

Criteria for assessment of results from level 2 PSA

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Background

- The quantitative outcome of a probabilistic safety assessment (PSA) for a nuclear power plant is typically presented as
 - core damage frequency
 - frequency of radioactive release
 - societal and individual risk
- In order to judge on the acceptability of results, various criteria for interpretation of results and assessment of their acceptability need to be defined
- Target values for PSA results, both for CDF and for radioactive releases, are in use (officially or unofficially) in most countries having nuclear power plants

Scope of the comparison of level 2 PSA criteria

- Survey of target values performed jointly in
 - Nordic research project “The Validity of Safety Goals”
 - OECD/NEA WGRISK Task ”Probabilistic Risk Criteria”
- Countries: Canada, Finland, France, Germany, Hungary, Korea, the Netherlands, Slovakia, Sweden, Switzerland, Taiwan, UK, USA
 - 13 regulators
 - 4 utilities
- Organisations: IAEA, EUR

Dimensions of comparison

- Type of numerical criteria defined
- Definitions for accidental release (level 2)
- Numerical values used

Types of numerical criteria defined by different organisations

Who has defined the criteria

- law
- regulatory body, supporting advisory commission
- utility, utility organisation

Role of the criteria in decision making

- limit
- objective

For which levels criteria have been defined (including proposals/drafts)

- No probabilistic criteria defined
- Level 1 PSA criteria defined but no level 2 criteria
- Level 1 and 2 PSA criteria defined
- Level 1, 2 and 3 PSA criteria defined

Existing vs. future plant

- Same criteria
- Harder criteria for future plants

Different definitions for accidental release for which numerical criteria have been given

Large Release

- 100 TBq of Cs-137 [CNSC/Canada, Finland]
- 10 000 TBq I-131, 200 TBq Cs-137 [UK]
- 1% of core inventory of Cs-137 [OPG/Canada]
- 0,1 % of Cs-134 and Cs-137 in a 1800 MWt core [Sweden/SSI]

Large early release

- Large off-site releases requiring short term off-site response [IAEA]
- Significant, or large release of Cs -137, fission products before applying the offside protective measures [Slovakia]
- Rapid, unmitigated large release of airborne fission products from the containment to the environment, resulting in the early death of more than 1 person or causing the severe social effect [Korea]

