

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

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The RiskPoll Program

1. *The need for simplicity*
2. *Introduction*
3. *The Uniform World Model*
4. *Impact assessment for airborne emissions*
5. *Multimedia assessment for toxic metals
(discussed earlier)*



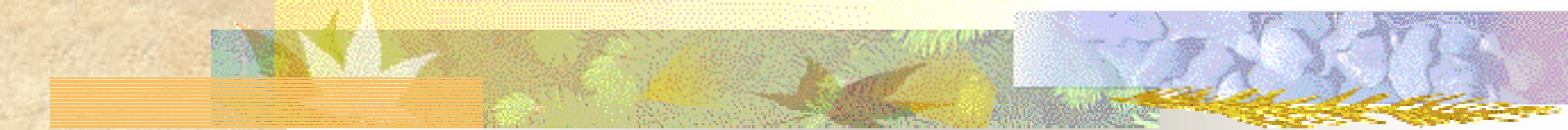
RiskPoll program – The need for simplicity

- ❑ Usually, people tend to use site-specific results as if they were typical values \Rightarrow *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 (multi-disciplinary analysis); and
 - trained personnel to select the most appropriate input parameters, run the models and interpret 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

- ❑ 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, SO₂, NO_x, CO and secondary aerosols (inhalation pathway),
 - changes in crop yield from exposure to SO₂,
 - surface area of materials damaged from exposure to SO₂, 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>).

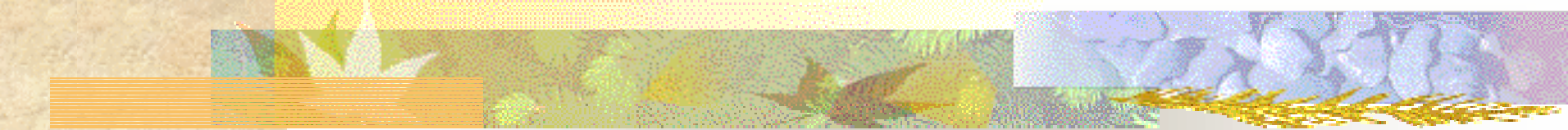


RiskPoll program – Introduction (2)

- ❑ 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.

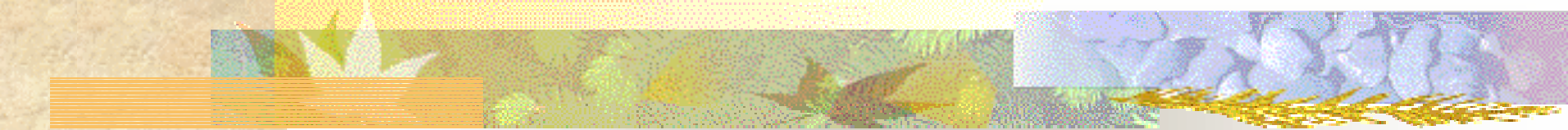
- ❑ RiskPoll provides results that are “reasonably” accurate and reliable as shown by comparison with detailed models. In many cases, deviations in site-specific results are less than $\pm 50\%$.



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 verifying 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
 - ExternE, EU (impact assessment methodology)
 - 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

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

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

- Elevated point sources

- $R \leq 7$ for site-specific industrial or power plant emissions
- but, R is typically ≤ 2 (except when source is close to a large city, then $R \sim 5$)
- for aggregated calculations involving sources located at different sites and with different characteristics, particularly stack height, $R \sim 1$

- Ground-level emission sources

- $R \sim 1$ 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)

