



Environmental Pollution and Externalities of Energy: The Multimedia Assessment in RiskPoll

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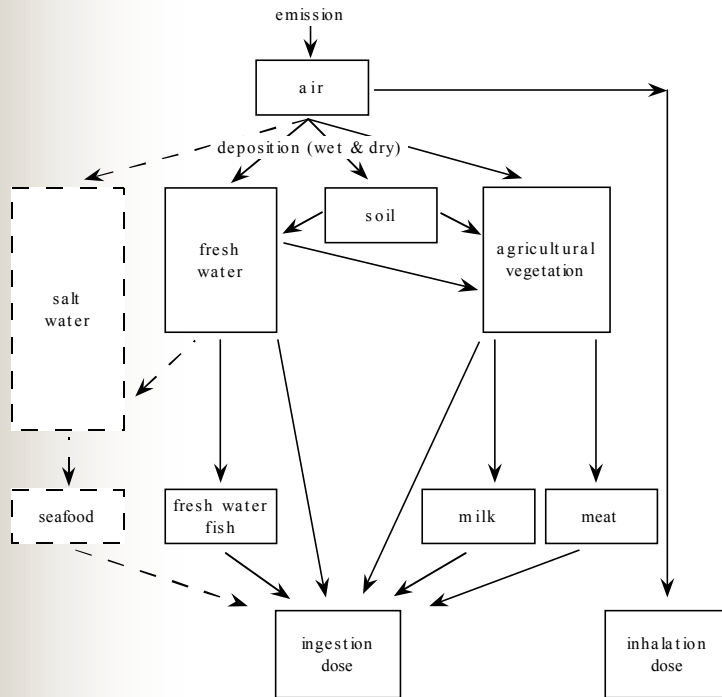
RiskPoll program – Multimedia assessment for toxic metals (1)

- ❑ The *RiskPoll_Multimedia* model is based on the US EPA multimedia pathways methodology
 - Health risk assessment protocol for hazardous waste combustion facilities, 1998; <http://www.epa.gov/epaoswear/hazwaste/combust/riskvol.htm#volume1>.

- ❑ A copy of the software (Excel spreadsheet) may be downloaded from <http://www.arirabl.com>.

RiskPoll program – Multimedia assessment for toxic metals (2)

- Dose and impact calculations are based on the UWM approach



■ Inhalation

- ✓ UWM has been validated by comparisons with detailed model results for sites in EU, Eastern Europe, China, Thailand, Argentina, Brazil, Paraguay and the USA.

- ✓ Collective dose rate

$$D_{inhalation} = \dot{V}_{inhalation} \rho \frac{\dot{m}}{v_{dep}}$$

- ✓ Collective impact rate

$$I_{inhalation} = s_{CRF} \rho \frac{\dot{m}}{v_{dep}}$$

$\dot{V}_{inhalation}$ = mean annual breathing rate

ρ = population density

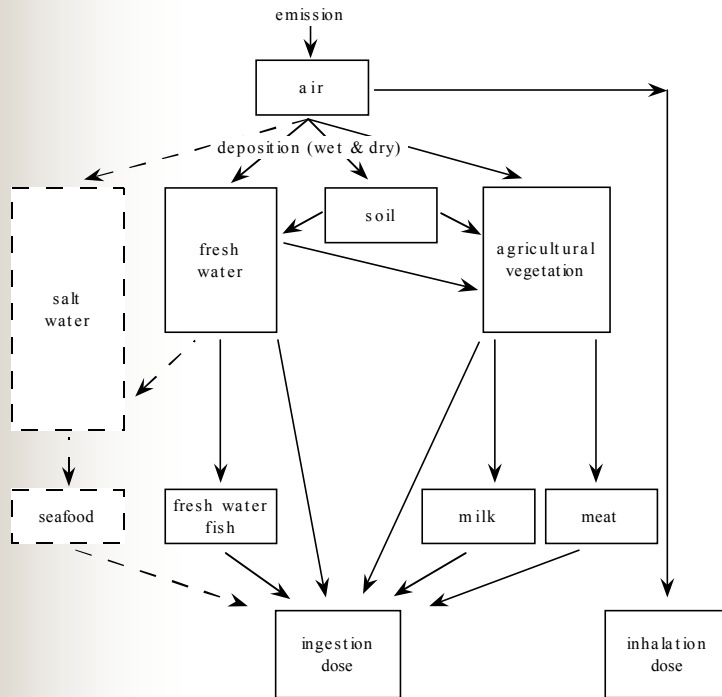
\dot{m} = pollutant emission rate to air

v_{dep} = deposition velocity (dry + wet)

s_{CRF} = Concentration Response Function slope

RiskPoll program – Multimedia assessment for toxic metals (3)

□ Dose and impact calculations are based on the UWM approach (cont.)