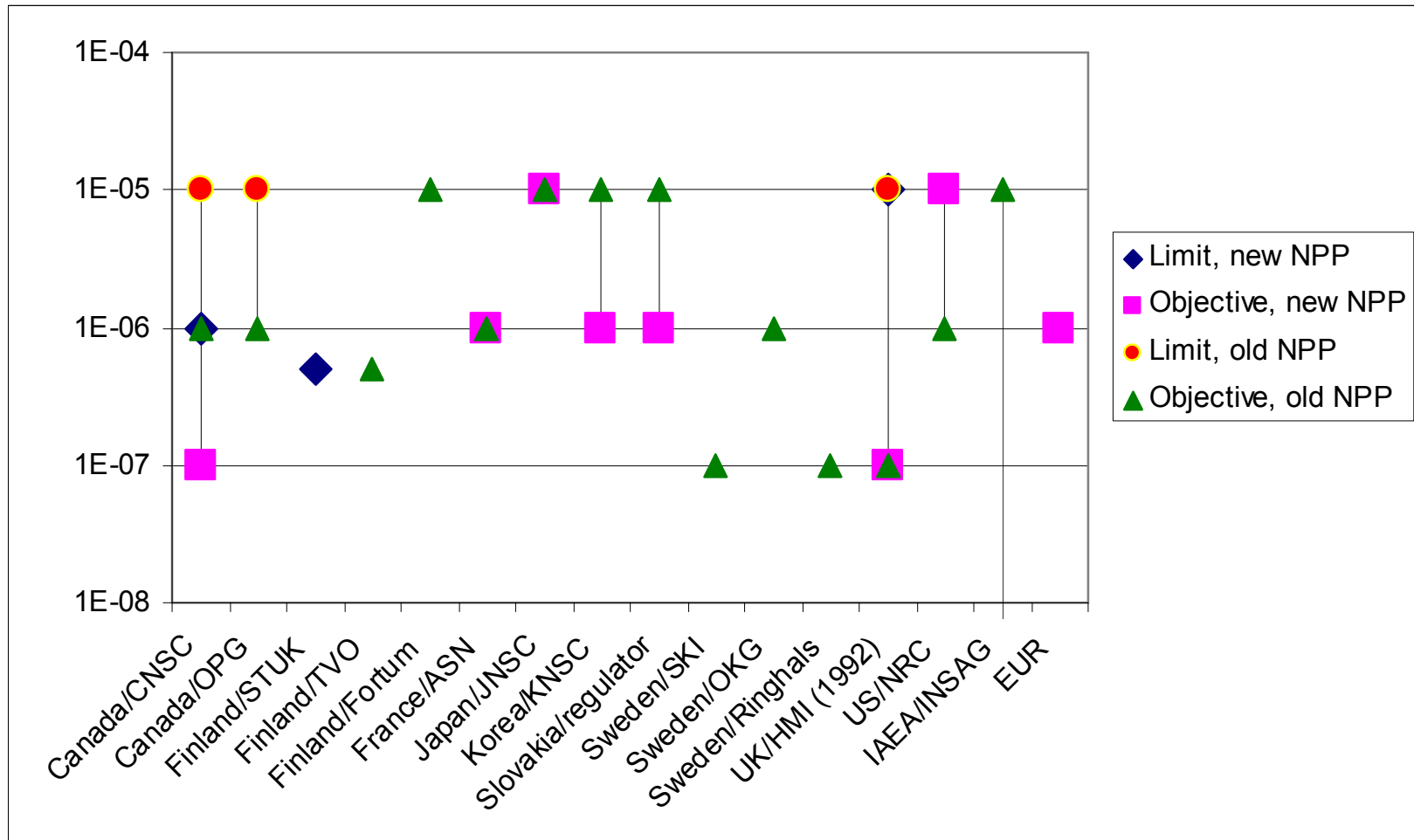
Small release

- 1000 TBq of I-131 [CNSC/Canada]

Unacceptable consequence [France]

Containment failure [Japan]

Numerical values defined* for the large release** criterion



* Some definitions are presented in official documents, others are unofficial or proposals

** The definition of "large release" varies

Comparison of the Finnish level 2 PSA criteria with individual and societal risk

Reference: STUK - Finnish Regulatory Guide, YVL Guide 2.8, for PSA

- The following numerical design objectives cover the whole nuclear power plant:
 - The mean value of the probability of core damage is less than $1E-5/a$.
 - The mean value of the probability of a release exceeding the target value defined in [section 12](#) of the Government Resolution (359/1991) must be smaller than $5 \cdot 10^{-7}/a$.

Section 12 - **Large release** shall not cause

- 1) neither acute harmful health effects nor
 - 2) any long-term restrictions on the use of extensive areas of land and water
- For long-term effects, the limit for an atmospheric release of **Cs-137 100 TBq**
 - STUK has not set criteria at level 3 → comparisons with other recommendations, e.g., ICRP recommendations (**10...100 mSv**)

Reference risk and dose levels

- In general the probability of accidental death for an individual during one year is at the level $1E-4$
- How much less the risk from a radioactive release should be?
 - U.S. NRC recommends the factor of 1000
 - Tentative safety goal for individual risk of prompt death $1E-7/yr$
- In general fatal cancer death is at the level $1E-3$ cases per year
 - Tentative acceptance criterion in the case of radioactive release, the value of acceptable individual risk for latent death $1E-6$ cases per year
- ICRP Publication 82's limit value of 10 mSv
- IAEA criterion for terminating temporary relocation with the value 10 mSv/month