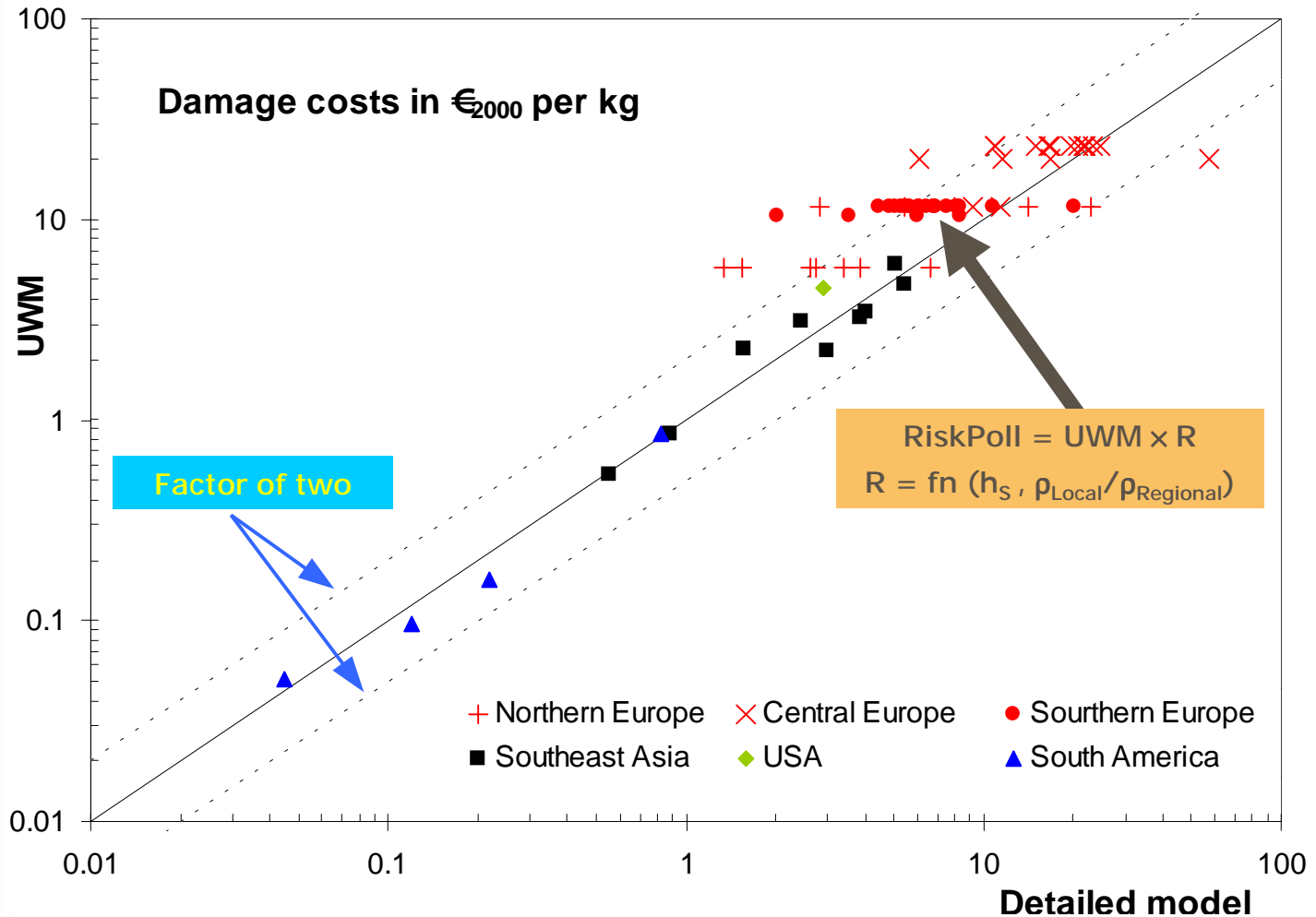
- ❑ For a uniform receptor density, $R = 1$ (conservation of matter).
- ❑ The UWM impact assessment equation is

$$UWM \text{ damage cost} = \frac{\rho_{avg} f_{ER} Q U_v}{k}$$

- ❑ Equation can be used for both primary and secondary species provided the depletion velocity includes the chemical transformation rate (PM₁₀ → 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.

