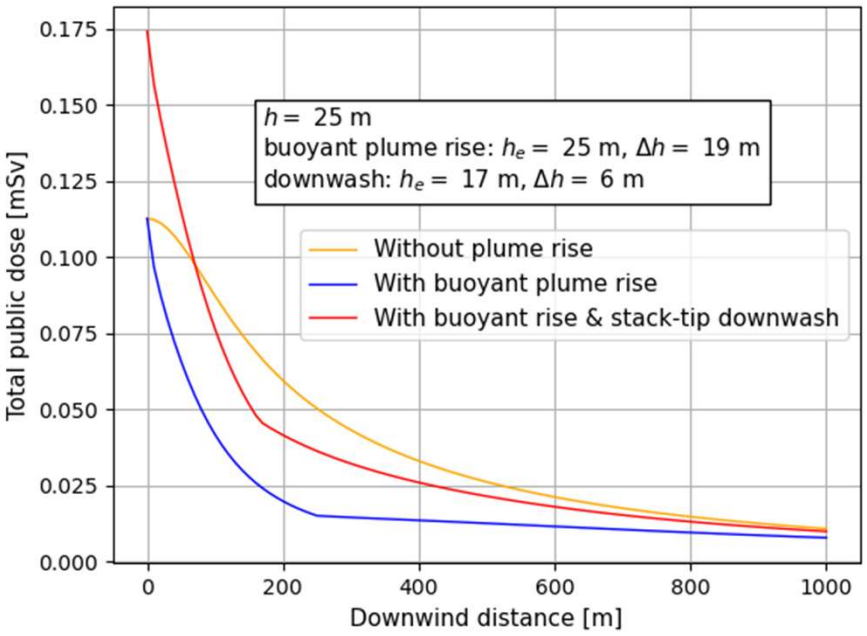
Public Dose vs Downwind Distance: Plume Model





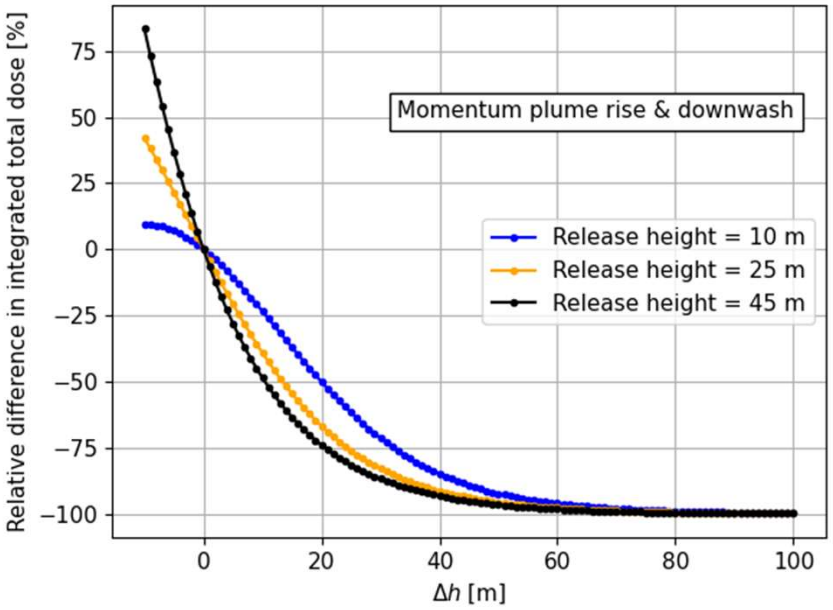
- **Momentum Rise & Stack-tip Downwash**

Public Dose vs Downwind Distance: Plume Model

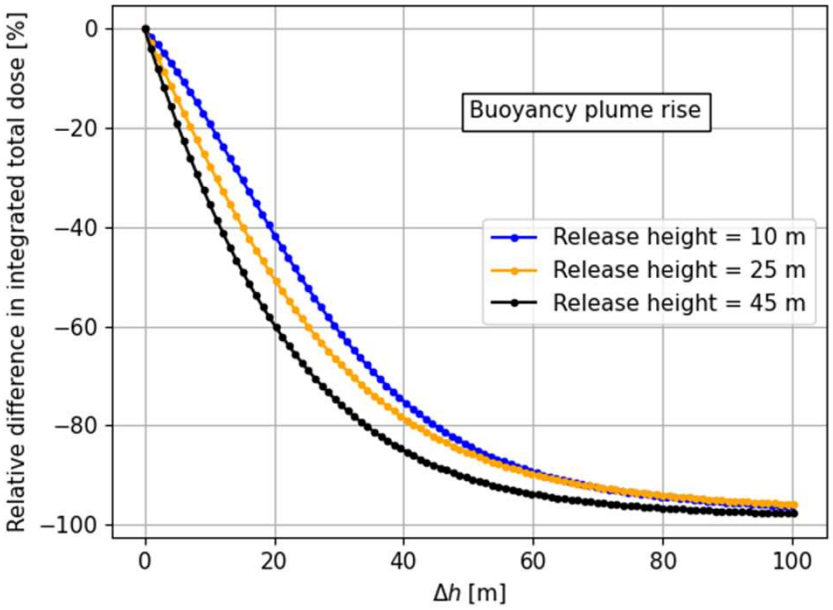


- **Buoyancy Rise & Stack-tip Downwash**

Sensitivity Study: Plume Model



- **Momentum Rise & Stack-tip Downwash**



- **Buoyancy Rise**

Verification and Performance

Verification

- Benchmarked against previous implementation
- Excellent numerical agreement
- Robust convergence
- Faster calculations
- Improved traceability

Key Takeaways

Vysus Dose Calculation Tool

✓ Integrated dose assessment platform

✓ Advanced transport modelling

✓ Weather-aware dispersion

✓ Complete radionuclide calculations

✓ Automated workflow

✓ Faster, more reliable analyses

Conclusions

- A new dose calculation tool has been developed by Vysus Group, for calculating activity concentrations and doses to workers and to the public, which produce lists of the nuclides that dominate in contributing to the doses.
- The methodology rests on a solid theoretical foundation.
- State-of-the-art radiological consequence assessment
- Improved physics and computational efficiency
- Supports safety analysis, licensing and emergency preparedness
- The tool can be customized to any nuclear facility, e.g., to nuclear power plants, to nuclear fuel factories, or to waste management and storage facilities – with nuclear accident scenarios and emergency preparedness as the common denominator.

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Thank you