RiskPoll: An Integrated Impact Assessment Computer Tool for Estimating Health and Environmental Risks of Airborne Pollution

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RiskPoll program – Introduction

- RiskPoll is a set of “simplified” risk assessment tools for quantifying impacts to public health, agricultural crops and building materials from routine airborne emissions.

- Currently, the model can assess the local and regional impacts and damage costs associated with
  - respiratory health diseases from exposure to PM, SO_2, NOx, CO and secondary aerosols (inhalation pathway),
  - changes in crop yield from exposure to SO_2,
  - surface area of materials damaged from exposure to SO_2, and
  - toxic metal emissions (multimedia assessment).

- Future plans include radionuclide assessment, ...

- The RiskPoll software is being developed by J.V. Spadaro of the Ecole des Mines de Paris within the context of the ExternE Project (*JAASSpadaro@aol.com*; *http://www.arirabl.com*).

RiskPoll program – The need for simplicity

- Usually, people tend to use site-specific results as if they where typical values ⇒ *precisely wrong rather than approximately right*.
- Most policy applications need typical or aggregated values instead of “worse” case scenario or “conservative” estimates.
- Detailed environmental impact analyses (EIA) are time intensive exercises that require in addition to physical resources:
  - extensive databases of knowledge and know-how covering different fields of expertise (mutil-disciplinary analysis); and
  - trained personnel to select the most appropriate input parameters, run the models and interprete the results.
- Oftentimes, EIA software is a “black box”, with assumptions and computation routines that are not at all transparent to the analyst. There is a need, therefore, to perform a “sanity” check.

RiskPoll program – Introduction (2)

- The RiskPoll methodology has the advantage of being
  - transparent
  - simple to use, and
  - requires fewer input data – the simplest estimate requires only 4 numbers (emission rate, population density, ERF and pollutant depletion velocity).
- Health risk assessment
  - Four models are available, each using a different approach to estimate the physical impacts and damage costs based on data availability.
- RiskPoll provides results that are "reasonably" accurate and reliable as shown by comparison with detailed models. In many cases, deviations in site-specific results are less than ±50%.

RiskPoll program – Impact analysis for airborne emissions

- Health risk assessment
  - Four models are available, each using a different methodology and input dataset (based on “availability”) to estimate the physical impacts and damage costs.
  - Common to all models are the assumptions of (a) single, elevated point source, (b) steady emission rate, (c) linear no threshold ERFs, (d) negligible local pollutant depletion and (e) flat terrain conditions.
  - Assessment models:
    1. The Simple UWM – SUWM; see previous slides for details
    2. The Robust UWM – RUWM; compared to SUWM two important differences:
       - ✓ Local and regional populations are treated separately, although uniformly distributed in each domain, and
       - ✓ stack parameters and local meteo are incorporated into the analysis using a simple Gaussian dispersion model based on uniform wind rose.

RiskPoll program – Impact analysis for airborne emissions (2)

- Health risk assessment (cont.)
  - Assessment models:

3. The QUERI model; three calculation algorithms are provided
   - ✓ *Basic* and *Intermediate* estimates are semi-empirical approaches in which the SUWM result is “adjusted” according to scaling factors that depend on source location (Site ID), ratio of local-to-regional population density and stack parameters (height).
   - ✓ *Best* estimate employs a Gaussian dispersion model for the local analysis and SUWM for regional calculations. At the local scale, detailed population statistics (5 by 5 km resolution) and hourly meteorological data are used.
4. The URBAN model applies to urban sources
   - ✓ URBAN model is similar to QUERI’s Best estimate, except for the use of statistical weather data and uniform wind rose for calculating plume rise and local concentrations.

RiskPoll program – Impact analysis for airborne emissions (3)

- Input data requirements for assessing health impacts

Parameter	SUWM	RUWM Intermediate	RUWM Best	QUERI Basic	QUERI Intermediate	QUERI Best	URBAN
Local characteristics							Applies to urban sites only
ↄ Urban or rural location		✓	✓	✓	✓	✓	
ↄ Receptor density		✓	✓	‡	✓		
ↄ Receptor data (5 by 5 km^2)		†	†			✓	✓
Regional characteristics							
ↄ Receptor density	✓	✓	✓	✓	✓	✓	✓
Local weather data							
ↄ Mean wind speed			✓				✓
ↄ Mean ambient temperature			✓				✓
ↄ Pasquill class distribution			✓				✓
ↄ Detailed hourly data			§			✓	§
Stack data							
ↄ Height			✓		✓	✓	✓
ↄ Exit diameter			✓			✓	✓
ↄ Exhaust gas temperature			✓	‡	‡	✓	✓
ↄ Exhaust gas velocity			✓	‡	‡	✓	✓
ↄ Pollutant emissions	✓	✓	✓	✓	✓	✓	✓
ↄ Pollutant depletion velocity	✓	✓	✓	✓	✓	✓	✓
Other							
ↄ ER functions	✓	✓	✓	✓	✓	✓	✓

✓ mandatory input datum
† can be substituted for the local receptor density
§ can be substituted for mean weather statistics
‡ if known an improved impact estimate will be calculated

All models share the same Basic estimate result

RiskPoll program – Introduction (3)

- Potential users: local and regional governments, company leaders, utility managers, regulators, policy-makers, etc.

- Intended uses of RiskPoll include:
  - process or technology evaluation,
  - comparative analysis of energy choices (e.g., fossil vs. renewables, ...),
  - land use planning (e.g., siting of industrial sources, power plants, ...),
  - ranking and cost-effectiveness of environmental mitigation and policy options,
  - viability of sustainable development strategies (e.g., by investigating the role of environmental regulations in shaping the future development of a country's power sector – energy mix),
  - to assist the analyst who is faced with insufficient data, limited resources or lack of manpower to carry out a detailed assessment,
  - to serve as a "sanity" check in verifing the "correctness" of detailed analysis results (e.g., screening of technical and/or human errors),
  - etc.