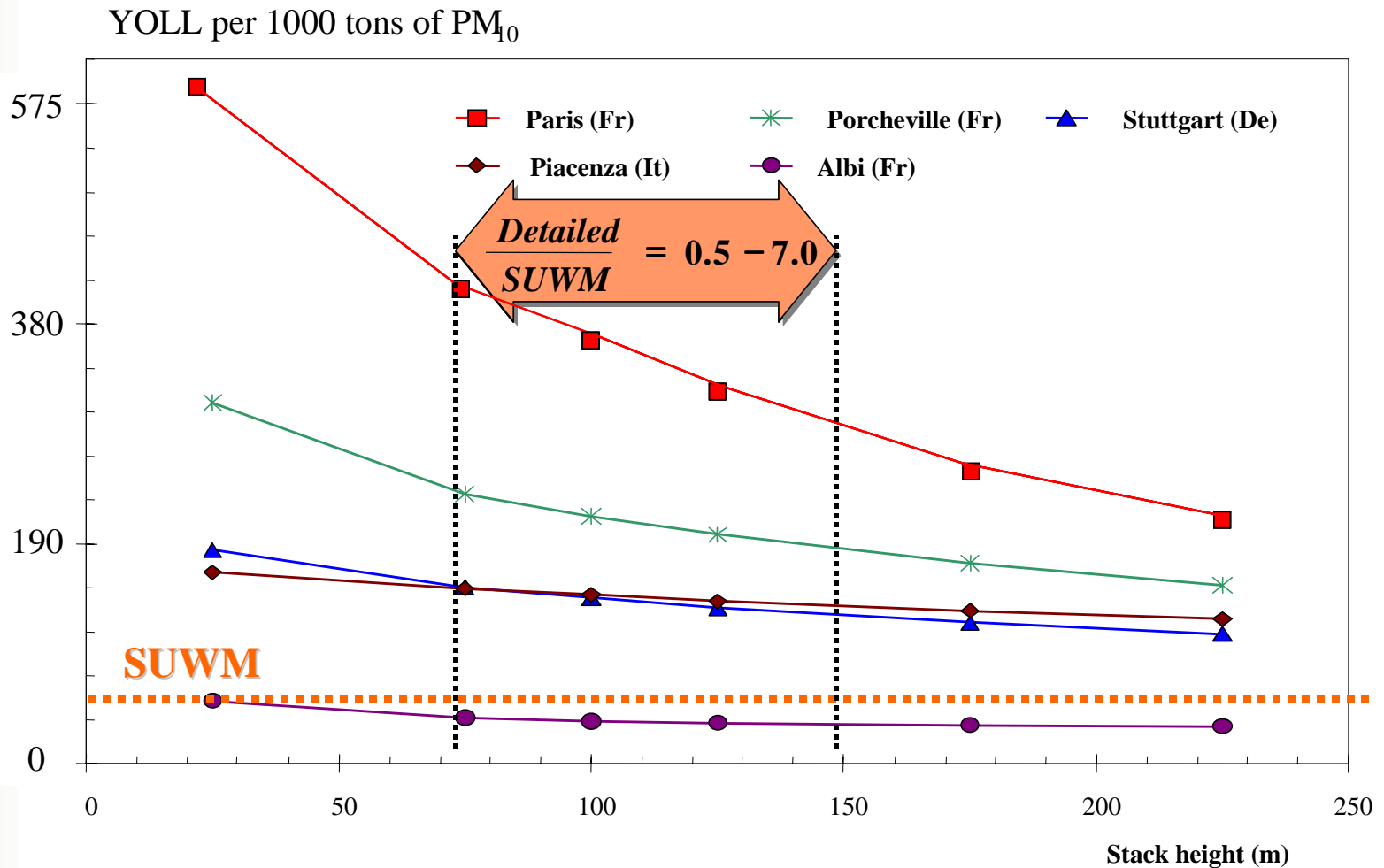
RiskPoll program – The Uniform World Model (4)

UWM vs. detailed model – PM₁₀ (including detailed local dispersion)



