

# ADDAM (Atmospheric Dispersion and Dose Analysis Method)

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Urban Areas Working Group

Nuclear Power Plant mid-range atmospheric dispersion scenario

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# General Aspects of ADDAM

- Developed for safety assessment of Canadian nuclear facilities
- Calculates doses to members of the public following a hypothetical accidental release of radioactivity to the atmosphere
- Based on the models described in CSA N288.2
- Runs repeatedly, combining release data with historical meteorological data collected over the course of many years
- Predicts a distribution of doses that allows probabilistic statements to be made regarding the consequences of the accident
- Fully documented and quality assured

# Processes Considered

- ADDAM is a Gaussian plume model that considers the following atmospheric dispersion phenomena (all have been validated):
  - Plume rise, downwash, and entrainment (effective release height)
  - Fumigation
  - Reflection from an elevated inversion
  - Transport and dispersion (plume broadening and plume diffusion)
  - Wet and dry deposition and plume depletion
  - Air concentration
  - Radioactive decay and build-up
  - External exposure due to cloudshine (including a finite cloud model) and groundshine
  - Internal exposure due to inhalation

## ADDAM Improvements from N288.2

- Runs probabilistically with respect to the meteorological data
- Quantifies some areas of the plume rise models where N288.2 is vague
- The plume rise model can treat buoyant horizontal releases, and to accept stack gas temperature and exit velocity as inputs
- Has a lower threshold speed for entrainment
- Can calculate the lateral dispersion parameter directly from the standard deviation in wind direction
- Handles deposition due to fog using a special algorithm
- Implements the latest Dose Conversion Factors
- Uses a more refined finite cloud model
- Sheltering by individuals can be credited

# ADDAM Improvements from N288.2 (continued)

- The population is assumed to be uniformly distributed within each cell when calculating collective dose
- Assessments can be made for tritiated hydrogen gas (HT)

# Assumptions

- Meteorological conditions are constant over the averaging time of the meteorological data
- The terrain is flat
- Terrain roughness and cover are uniform by sector
- Precipitation type and rate are uniform over the region of analysis
- Inversion height has a set value for a given stability class and is constant with downwind distance
- The activity of radionuclides deposited on the ground decreases through decay only

# Inputs

- Site characteristics
  - Ground cover
  - Roughness length
  - Release location and configuration
  - Locations and dimensions of nearby buildings
  - Population distribution
- Release characteristics
  - Time-dependent mass and energy released
  - Time-dependent activity of each radionuclide released
  - Four release paths(Stack, Inlet, Leakage and Hole)

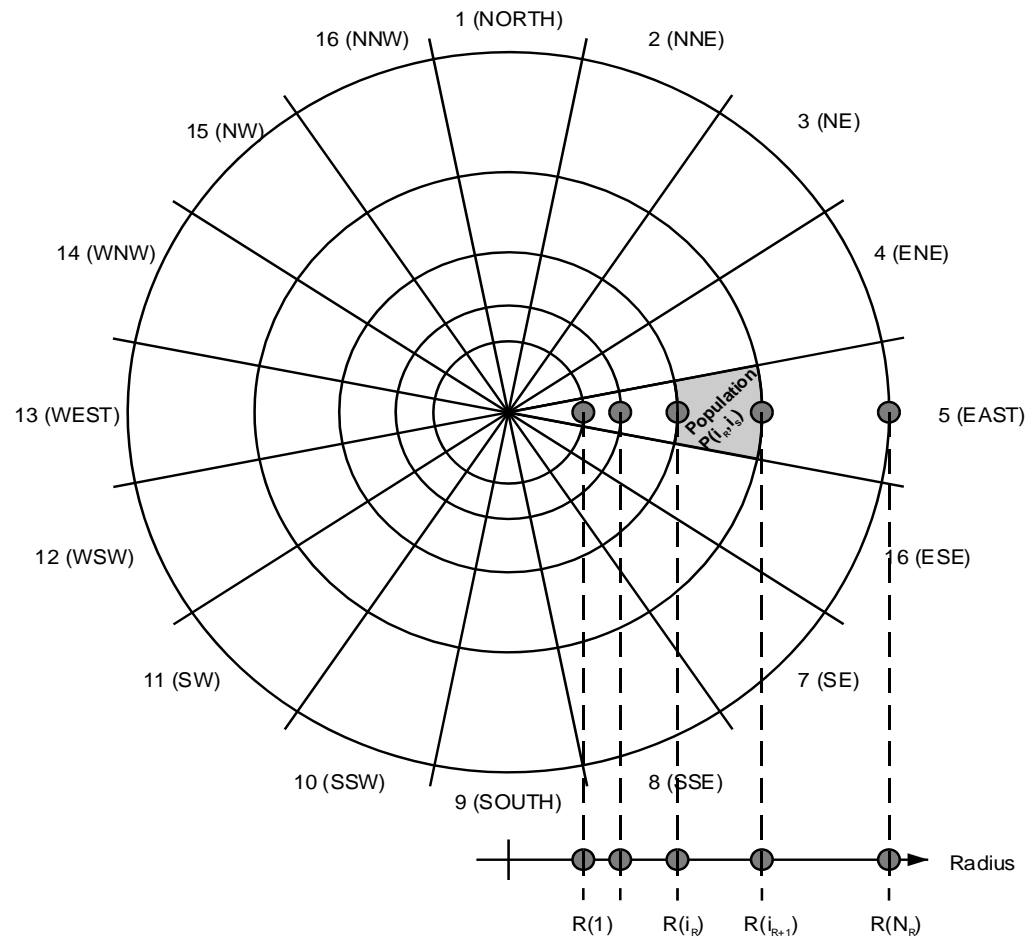
# Inputs (continued)