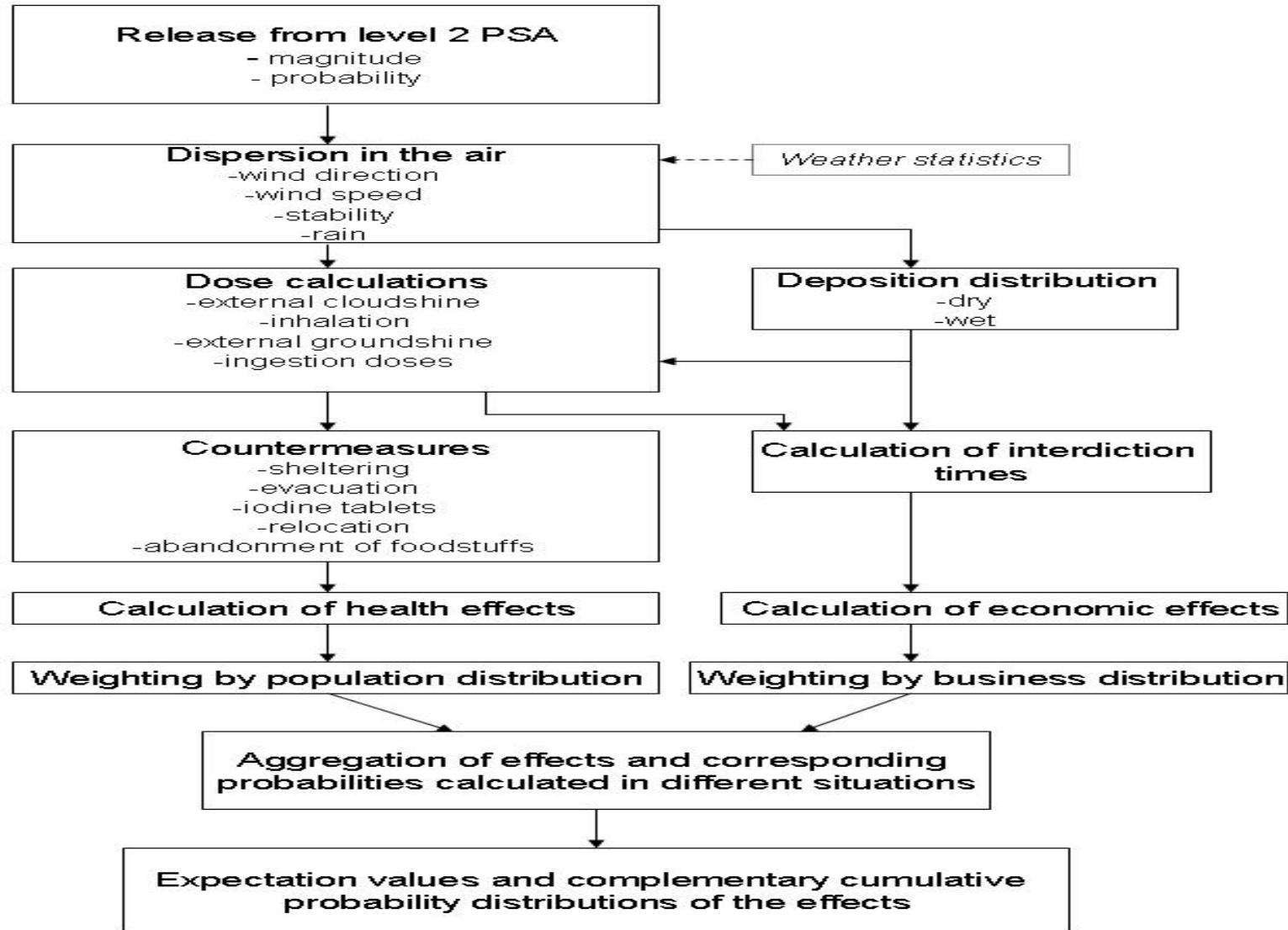
Scope of the evaluation - what was calculated

Large release was used as a reference release and off-site doses and areas of contamination were calculated