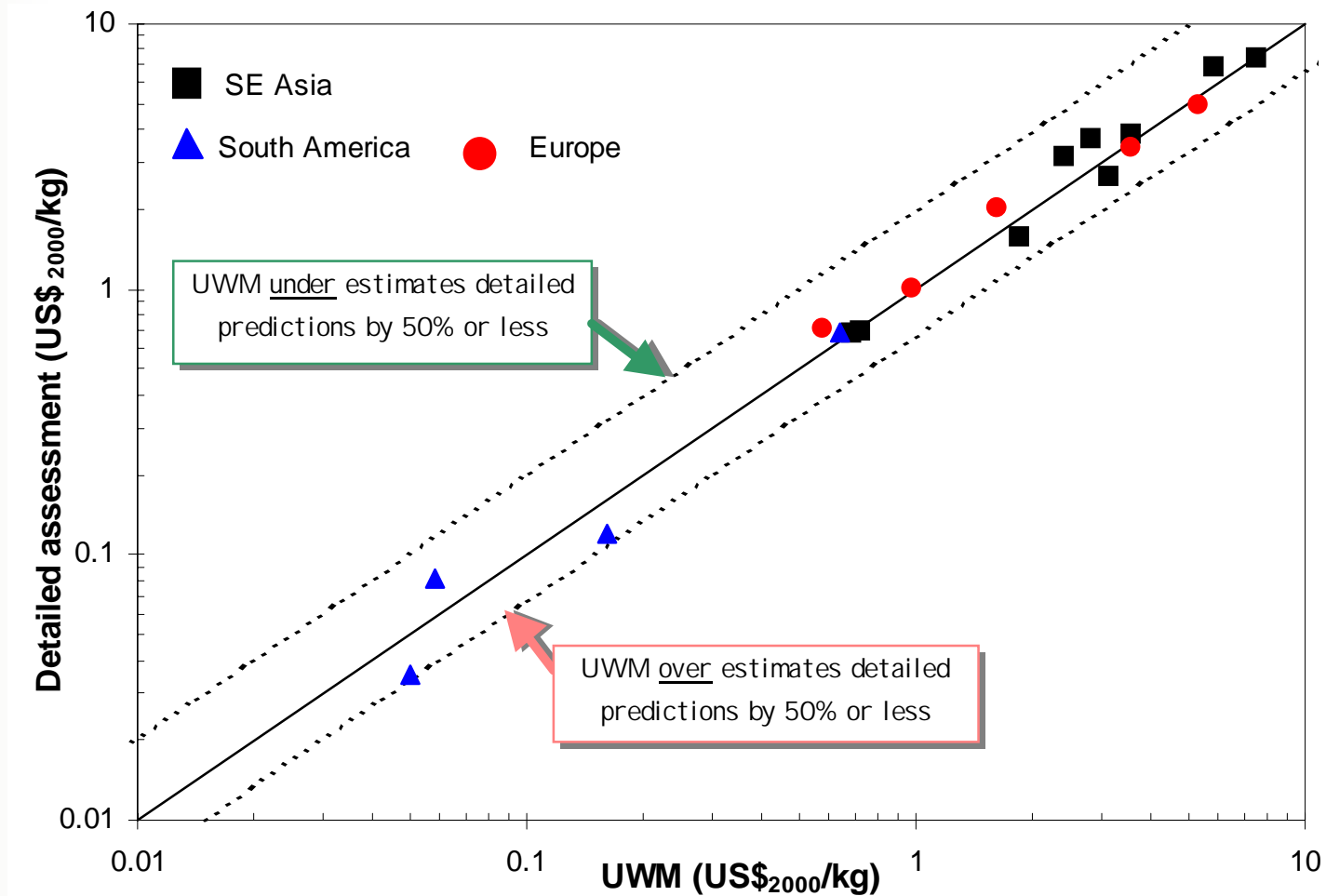
RiskPoll program – The Uniform World Model (5)