■ Ingestion

- ✓ UWM is anticipated to be even better because food is transported over large distances between different areas where food is grown.
- ✓ Collective dose and impact rates

$$D_{\text{ingestion}} = \rho \frac{\dot{m}}{v_{\text{dep}}} \sum_p X_{\text{food}, p} Q_{\text{food}, p}$$

$$I_{\text{ingestion}} = s_{\text{DRF}} \rho \frac{\dot{m}}{v_{\text{dep}}} \sum_p X_{\text{food}, p} Q_{\text{food}, p}$$

$$X_{\text{food}, p} = \frac{C_{\text{food}, p}}{C_{\text{air}}} \quad \text{air} \rightarrow \text{food transfer factor}$$

$Q_{\text{food}, p}$ = annual food consumption of product p

C = concentration

ρ = population density

m = pollutant emission rate to air

v_{dep} = deposition velocity (dry + wet)

s_{DRF} = Dose Response Function slope

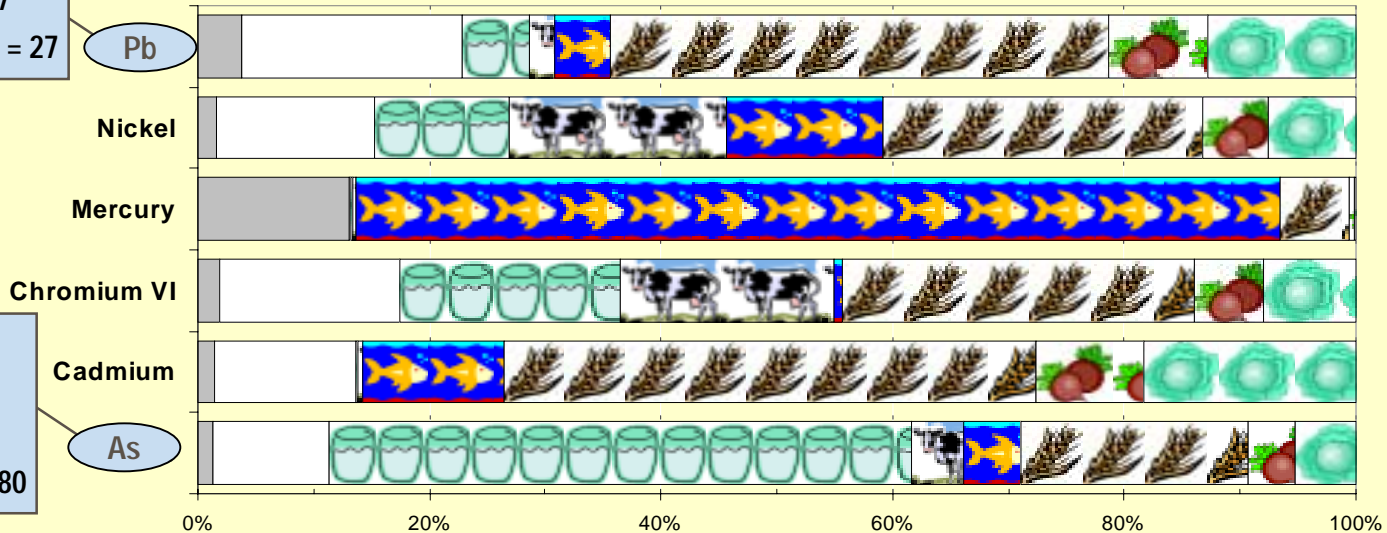
RiskPoll program – Multimedia assessment for toxic metals (4)

Impact of toxic metal emissions for central European conditions (cont.)

$\tau_{\text{soil}} \text{ (crops)} = 380 \text{ yr}$
 $\tau_{\text{water}} = 0.5 \text{ yr}$
 Total intake = 187
 Total / Inhalation = 27

Collective dose by pathway as a percentage of total
 [table values as mg intake per kg emission; Cutoff time 100 yr]

100 yr time integration



$\tau_{\text{soil}} \text{ (crops)} = 16 \text{ yr}$
 $\tau_{\text{water}} = 4 \text{ yr}$
 Total intake = 310
 Total / Inhalation = 80

	Arsenic	Cadmium	Chromium VI	Mercury	Nickel	Lead
Green vegetables	16.2	47.5	15.9	0.3	17.7	24.0
Root vegetables	12.4	24.1	12.0	0.7	13.1	16.0
Grains	60.8	119.5	60.4	10.1	64.4	80.4
Freshwater fish	15.6	31.7	1.6	134.9	31.6	9.0
Cattle meat	13.8	1.4	36.8	0.3	43.9	4.1
Cattle milk	156.2	0.3	38.0	0.4	27.2	10.8
Water	31.1	31.7	31.0	0.3	31.5	35.5
Inhalation	3.9	3.9	3.9	22.0	3.9	7.1

RiskPoll program – Multimedia assessment for toxic metals (5)

- Impact of toxic metal emissions for central European conditions (cont.)
 - Collective doses, impacts and social costs (2 M€ per cancer; 3000 € per IQ point)