- Receptor Characteristics
  - Locations (downwind distance, direction) of realistic critical group
  - Ages, organs
- Meteorological Conditions
  - Wind speed
  - Wind direction
  - Standard deviation in wind direction
  - Air temperature
  - Vertical temperature gradient
  - Stability class
  - Precipitation rate
  - Presence or absence of fog



# ADDAM Domain of Analysis

The domain of interest is broken down into 16 sectors and a user-specified number of radial distances



UNRESTRICTED / ILLIMITÉ

# Outputs

- For a given release, dilution factors (concentration divided by release rate) and doses are calculated at each distance in the affected sector(s)
- Dilution factors can be broken down by release path
- Individual doses can be broken down by
  - Release path
  - Exposure path
  - Age group (adult, infant or other)
  - Organ (effective, thyroid or other)
- Population doses can be calculated by summing the individual doses

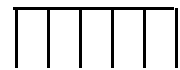
# Probabilistic Features

- Multiple calculations of dose consequences are performed by ADDAM, with successive calculations beginning at the next record in the meteorological file

Time →

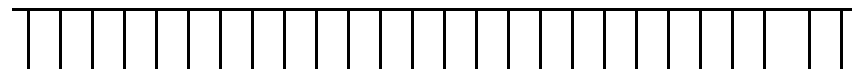


Met records



Release intervals

Time →



Met records



Release intervals

## Probabilistic Features (continued)

- Each calculation results in a prediction of dose at each radial distance in the sector(s) affected
- Doses are set equal to zero in unaffected sectors for that calculation
- The final output is a set of doses at each radial distance in each sector. These sets include zeros.
- A number of statistics can be derived from these sets:
  - Minimum and maximum doses
  - Cumulative frequency distributions (CFD)
  - Doses corresponding to a given percentile in the CFD

# Results

- The predictions are made for realistic critical groups located on the grid. The individual receiving the highest dose corresponding to a given cut-off percentile is used in the assessment.

## Limitations

- The model is not suitable for puff releases (release duration should be greater than the travel time)
- The release period must be divided into intervals within which the release rate is assumed to be constant
- Uncertainties increase for downwind distances  $< 3$  building heights and  $> 30$  km
- Concentrations and individual doses are calculated on the plume centreline; off-axis estimates are not available in ADDAM, **but our other code can fulfil that need**
- ADDAM cannot treat calm winds

## Limitations (continued)

- ADDAM can handle point sources only. It cannot treat line, area or volume sources
- ADDAM cannot treat dense gases
- The endpoint of ADDAM is dose. The model cannot calculate risks.
- Due to the lack of test data, ADDAM has not been adequately validated in the areas of wet deposition and plume depletion by snow, and dry deposition to vegetation and snow

# Uncertainties

- For a given hour
  - the 90% confidence intervals in the maximum air concentration and cloudshine and inhalation doses are about a factor 2 - 5
  - the 90% confidence intervals in the maximum ground concentration and groundshine dose are greater than a factor of 10
- The uncertainties at the extremes of the distribution of doses would be similar, but the uncertainties at a given interior percentile in the distribution would be lower



## Conclusions Regarding ADDAM Validity

- When uncertainties are taken into account, ADDAM predictions of cloudshine and inhalation doses pass all validation acceptance criteria
- ADDAM predictions of groundshine doses are extremely conservative for most radionuclides but the model is acceptable as long as large overestimates can be tolerated

# Acknowledgement to ADDAM Development and Meteorological Data Collection Team:



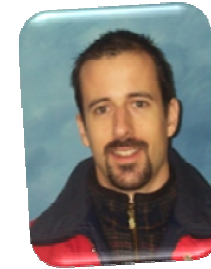
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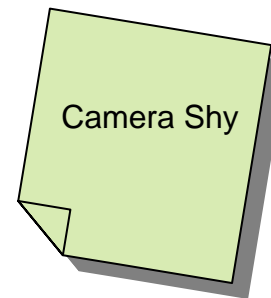
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