□ Influence of stack height and local population distribution



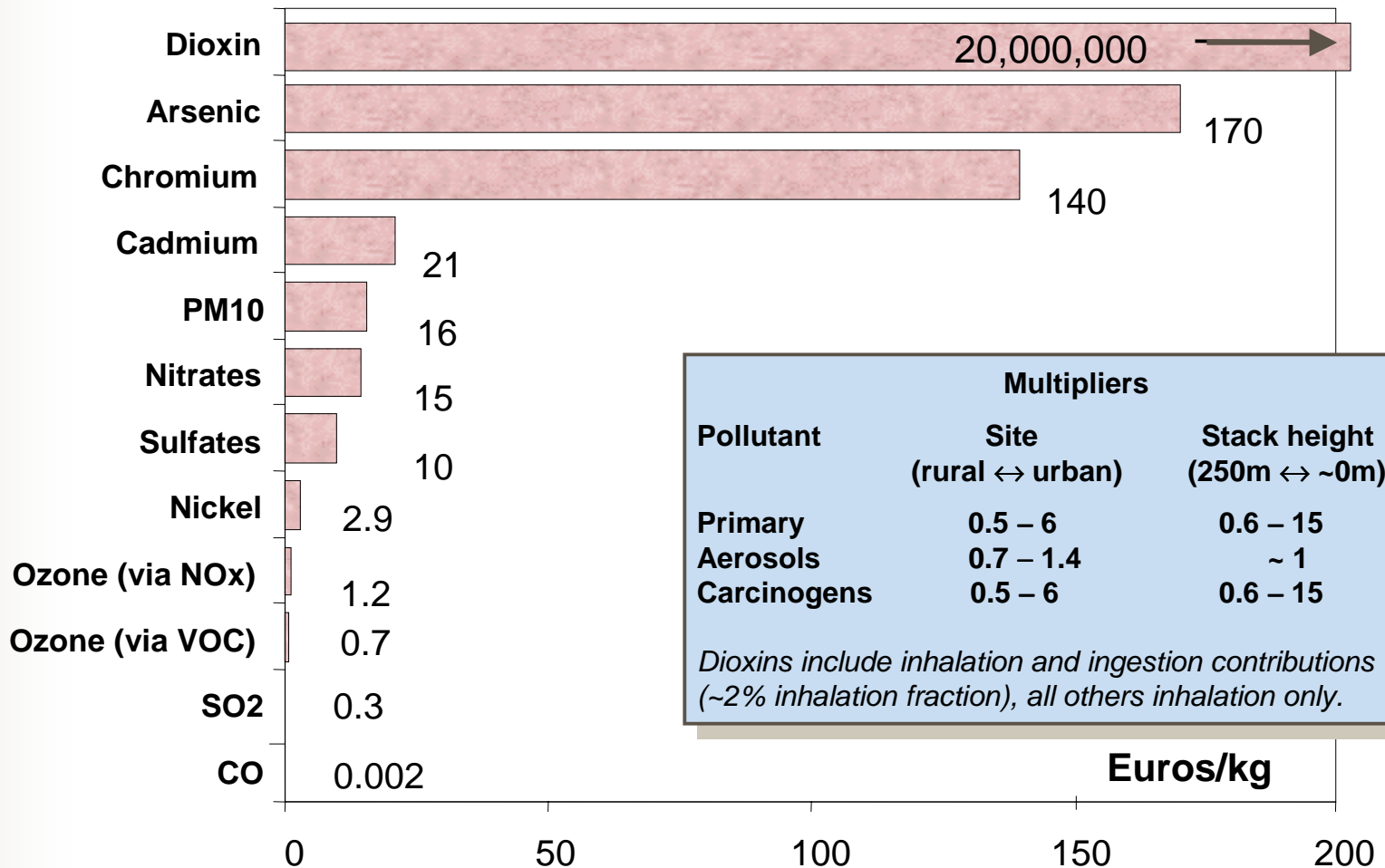
RiskPoll program – The Uniform World Model (6)

□ Detailed model vs. UWM – sulfate aerosols (\$/kg of SO₂)



RiskPoll program – The Uniform World Model (7)

❑ Damage costs in €₂₀₀₀ per kg of (precursor) pollutant in Europe



Pollutant	Multipliers	
	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.

Euros/kg

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

Impact assessment model: QUERI

Case Study Comments | Pollutant Inventory | ExpResp Functions | Monetary Values

Stack Parameters | Meteorological Data | Receptor Data

Emission source characteristics

	Longitude	Latitude
Source Coordinates (deg)	358.8	49.1
Source Location <small>Site index is an integer 0 to 6</small>	1	
Stack Height (m)	65	
Stack Diameter (m)	9.7	
Flow Velocity (m/s)	14.7	
Gas Temperature (K)	378	

Case data: Source coordinates (longitude: degrees West of Greenwich Meridian, 0 to 360 deg; latitude: degrees North or South of Equator, -90 to +90 deg); source location: integer between 0 and 6