RiskPoll program – Introduction (4)

- A (partial) list of studies that have used RiskPoll
  - SusTools, EU (tools for sustainable development)
  - NewExt Project, EU (country-specific unit damage costs)
  - ExternE-Pol Project, EU (multimedia assessment of toxic metals)
  - CETP, China (health impact assessment of air pollution for the Shandong region)
  - Health impact estimates of major thermal power plants in Pakistan (Pakistan Atomic Energy Agency)
  - An assessment of the practicality of renewable energy resources in Poland (Agencja Rynku Energii S.A.)
  - Health impacts of electricity in Brasil (Ministry of Science & Technology)
  - Comprehensive Assessment of Different Energy Sources for Electricity Generation in Indonesia (study requested by the Indonesian Government under a Technical Cooperation project sponsored by the IAEA).

RiskPoll program – The Uniform World Model (UWM)

- Risk assessment routines in RiskPoll are based on the UWM estimation.

- UWM key assumptions
  - source-based coordinate system
  - steady emission rate Q
  - stack parameters are not considered (e.g., stack height h_S)
  - uniform population distribution ρ_{avg}
    (sum of receptors averaged over land and water; range of impact depends on source location: 500 km when source is located near a large city, otherwise 1000 km)
  - uniform dispersion & chemistry (processes characterized by the depletion velocity k)
  - linear, no threshold ERF, f_{ER}
  - mean unit values (costs), U_v .

RiskPoll program – The Uniform World Model (2)

- The damage cost D is calculated using the relationship

$$D = \frac{\rho_{avg} \, f_{ER} \, Q U_v}{k} R \qquad \text{with} \qquad R = \int_{impact\,region} \frac{\rho(r,\theta)}{\rho_{avg}} \frac{M(r,\theta)}{Q} \, r \, dr \, d\theta$$

$M(r,\theta)$ = pollutant ground-level removal flux from deposition and chemical transformation;

$\rho(r,\theta)$ = population distribution, U_v = unit monetary value, k = deposition velocity, Q = emission, f_{ER} = slope of ERF

- Elevated point sources
  - R ≤ 7 for site-specific industrial or power plant emissions
  - but, R is typically ≤ 2 (except when source is close to a large city, then R ~ 5)
  - for aggregated calculations involving sources located at different sites and with different characteristics, particularly stack height, R ~ 1
- Ground-level emission sources
  - R ~ 1 in rural areas
  - R up to 100 for releases near urban centers
  - R up to 20 for aggregate ground-level emissions

RiskPoll program – The Uniform World Model (3)

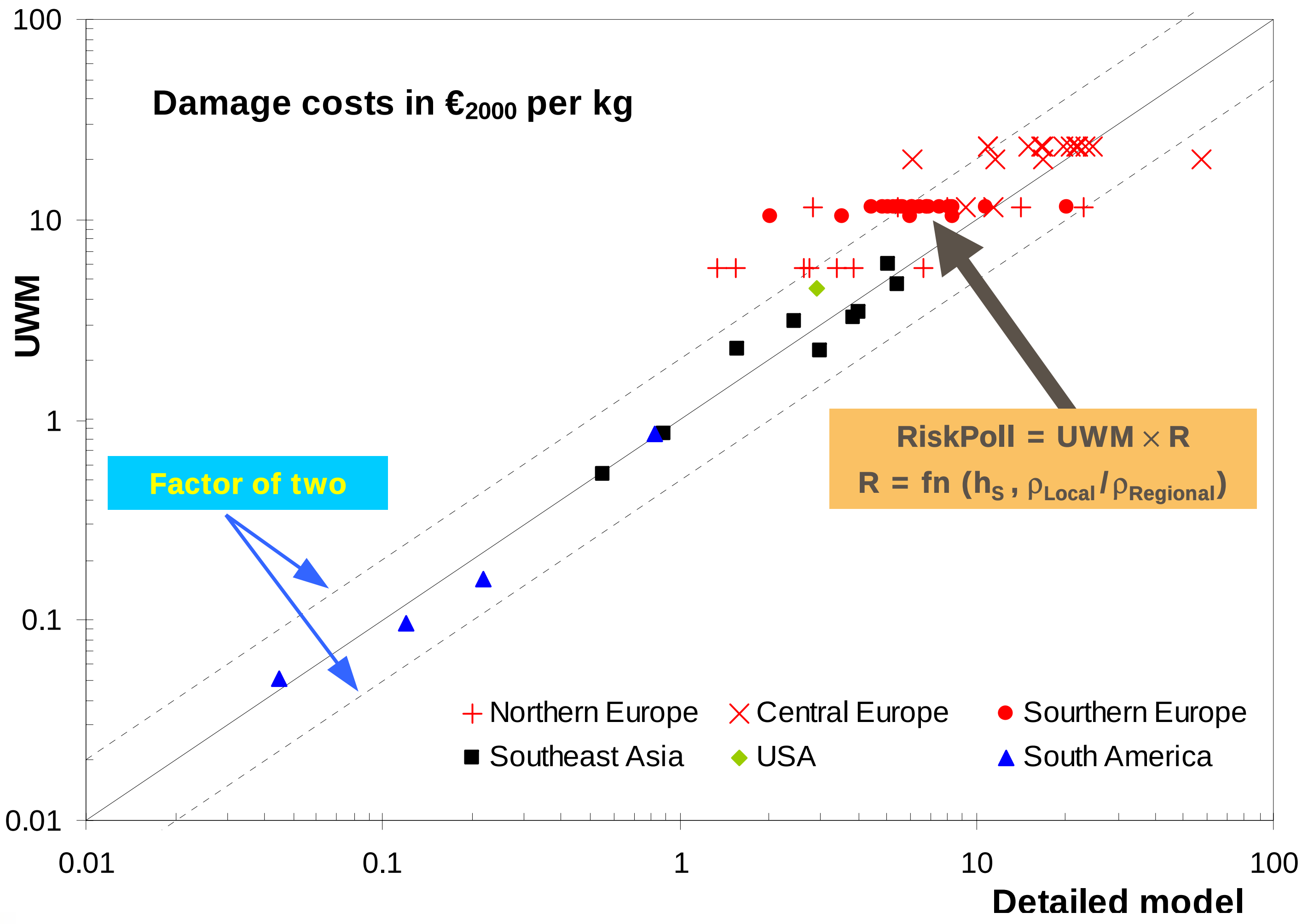
- For a uniform receptor density, R = 1 (conservation of matter).
- The UWM impact assessment equation is

$$UWM damage\cos t = \frac{\rho_{avg} f_{ER} Q U_v}{k}$$

- Equation can be used for both primary and secondary species provided the depletion velocity includes the chemical transformation rate
(PM$_{10}$→ k ranges from 0.6 to 0.9 cm/s in Europe; but can be as high as 3 cm/s in Brazil.)
- UWM is exact for uniformly distributed sources. Therefore, UWM provides “typical” damage cost results, which is what is needed for environmental policy taking decisions.