- conditional individual dose frequency
- conditional collective dose frequency

- Note: This is not a full scale level 3 study

Off-site consequence assessment



Input data

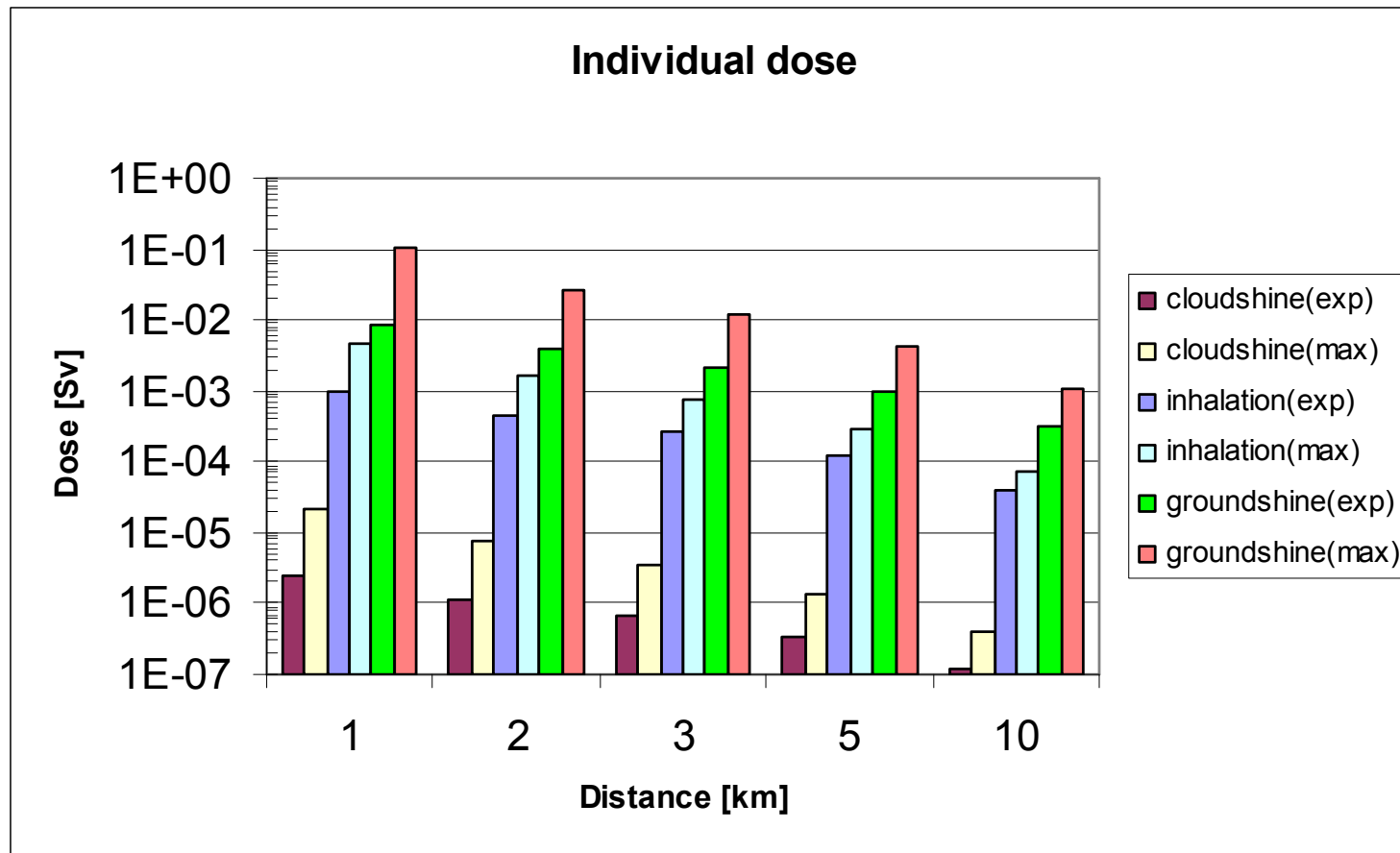
- 1) Source term
 - the reference source term: 100 TBq Cs-137, 148 TBq Cs-134
 - 1 hour release duration
 - 20 m release altitude

- 2) Weather data
 - based on the measurements at the Olkiluoto weather mast
 - annual distribution
 - dry and wet deposition