Optional values | Reset Optional values | Reset stack entries

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

Impact assessment model: QUERI

Case Study Comments | Pollutant Inventory | ExpResp Functions | Monetary Values

Stack Parameters | **Meteorological Data** | Receptor Data

Weather statistics

I have NO meteo data

I have detailed meteo data

I have statistical weather data

Select weather filename

Anemometer Height (m) 240

Meteo Filename:
 W:\Desktop\RED Project\Doc\LauffenMeteo.dat

Check box when Pollut. class and tracing height data are included in the meteo file

[MCC 170r]

Desktop

RED Project

Docs

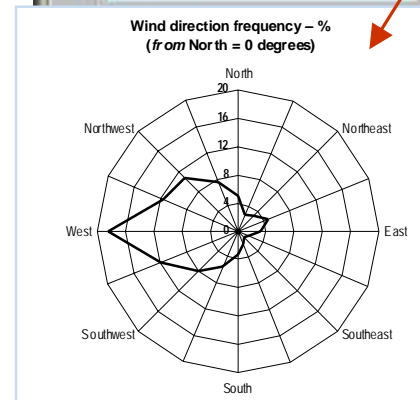
E:\calculator\Flama+\.sit

LauffenMeteo.dat

LauffenPop.dat

LNT_Preston.pdf

Reset meteo entries



RiskPoll program – Impact analysis for airborne emissions (2)

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

Impact assessment model: QUERI

Case Study Comments | Pollutant Inventory | ExpResp Functions | Monetary Values | Stack Parameters | Meteorological Data | **Receptor Data**

Receptor distribution

Regional Population (pers/km²)
regional size varies from 500 to 1000 km

Local Population (pers/km²)
local domain is typically 50 km

Radius of Local Domain (km)
emission source located at the origin [0,0]

Select population datafile

Pop Filename:

Optional local receptor data

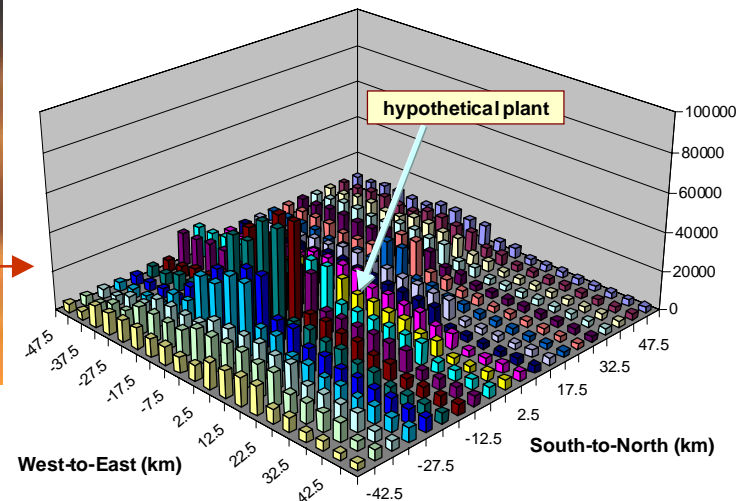
I only have the local population density

I have detailed local population statistics (5x5 km resolution; area = 10,000 km²)

I want to use a Gaussian function to model population of an urban site (Site ID = 1,2,3)

Core data: Regional population density (persons per square km, pers/km²)

Local population distribution
Reference site: 30 km north of Stuttgart, Germany
(424 pers/km²; peak: 56,932 persons per 25 km²)



RiskPoll program – Impact analysis for airborne emissions (3)

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

Impact assessment model: QUERI

Stack Parameters Meteorological Data Receptor Data

Case Study Comments

Pollutant Inventory ExpResp_Functions Monetary Values

Pollutant discharges and removal data

	SUWM calculation	Emission Rate tons/yr	Depletion Velocity cm/s
<input checked="" type="checkbox"/> Particles (PM10)	<input type="checkbox"/>	1000	0.78
<input checked="" type="checkbox"/> Sulfur dioxide (SO2)	<input type="checkbox"/>	1000	0.73
<input checked="" type="checkbox"/> Sulfate aerosols			1.94
<input checked="" type="checkbox"/> Nitrogen oxides (NOx)	<input type="checkbox"/>	1000	1.01
<input checked="" type="checkbox"/> Nitrate aerosols			0.83
<input type="checkbox"/> Carbon monoxide (CO)			
<input type="checkbox"/> Other pollutant			