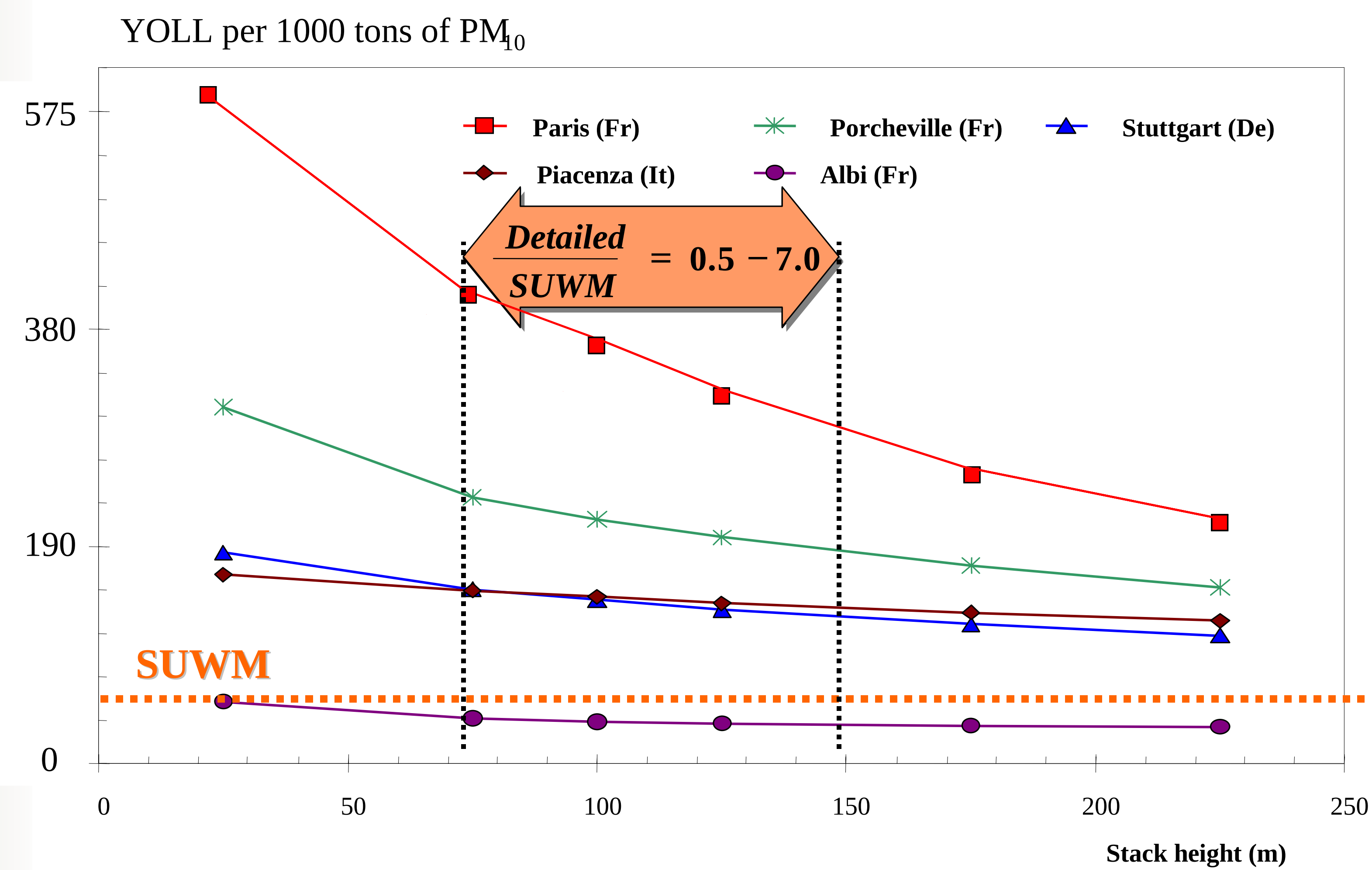
RiskPoll program – The Uniform World Model (4)

- UWM vs. detailed model – PM_{10} (including detailed local dispersion)



