

Risk Analysis of Highly-integrated Systems

RB I: Result Representation (Expected Value, Frequency-Consequence-Diagram, Uncertainties), Visualisation (GIS), Risk Assessment, Regional Aspects



Frequency-Consequence-Diagram

- Coordinate system with event frequency and damage consequence (consequence assigned to frequency)
- No connection to a risk value
- Synonyms for the frequency-consequence-diagram
 - F-C-Diagram (Frequency-Consequence)
 - F-N-Diagram (Frequency- Number of Fatalities)
 - W-A-Diagram (Probability-Consequence) is misleading

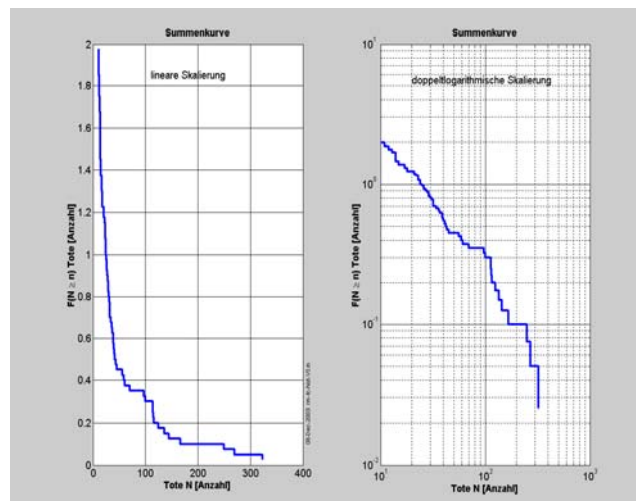
Example: Number of deaths from tornados in the US between 1938 and 1977

- Accumulated frequency as a base for the F-C-diagrams
- Procedure for the construction of a F-C-sum-diagram (CCDF)

$$F(N \geq n) = \sum_{i=1}^k F(N=n)$$

Number of deaths: n_i	Number of Tornados with i Deaths: $f(N=n_i)$	Accumulated frequency: $F(N \geq n_i)$	Accumulated frequency per year: $F(N=n_i)/40$
10	5	79	1.975
11	4	74	1.850
12	3	70	1.750
...
250	1	3	0.075
270	1	2	0.050
323	1	1	0.025

F-C-diagram

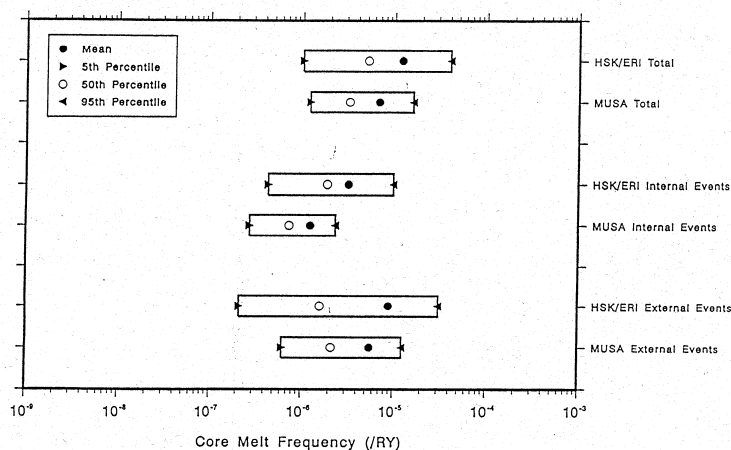


Probabilistic Risk Analysis (PRA)

The analysis level in nuclear technology:

- **Level 1**
Plant relevant analysis to identify dangerous or undesired scenarios and events. E.g. identification of scenarios, which lead to a core melt and determining their occurrence probability.
- **Level 2**
Analysis of possible impact on the plant by undesired events, and determining the release of energy and substances into the environment. E.g. categorised releases (amount, conditions, frequency) from the containment.
- **Level 3**
Analysis of transport mechanisms within the environment, assessment of the consequences from an accidental activity release, and their frequency. E.g. loss of human life, area contamination etc. including specific occurrence probability.