Check SUWM box to carry out a Single Uniform World Model calculation

Core data: For a given pollutant, the annual emission rate (tons per year) and removal rate (characterized by the depletion velocity, cm/s) must be specified. For secondary species (aerosols), the creation rate is related to the precursor emission rate, only the depletion velocity is required.

Reset pollutant entries

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
<i>Particulates (PM₁₀)</i>		
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}	Cases per (yr.person.μg/m ³)
Lower Resp. symptoms (LRSC)	8.40×10^{-4}	Cases per (yr.person.μg/m ³)
<i>Sulfur dioxide (SO₂)</i>		
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)

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

ERF = Increased Risk Ratio (% per μg/m³)
 × Incidence rate (cases per person per yr)

ERFs for Nitrates = ERFs for PM₁₀; ERFs for Sulfates = 1.67 × ERFs for PM₁₀

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 - Out -

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+S
 Save case study input data Ctrl+S

Output 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 estimation algorithm used in the analysis, local and regional impact distribution and insights into sensitivity analyses.

Impact	Damage Cost	Low cost	High cost
PM10 Long-term Mortality (YOULL) - Recommended; Adults over 30; PM10 (Rabi 2001)	2.552E+4	2.952E+0	9.894E+5
PM10 Chronic Bronchitis - Recommended; Adults over 18; PM10 (Rabi 2001)	2.861E+2	2.698E+7	6.720E+6
Sulfates Long-term Mortality (YOULL) - Recommended; Adults over 30; Sulfates (Rabi 2001)	5.983E+1	1.092E+7	3.552E+6
Nitrates Cardiovascular Hospital Adm. - Recommended; Adults > 65; Nitrates (Rabi 2001)	6.367E+1	6.430E+6	1.606E+6
Nitrates Long-term Mortality (YOULL) - Recommended; Adults over 30; Nitrates (Rabi 2001)	3.001E+0	1.029E+4	3.421E+3
Nitrates Chronic Bronchitis - Recommended; Adults over 18; Nitrates (Rabi 2001)	9.290E+1	9.393E+6	2.346E+6
Sulfates Chronic Bronchitis - Recommended; Adults over 18; Sulfates (Rabi 2001)	2.082E+1	3.732E+6	1.242E+6
Sulfates Chronic Bronchitis - Recommended; Adults over 18; Sulfates (Rabi 2001)	1.434E+1	2.549E+6	8.496E+5

Impacts are expressed in cases/year, while Damage costs are reported in US\$/year. Low and High costs refer to the 95% confidence interval.
 The coefficient in the last column identifies the estimation algorithm used to calculate the impact, with the following meanings: 0 = SUAM, 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 estimate 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 ("Sensitivity 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) Metro file includes Pasquill class distribution and mixing layer height data;
 (d) ERFs are those recommended by Rabi (2001); and

Stack Parameters

Parameter	Value
Source longitude (0 to 360 deg)	350.0
Source latitude (-90 to +90 deg)	49.1
Source location (integer between 0 and 5)	1
Stack height (m)	65.0
Stack diameter (m)	5.7
Flue gas velocity (m/s)	14.7
Exhaust temperature (K)	376.0
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/m2)	424.2
Local relief (m)	56.0
Regional population (pers/m2)	80.0