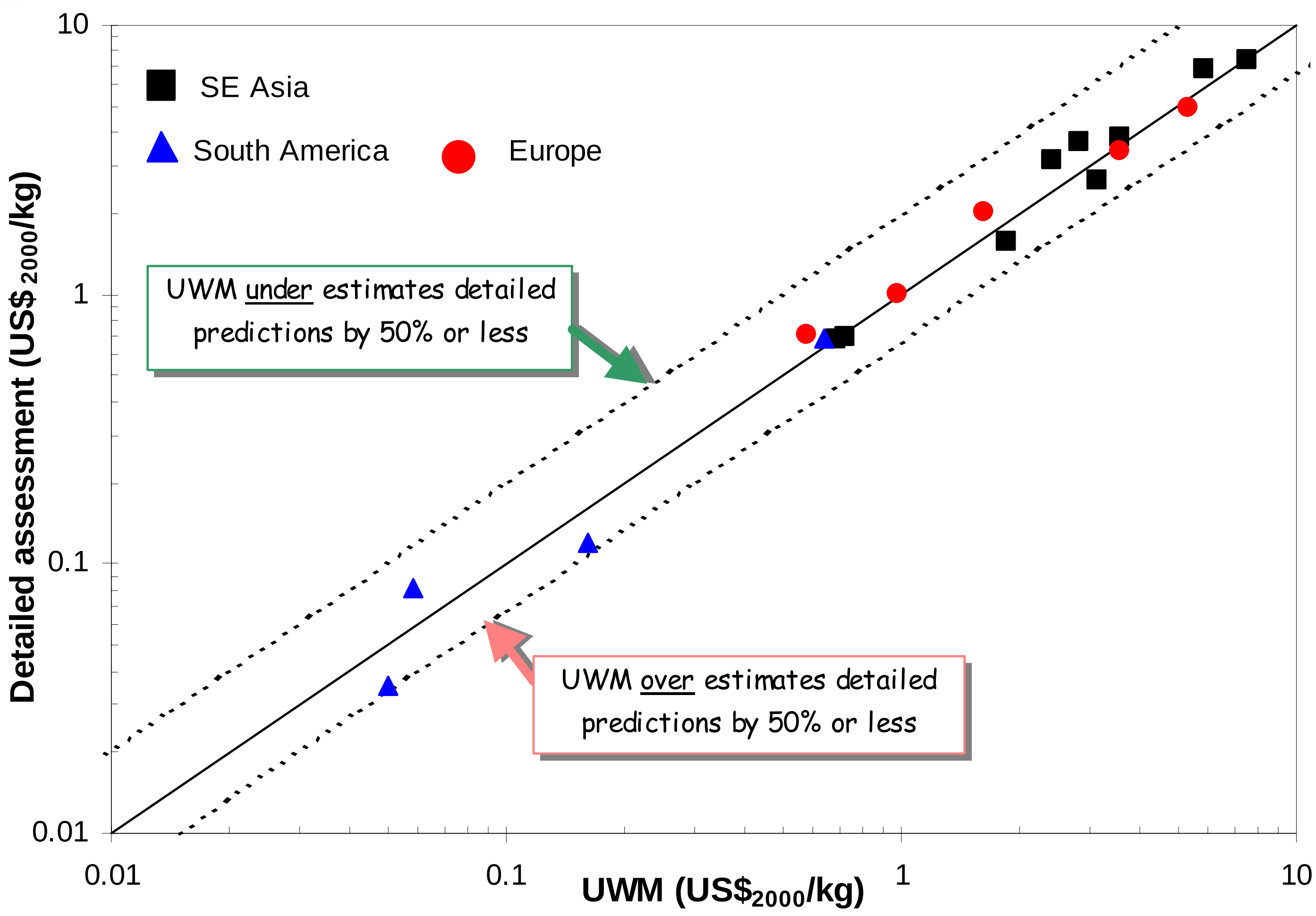
RiskPoll program – The Uniform World Model (5)

- Influence of stack height and local population distribution



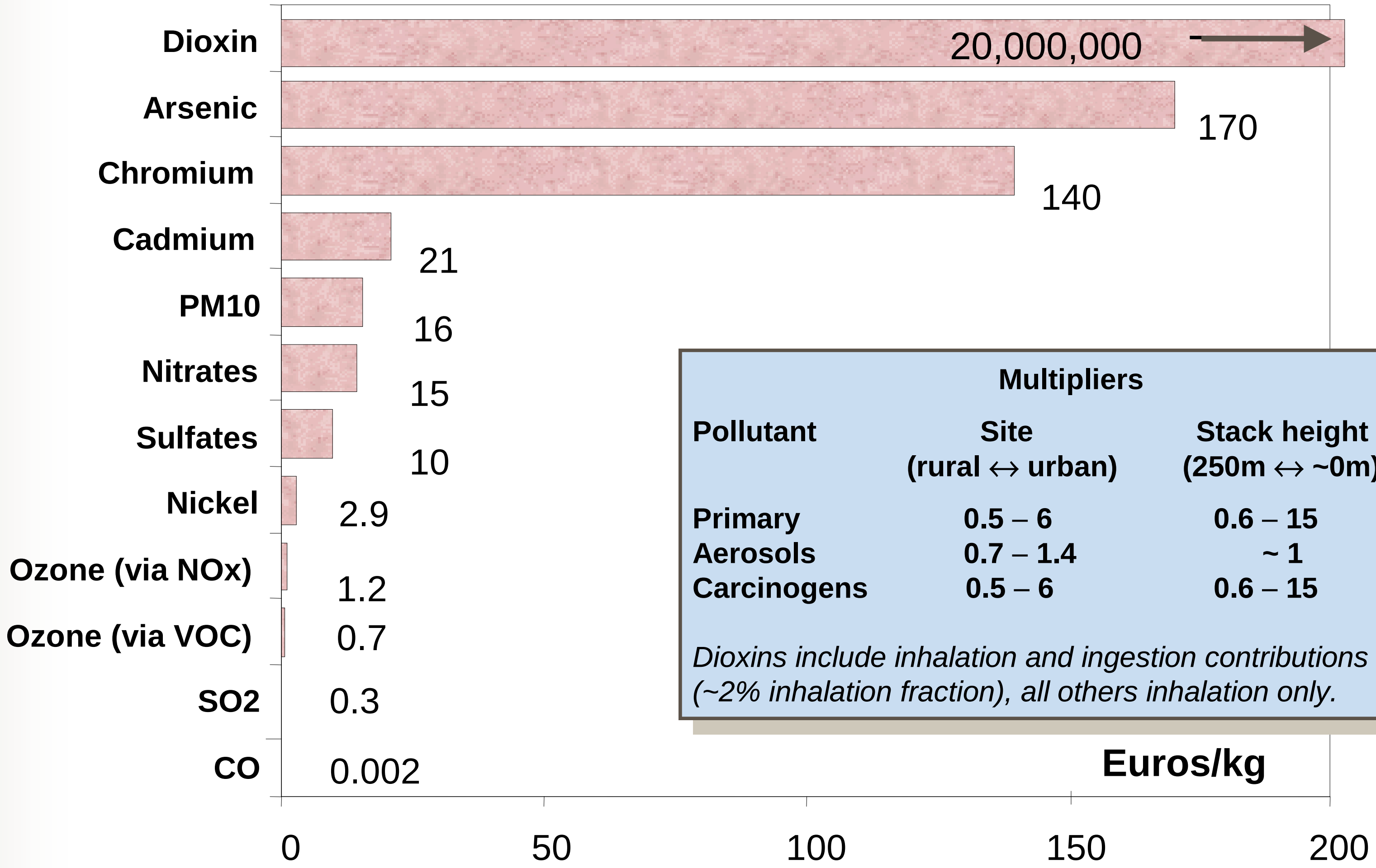
RiskPoll program – The Uniform World Model (6)