Core Melt Frequency (MUSA and HSK/ERI-Analyses)



MUSA: Mühleberg Safety Analysis
HSK: Hauptabteilung für Sicherheit von Kernanlagen
ERI: Energy Research, Inc.

The Source-Term

- The amount and the isotope composition, combined with physical and chemical properties, the heat quantity in a contaminant plume resp. –cloud, the time profile and the height of release describe the Source-Term.
- The Source-Term is depending on the accident sequence.

Examples of different Source-Terms:

Quellter m	Zeit vor Freisetzung [h]	Dauer der Freisetzung [h]	Freisetzungsr ate [MW]	Freisetzungshöhe [m]	Zeit zur Alarmierung [h]	Freigesetzter Anteil						
						Xe- Kr	Org-I	I	Cs-Rb	Te-Sb	Ba-Sr, Ru	La
QT1	2.0	1.0	2.0	10	1.0	1.0	0.001	0.1	0.1	0.05	0	0
	3.0	5.0	0.2	10	-	-	-	-	-	0.05	0.01	0.001
QT2	2.0	1.0	0	10	1.0	1.0	0.001	0.1	0.1	0.1	0.01	0.001
QT3	2.0	1.0	0	10	1.0	0.1	0.00001	0.001	0.001	0.001	0.0001	0.00001
QT4	2.0	1.0	0	10	1.0	1.0	0.00033	0.033	0.033	0.033	0.0033	0.00033
	3.0	1.0	0	10	-	-	0.00033	0.033	0.033	0.033	0.0033	0.00033
	5.0	1.0	0	10	-	-	0.00033	0.033	0.033	0.033	0.0033	0.00033
QT5	2.0	24.0	0	10	1.0	1.0	0.001	0.1	0.1	0.1	0.01	0.001

Uncertainty: Percentiles

- A percentile is the value of a variable below which a certain percent of observations fall.
- So the 95th (5th) percentile is the value below which 95% (5%) of the observations may be found.
- The 50th percentile is the value where half of the values will be below and half will be above. It is called the median.
- The 50th percentile and the average are different measures.

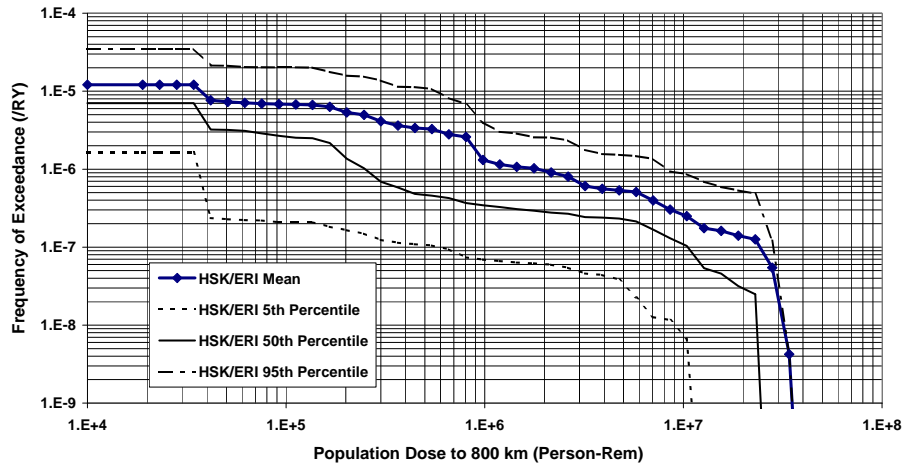
Example:

2, 3, 5, 9, 11

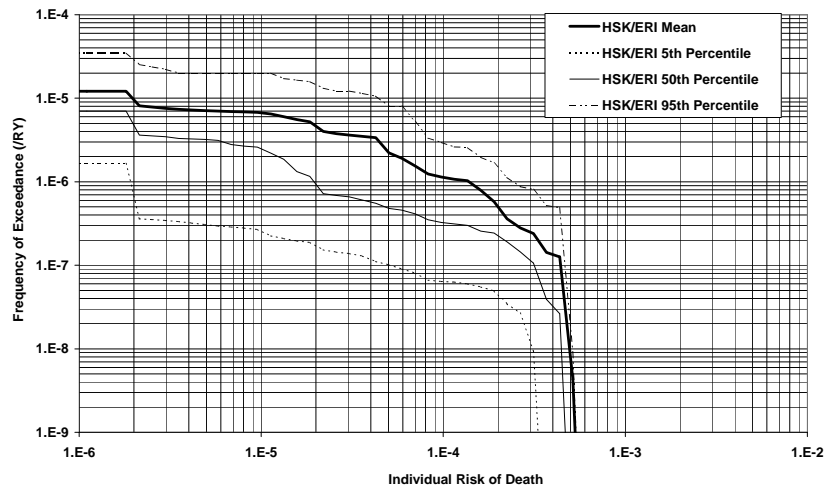
50th percentile=5

Average=6

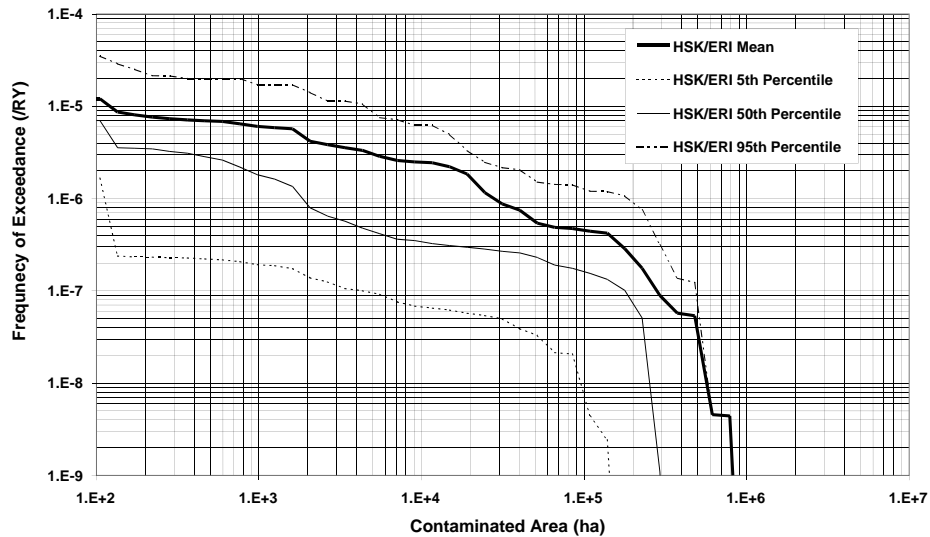
CCDF Form with Confidence Intervals



Further Damage Parameters - Individual Death Risk



Contaminated Area



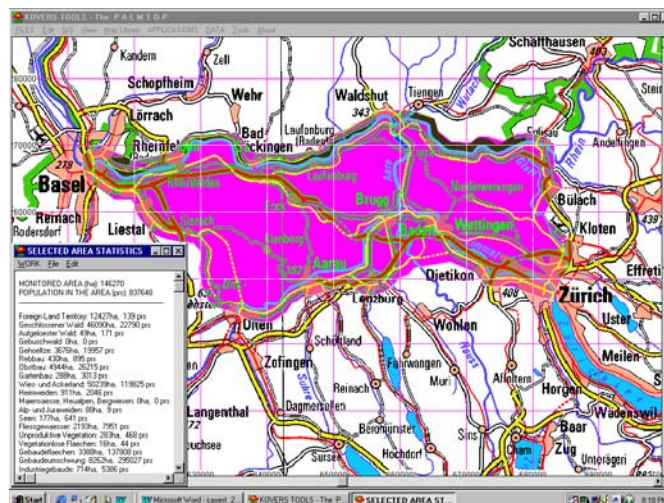
More risk representation: examples from a LSA case study