Local receptor details: C:\My Folder\My Professional\My Soft

Meteorological Data

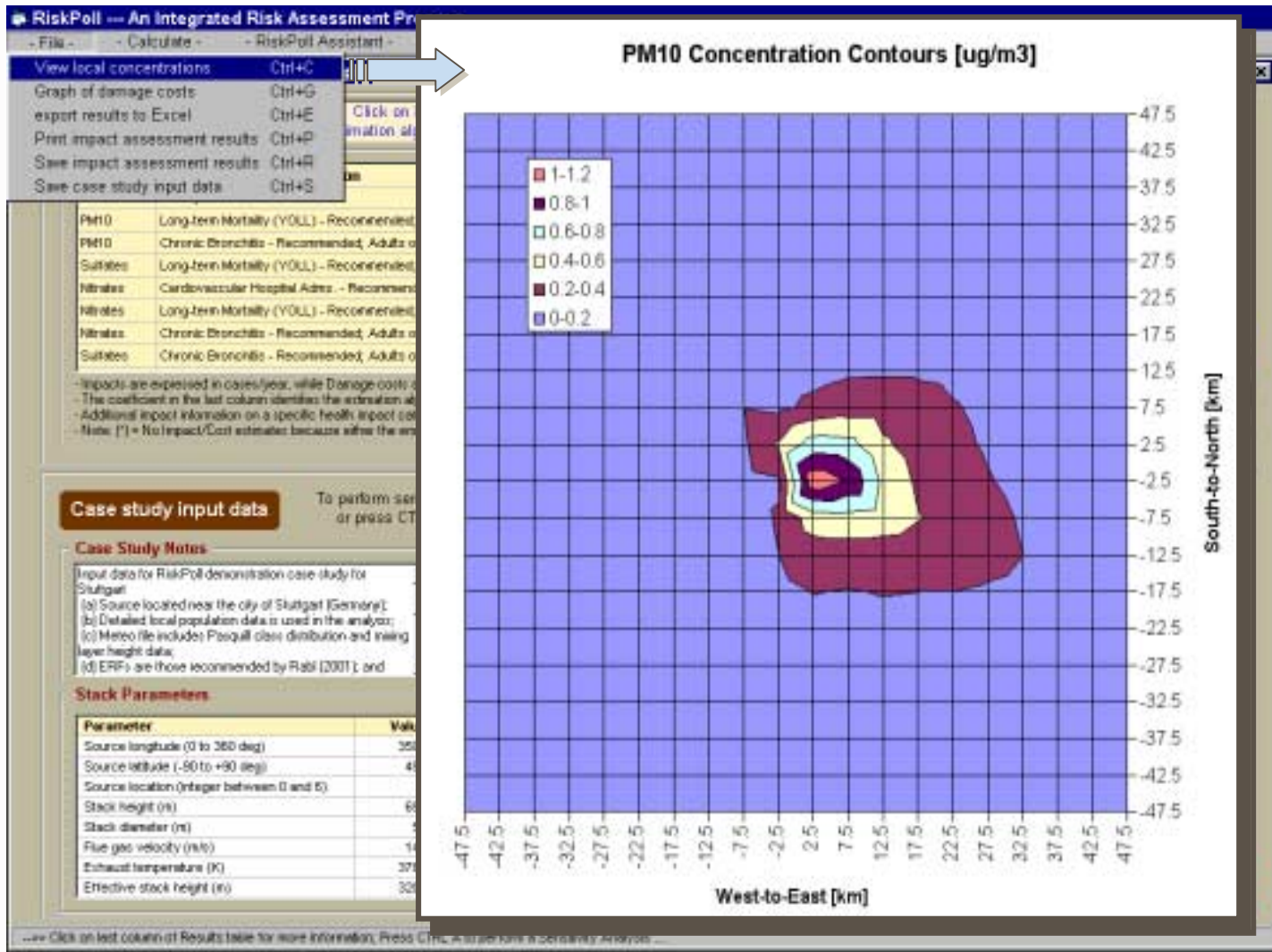
Parameter	Value
Mean ambient temperature (K)	294.3
Mean wind speed (m/s)	4.6
Anemometer height (m)	240.0
Pasquill Frequency Class A (%)	5.7
Pasquill Frequency Class B (%)	9.6
Pasquill Frequency Class C (%)	8.2
Pasquill Frequency Class D (%)	35.3
Pasquill Frequency Class E (%)	30.1
Pasquill Frequency Class F (%)	11.2
Mean mixing layer height (m)	561.9

Local metro details: C:\My Folder\My Professional\My Soft

... 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



RiskPoll program – Impact analysis for airborne emissions (7)

Results for Lauffen case study – low stack