- Detailed model vs. UWM – sulfate aerosols ($/kg of SO_2)



RiskPoll program – The Uniform World Model (7)

- Damage costs in €$_{2000}$ per kg of (precursor) pollutant in Europe



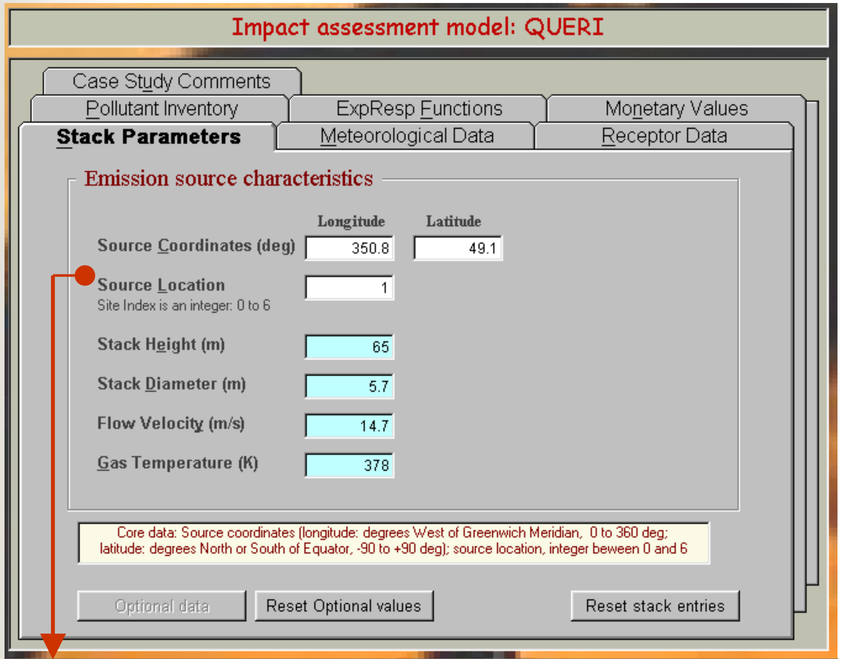
Multipliers

Pollutant	Site (rural ↔ urban)	Stack height (250m ↔ ~0m)
Primary	0.5 – 6	0.6 – 15
Aerosols	0.7 – 1.4	~ 1
Carcinogens	0.5 – 6	0.6 – 15

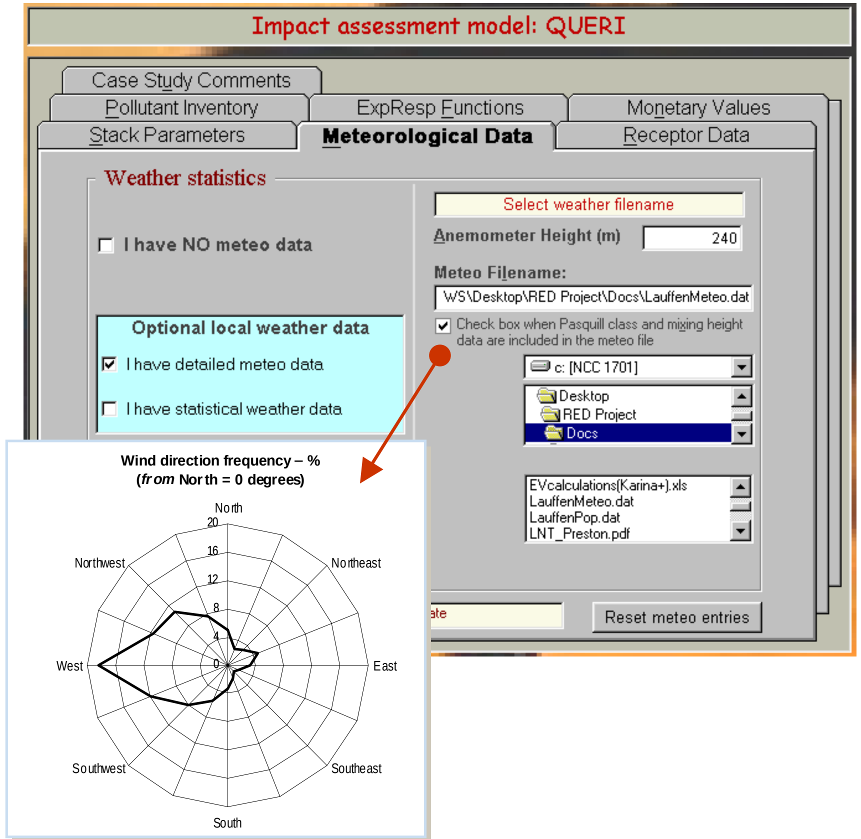
Dioxins include inhalation and ingestion contributions (~2% inhalation fraction), all others inhalation only.