- Objective of the case study: Assessment of a virtual, dangerous cargo mission to the effect of minimising the risks to the environment and the population, that may be entailed by an unplanned, on-route release-off-containment of the substance.
- Use of LSA software toolkit.
- Cargo mission: Carry a cargo consisting of 28000 kg of Vinyl Chloride (VCL) between delivery base Basel-East (Pratteln) Railway Station and destination - Zurich Central, Cargo Railway Station.
- VCL: Colourless, flammable and toxic gas.

Route selection (1/2)

- ROUTE #1 starts at Basel East and continues via Pratteln, Liestal, Sissach, Thurnen, Olten, Aarau, Lenzburg, through Baden South-Dietikon tunnel to Zurich Central Cargo.
- ROUTE #2 goes from Basel East to Pratteln, and continues along the Northern Swiss border via Rheinfelden, Laufenburg, Zurzach, Eglisau-West, to turn South via Bulach, go West of Zurich International Airport and enter Zurich to join the destination.
- ROUTE #3 shares with Route #2 the segment Basel-East to the junction South of the German city of Bad-Sackingen. Then it departs via Frick, Brugg, Baden, and joins Route #1 at the Eastern exit of the Dietikon tunnel to continue down to the destination.
- Route selection based on 245 risk related criteria (like topometric data, minimum peak population density encountered etc.).
- Result: Route #3 is the preferred route.

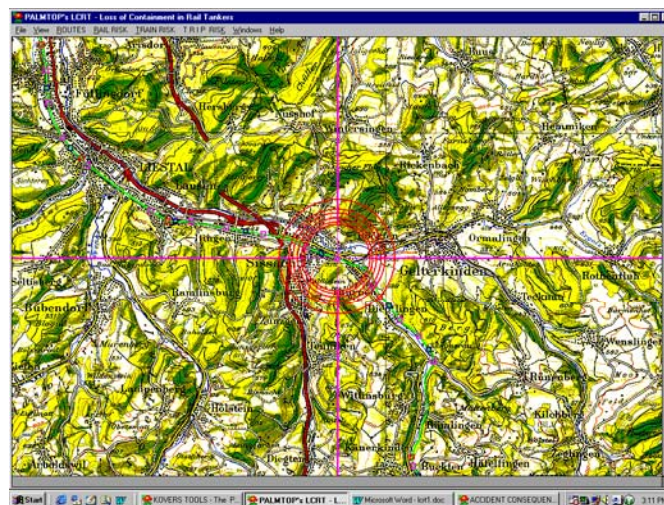
Route selection (2/2)



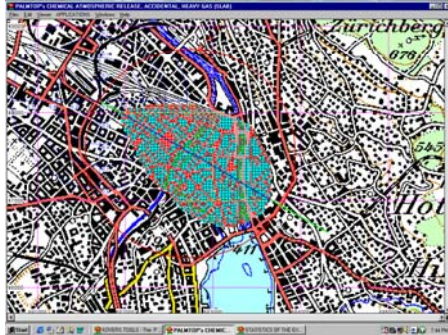
Impact areas (1/2)

- Definition based on
- Immediately Dangerous for Life and Health Limit (IDLH)
- Threshold Limit Value (TLV)
- Short Term Exposure Limit (STEL)
- Emergency Response Planning Guidelines (ERPG)
- Expected Lethality Percentages calculated via Probit functions
- Circular Risk Areas (CRA) for the BLEVE (see figure)