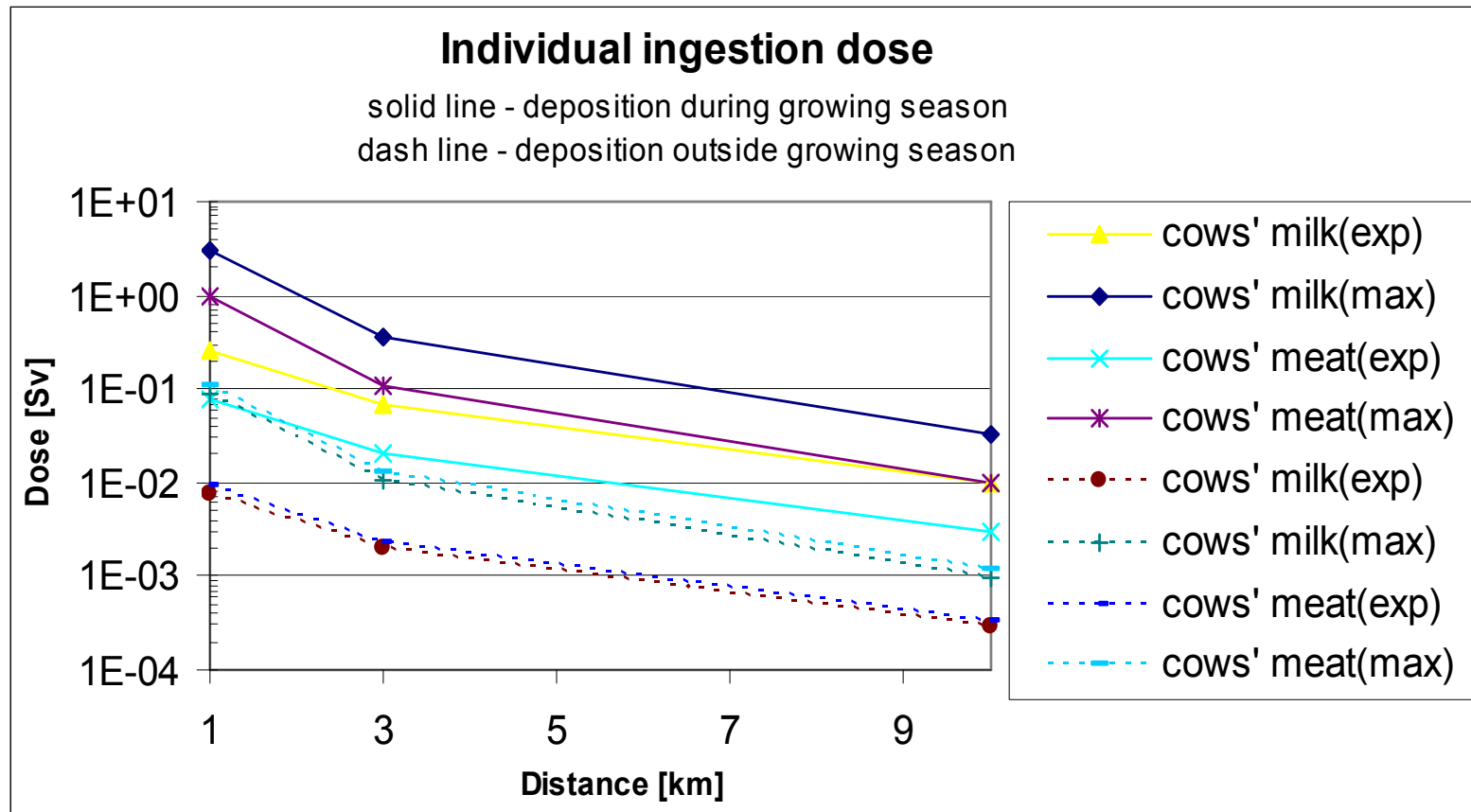
- 3) Environmental data
 - population distribution (0-100 km real, 100-300 km average)
 - shielding factors
 - ingestion rates (milk, meat, green and root vegetables, grain)