RiskPoll program – Impact analysis for airborne emissions (1)

- Example 1: Consider a hypothetical emission source located in Lauffen in Central Europe, roughly 30 km North of the city of Stuttgart (Germany).
- Input data for Lauffen case study
  - Stack parameters
  - Meteorological data

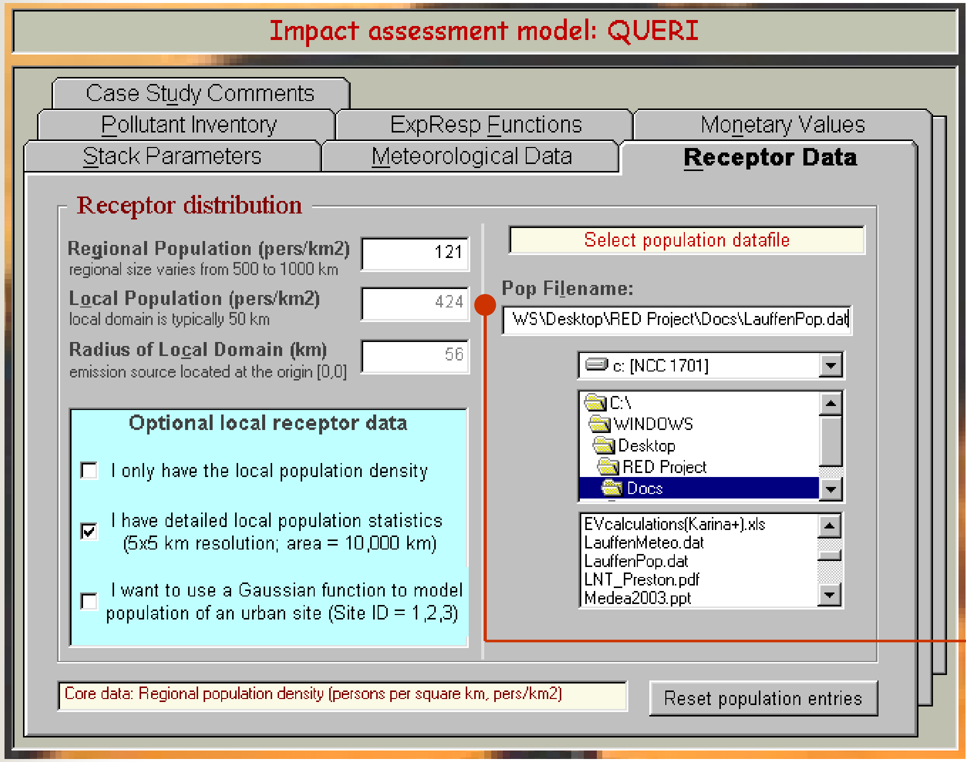


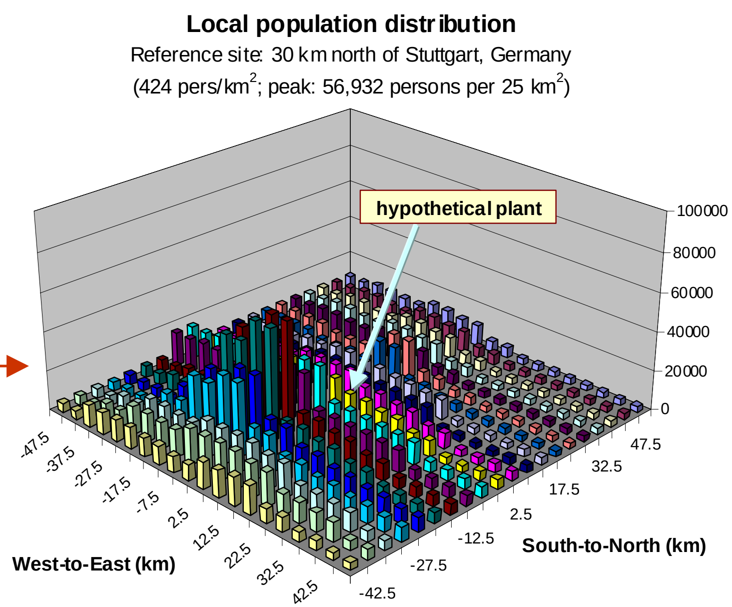
0 = rural location,
1, 2 or 3 = urban site (small to large)
4, 5 or 6 = source at different distances from an urban center



RiskPoll program – Impact analysis for airborne emissions (2)

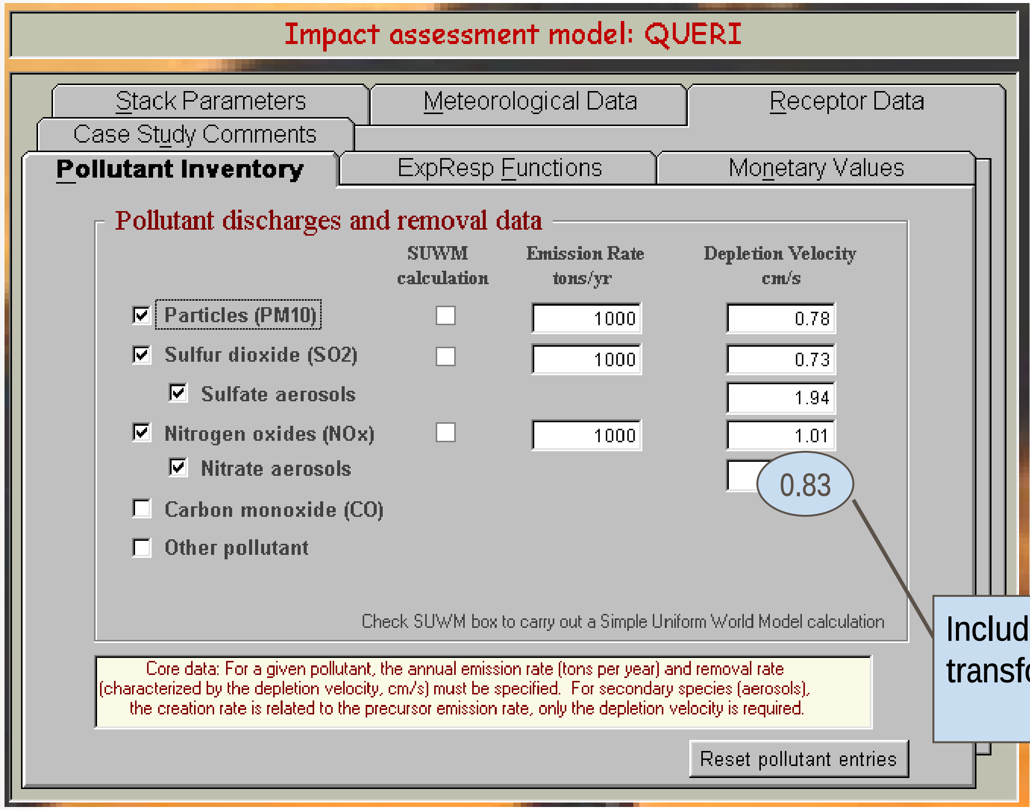
- Input data for Lauffen case study (cont.)
  - Population statistics