Parameter	Description	Units	Arsenic	Cadmium	Chromium VI	Nickel	Lead
INHALATION pathway							
Vdep	Total deposition velocity (dry+wet)	cm/s	0.49	0.49	0.49	0.49	0.27
s _{CR}	Slope concentration response function	cancers/(pers. yr. kg/m ³)	6.14E+04	2.57E+04	1.71E+05	3.43E+03	
D _{inhal}	Collective inhalation dose	kg/yr	3.89E-03	3.89E-03	3.89E-03	3.89E-03	7.06E-03
I _{inhal}	Collective impact	cancers/yr	3.18E-02	1.33E-02	8.85E-02	1.78E-03	
Cost _{inhal}	Social cost from inhalation	€ per yr	6.36E+04	2.66E+04	1.77E+05	3.55E+03	
Iu _{inhal}	Unit impact from inhalation	cancers per kg	3.18E-05	1.33E-05	8.85E-05	1.78E-06	
Uv _{inhal}	Unit cost from inhalation	€ per kg	63.6	26.6	177.1	3.6	
INGESTION pathway							
s _{CR}	Slope dose response function	cancers/kg_absorbed	1.07				
s _{CR_Pb}	Slope dose response function for Pb	IQ_points/kg_absorbed					3291
D _{food}	Collective ingestion dose	kg/yr	3.06E-01	2.56E-01	1.96E-01	2.29E-01	1.80E-01
I _{food}	Collective impact	cancers/yr	3.28E-01				
I _{food_Pb}	Collective impact for Pb	IQ_points/yr					5.92E+02
Cost _{food}	Social cost from ingestion	€ per yr	6.55E+05				1.78E+06
Iu _{food}	Unit impact from ingestion	cancers per kg	3.28E-04				
Iu _{food_Pb}	Unit impact from ingestion of Pb	IQ points per kg					0.592
Uv _{food}	Unit cost from ingestion	€ per kg	655.4				1775.6
TOTAL results							
	Collective dose				2.00E-01	2.33E-01	1.87E-01
	Collective impact		359	13	9	2	
	Collective impact of Pb	IQ_points/yr					5.92E+02
	Annual cost	€ per yr	7.19E+05	2.66E+04	1.77E+05	3.55E+03	1.78E+06
	Unit impact	cancers per kg	3.59E-04	1.33E-05	8.85E-05	1.78E-06	
	Unit impact of Pb	IQ points per kg					5.92E-01
	Unit cost	€ per kg	710.9	26.6	177.1	3.6	1775.6

Cancers per 1000 tons of emission

359 13 9 2



RiskPoll program – Multimedia assessment for toxic metals (6)

- Impact of toxic metal emissions for central European conditions (cont.)
 - Collective doses, impacts and social costs (2 M€ per cancer; 3000 € per IQ point)

Parameter	Description	Units	Arsenic	Cadmium	Chromium VI	Nickel	Lead
INHALATION pathway							
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Uv _{food}	Unit cost from ingestion	€ per kg	655.4				1775.6
TOTAL results							
	Collective dose		719	27	177	4	1776
	Collective impact						
	Collective impact of						
	Annual cost	€ per yr	7.19E+05	2.66E+04	1.77E+05	3.55E+03	1.78E+06
	Unit impact	cancers per kg	3.59E-04	1.33E-05	8.85E-05	1.78E-06	
	Unit impact of Pb	IQ points per kg					5.92E-01
	Unit cost	€ per kg	718.9	26.6	177.1	3.6	1775.6

Unit Costs € per kg (typical emissions)
 719 27 177 4 1776
 Compare with PM₁₀ = 16 €/kg



RiskPoll program – Multimedia assessment for toxic metals (7)

- Impact of toxic metal emissions for central European conditions (cont.)
 - Collective doses, impacts and social costs (2 M€ per cancer; 3000 € per IQ point)

Parameter	Description	Units	Arsenic	Cadmium	Chromium VI	Nickel	Lead
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I _{u_food}	Unit impact from ingestion	cancers per kg	3.28E-04				
I _{u_food_Pb}	Unit impact from ingestion of Pb	IQ points per kg					0.592
U _{v_food}	Unit cost from ingestion	€ per kg	655.4				1775.6
TOTAL results							
	Collective dose						1.87E-01
	Collective impact						5.92E+02
	Collective impact of Annual cost	€ per yr	7.13E+05	2.66E+04	1.77E+05	3.55E+03	1.78E+06
	Unit impact	cancers per kg	3.59E-04	1.33E-05	8.85E-05	1.78E-06	
	Unit impact of Pb	IQ points per kg					5.92E-01
	Unit cost	€ per kg	710.9	26.6	177.1	3.6	1775.6

Residual cost of Pb emissions from unleaded gasoline
 EU limit is 5 mg/L → 1776 €/kg × 5 mg/L ~ 0.01 €/L
 (~ 1% of fuel cost)