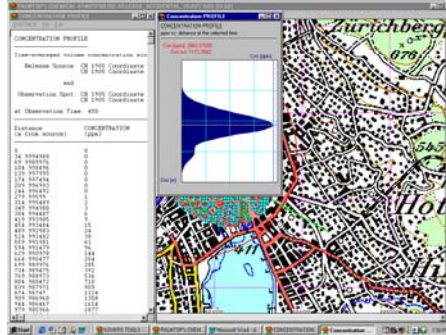
Impact areas (2/2)



Dispersion model



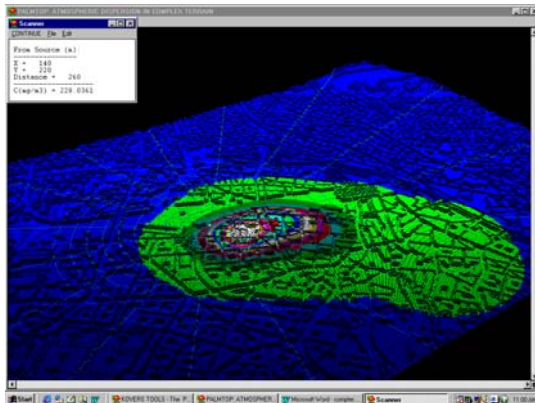
Impact area based on IDLH



Concentration Profile

Atmospheric dispersion in complex terrain

Influence of urban environment featuring sharp obstacles on the dispersion



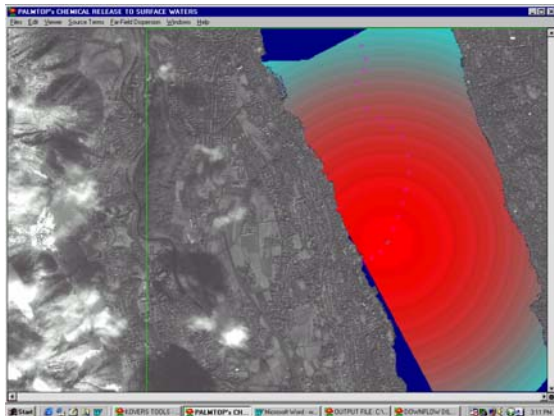
Spill into a river

Derailment of a rail tanker on the Rhine-crossing bridge as the train leaves the dispatching station Basel-East. The tank wagon is supposed to have been pierced in several places during derailment, falling into the river and settling at the river bottom shortly after the fall, down to the bridge.



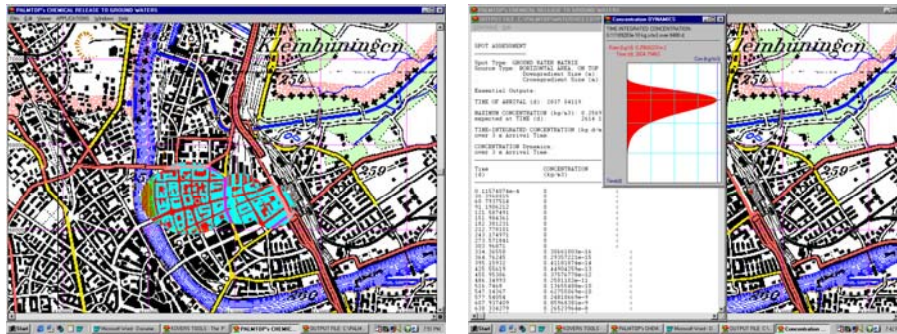
Spill into a lake

Instantaneous discharge of 14000 kg VCL in the Lake of Zurich, from the shore shuntyard of an industrial facility there, that is supposed to have been supplied from.



Ground water contamination

- Contamination in the ground water table.
- Pollutant concentration in tap water wells



Course material:

<http://www.lsa.ethz.ch/education/vorl>

Including the model uncertainties increases variance significantly

Sub modulus	Number of occurring model parameters	Number of parameters regarded in the uncertainty analysis
Atmospheric dispersion	28	24
Food chain model	162	35
Dose conversion factors	159	100
Model for health effects	27	27
Overall analysis	376	186