RiskPoll program – Impact analysis for airborne emissions (3)

- Input data for Lauffen case study (cont.)
  - Pollutant inventory



Includes deposition and chemical transformation processes

RiskPoll program – Impact analysis for airborne emissions (4)

- Input data for Lauffen case study (cont.)

EXPOSURE RESPONSE FUNCTIONS FOR EUROPE

Health endpoint	Value	Units
Particulates (PM_{10})		
Long-term mortality (LTM)	2.56×10^{-4}	YOLL per (yr.person.µg/m^3)
Infant mortality (IM)	0.278×10^{-4}	YOLL per (yr.person.µg/m^3)
Chronic Bronchitis (CB)	0.581×10^{-4}	*New* cases per (yr.person.µg/m^3)
Restricted Activity Days (RAD)	0.038	Cases per (yr.person.µg/m^3)
Resp. Hospital Admissions (RHA)	0.0256×10^{-4}	Cases per (yr.person.µg/m^3)
Congestive Heart Failure (CHF)	0.078×10^{-4}	Cases per (yr.person.µg/m^3)
Asthma attacks – Adults		
Bronchodilator usage (BDA)	16.0×10^{-4}	Cases per (yr.person.µg/m^3)
Lower Resp. symptoms (LRSA)	43.4×10^{-4}	Cases per (yr.person.µg/m^3)
Asthma attacks – Children		
Bronchodilator usage (BDC)	5.04×10^{-4}	
Lower Resp. symptoms (LRSC)	8.40×10^{-4}	Cases per (yr.person.µg/m^3)
Sulfur dioxide (SO_2)		
Short-term mortality (STM)	0.0228×10^{-4}	YOLL per (yr.person.µg/m^3)
Resp. Hospital Admissions (RHA)	0.0284×10^{-4}	Cases per (yr.person.µg/m^3)

ERF = Increased Risk Ratio (% per µg/m^3)
$\times$ Incidence rate (cases per person per yr)

MONETARY UNIT COSTS FOR EUROPE (US$_{2000}$ PER CASE)

Health endpoint	Value
Long-term mortality	101,000
Infant mortality	101,000
Short-term mortality	174,000
Chronic Bronchitis	177,800
Restricted Activity Days	116
Resp. Hospital Admissions	4,540
Congestive Heart Failure	3,420
Bronchodilator usage	42
Lower Resp. symptoms	8

ERFs for Nitrates = ERFs for PM_{10}; ERFs for Sulfates = 1.67 $\times$ ERFs for PM_{10}

RiskPoll program – Impact analysis for airborne emissions (5)

- Results for Stuttgart case study – RiskPoll output options

RiskPoll --- An Integrated Risk Assessment Program

- File - | - Calculate - | - RiskPoll Assistant - | - Return to ... - | - Window - | - Quit -

View local concentrations	Ctrl+C
Graph of damage costs	Ctrl+G
export results to Excel	Ctrl+E
Print impact assessment results	Ctrl+P
Save impact assessment results	Ctrl+R
Save case study input data	Ctrl+S

...put data filename: ...\CaseStudyStuttgart.dat]

Click on last column of table to find out more information on a particular health endpoint, e.g., input data and ...imation algorithm used in the analysis, local and regional impact distribution and insights into sensitivity analyses.

	...on	Impact	Damage Cost	Low cost	High cost	
		2.559E+4	2.968E+6	9.894E+5	8.905E+6	3
PM10	Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 [Rabl 2001]	2.661E+2	2.688E+7	6.720E+6	1.075E+8	3
PM10	Chronic Bronchitis - Recommended; Adults over 18; PM10 [Rabl 2001]	5.993E+1	1.066E+7	3.552E+6	3.197E+7	3
Sulfates	Long-term Mortality (YOLL) - Recommended; Adults over 30; Sulfates [Rabl 2001]	6.367E+1	6.430E+6	1.608E+6	2.572E+7	0
Nitrates	Cardiovascular Hospital Adms. - Recommended; Adults > 65; Nitrates [Rabl 2001]	3.001E+0	1.026E+4	3.421E+3	3.079E+4	0
Nitrates	Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates [Rabl 2001]	9.290E+1	9.383E+6	2.346E+6	3.753E+7	0
Nitrates	Chronic Bronchitis - Recommended; Adults over 18; Nitrates [Rabl 2001]	2.092E+1	3.720E+6	1.240E+6	1.116E+7	0
Sulfates	Chronic Bronchitis - Recommended; Adults over 18; Sulfates [Rabl 2001]	1.434E+1	2.549E+6	8.498E+5	7.648E+6	0

- Impacts are expressed in cases/year, while Damage costs are reported in US$/year; Low and High costs refer to the 68% confidence interval.
- The coefficient in the last column identifies the estimation algorithm used to calculate the impact, with the following meanings: 0 = SUWM; 1 = Basic; 2 = Intermediate; 3 = Best.
- Additional impact information on a specific health impact category may be obtained by clicking on the last column.
- Note: (*) = No Impact/Cost estimates because either the emission or depletion velocity are unspecified; (**) = No cost estimate because the monetary unit value is 0 US$/case.

Case study input data

To perform sensitivity analyses, click on menu option Calculate and select item #2 from the list of choices ("Senstivity analysis") or press CTRL-A. Once all changes to the input data below have been made, press CTRL-I to recalculate the impacts/costs.