- 4) No countermeasures

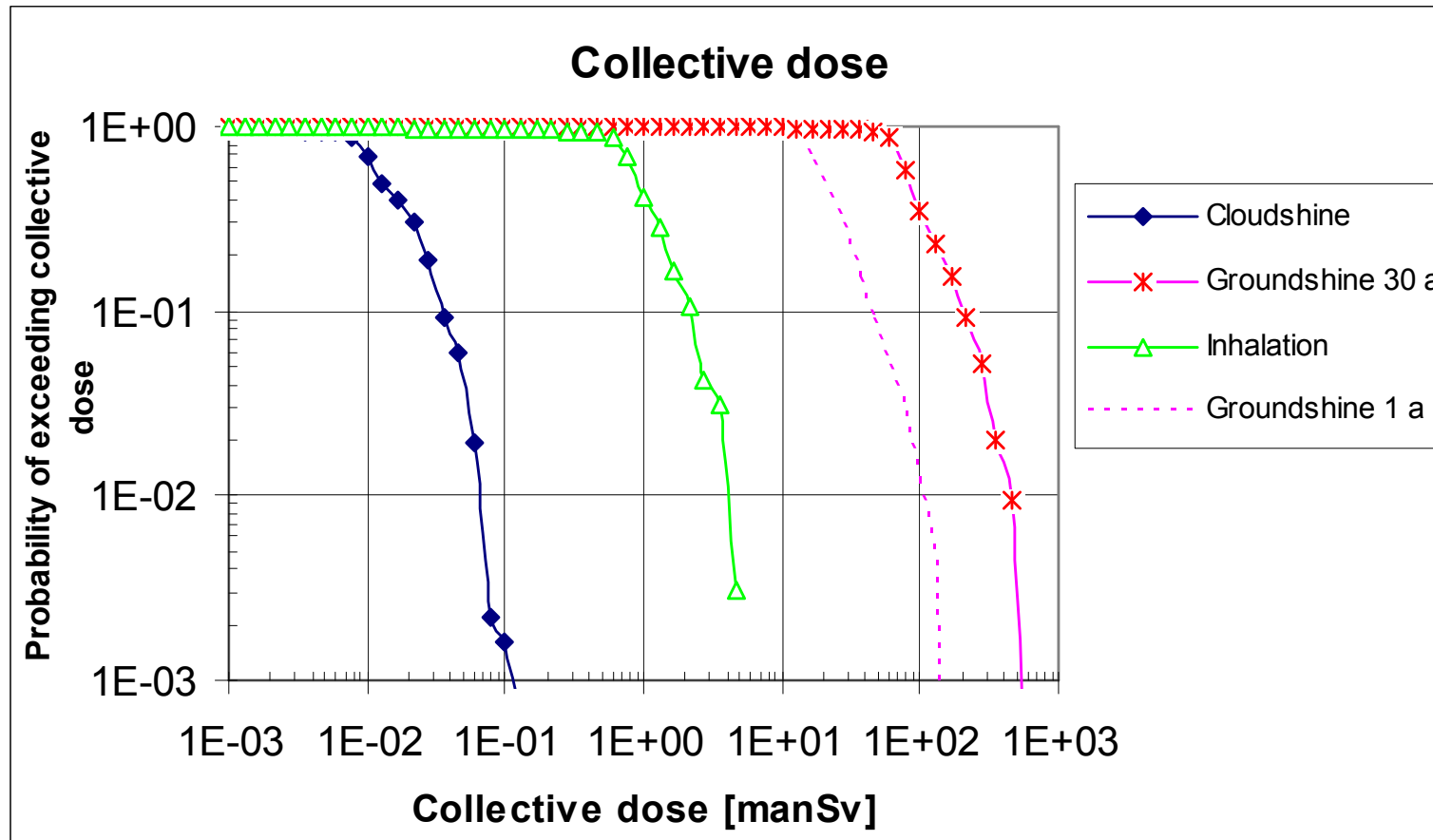
Individual dose (1 year exposure to groundshine)



Individual dose (ingestion time 30 years)



CCDF of the non-ingestion pathways



Contamination areas at the 99.5th percentiles based on the long-term exposure from cows' milk and from groundshine following the reference release. Three different dose criteria are applied.

Exposure pathway	Criterion for the contaminated area [km ²]		
	0.03 Sv/30a	0.1 Sv/30a	0.3 Sv/30a
Milk during growing season	350	70	20
Milk outside growing season	7	2	0.5
Groundshine	40	8	3

Conclusions about the "100 TBq Cs-137" criterion

- Criterion is purposed to reduce
 - contamination of large areas and
 - late health effects
- Largest contaminated areas due to ingestion pathways
 - in bad but infrequent weather sequences even hundreds of km²
 - food interdiction could reduce exposures but cause economic losses
- The expected value of calculated individual risk is lower than the predefined safety goal value
 - Even the 95 % fractile is lower
 - In this case the requirement of the safety goal is fulfilled

Conclusions

- Acceptance criteria for results from level 2 PSA differ a lot between countries
 - Both definitions for large release and probability values differ
 - The probability limits used vary from 1E-7/yr to 1E-5/yr
 - 1E-5/yr used for old reactors only
 - For new reactors 1E-7...1E-6/yr
 - The status of criteria differs from mandatory requirements to informal targets
- The aim of the definition for large release is such that the release magnitude no acute health effects are caused
 - only stochastic late effects can be expected
 - “100 TBq Cs-137” release would not cause acute health effects and late effects are minor
- To validate level 2 criteria, level 3 PSA assessments need to be made
 - Results are strongly dependent on population data, weather data, and whether or not countermeasures are accounted