Case Study Notes

Input data for RiskPoll demonstration case study for Stuttgart
(a) Source located near the city of Stuttgart (Germany);
(b) Detailed local population data is used in the analysis;
(c) Meteo file includes Pasquill class distribution and mixing layer height data;
(d) ERFs are those recommended by Rabl (2001); and

Stack Parameters

Parameter	Value
Source longitude (0 to 360 deg)	350.8
Source latitude (-90 to +90 deg)	49.1
Source location (integer between 0 and 6)	1
Stack height (m)	65.0
Stack diameter (m)	5.7
Flue gas velocity (m/s)	14.7
Exhaust temperature (K)	378.0
Effective stack height (m)	320.7

Pollutant Inventory

Pollutant	Emission Rate	Depletion Velocity
PM10	1.000E+03	0.67
SO2	1.000E+03	0.73
NOx	1.000E+03	1.47
CO	No value	No value
Other	No value	No value
Nitrates		0.71
Sulfates		1.73

Emission rate (tons/year), Depletion velocity (cm/s)

Receptor Data

Parameter	Value
Local population (pers/km2)	424.2
Local radius (km)	56.0
Regional population (pers/km2)	80.0

Local receptor datafile: C:\My Folder\My Professional\My Softv

Meteorological Data

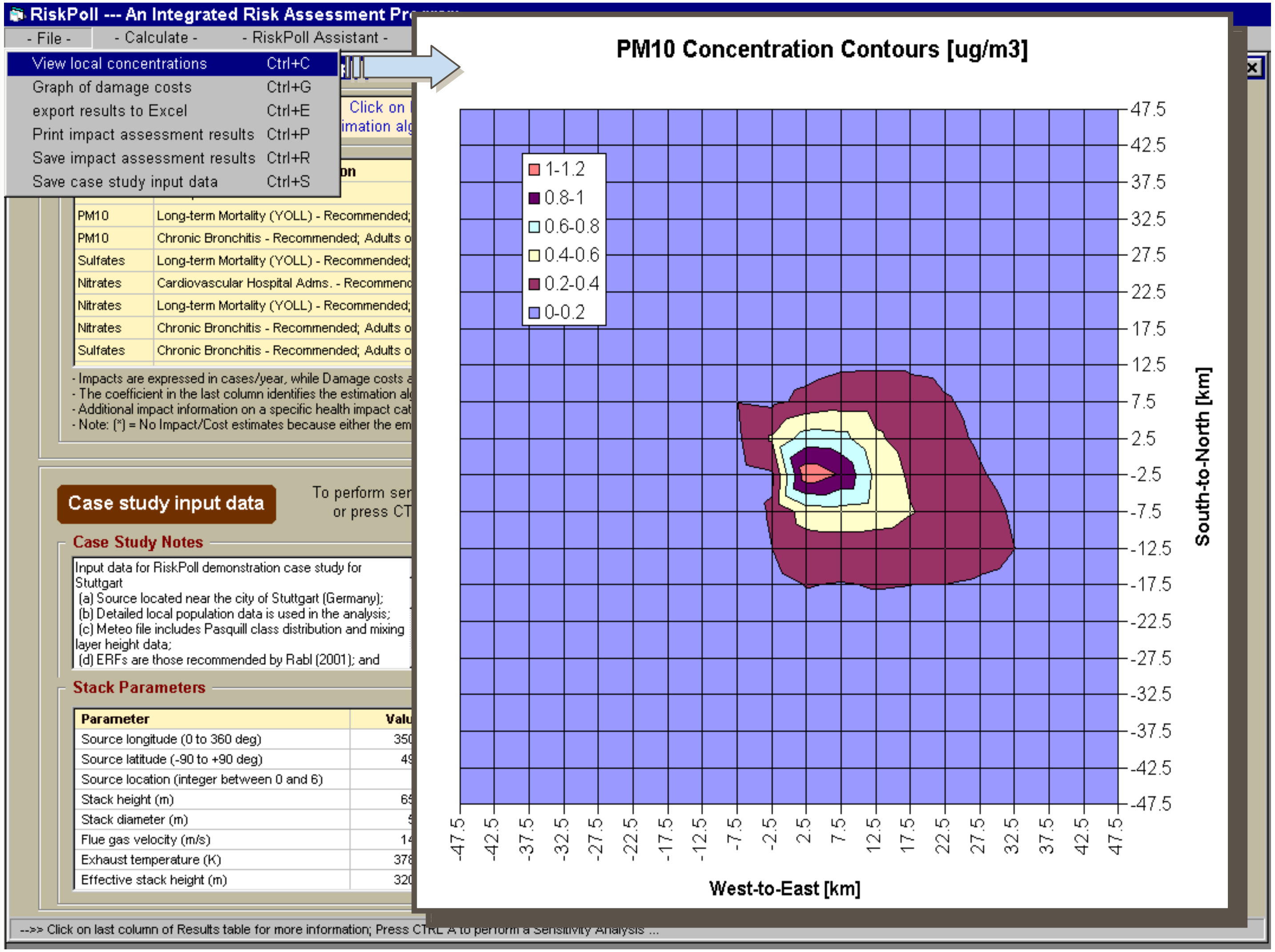
Parameter	Value
Mean ambient temperature (K)	284.3
Mean wind speed (m/s)	4.6
Anemometer height (m)	240.0
Pasquill Frequency Class A (%)	5.7
Pasquill Frequency Class B (%)	9.5
Pasquill Frequency Class C (%)	8.2
Pasquill Frequency Class D (%)	35.3
Pasquill Frequency Class E (%)	30.1
Pasquill Frequency Class F (%)	11.2
Mean mixing layer height (m)	561.9

Local meteo datafile: C:\My Folder\My Professional\My Sc

-->> Click on last column of Results table for more information; Press CTRL A to perform a Sensitivity Analysis ...

RiskPoll program – Impact analysis for airborne emissions (6)

- Results for Stuttgart case study – RiskPoll output options



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RiskPoll program – Impact analysis for airborne emissions (7)

- Results for Lauffen case study – low stack