Chain modeling for contaminants in the feed and food chain: the Cadmium case

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Safe animal feed products

- Considerations for relevance
  - Animal health and welfare
  - Human health
  - Animal production
  - Environment
- EC maximum levels for undesirable substances in feed and food products
  - Directive 2002/32/EC for feeding stuffs
    - E.g. Cadmium in feed materials of vegetable origin: 1 mg/kg (ppm) relative to moisture content of 12%
  - Regulation EC No. 1881/2006 for foodstuffs

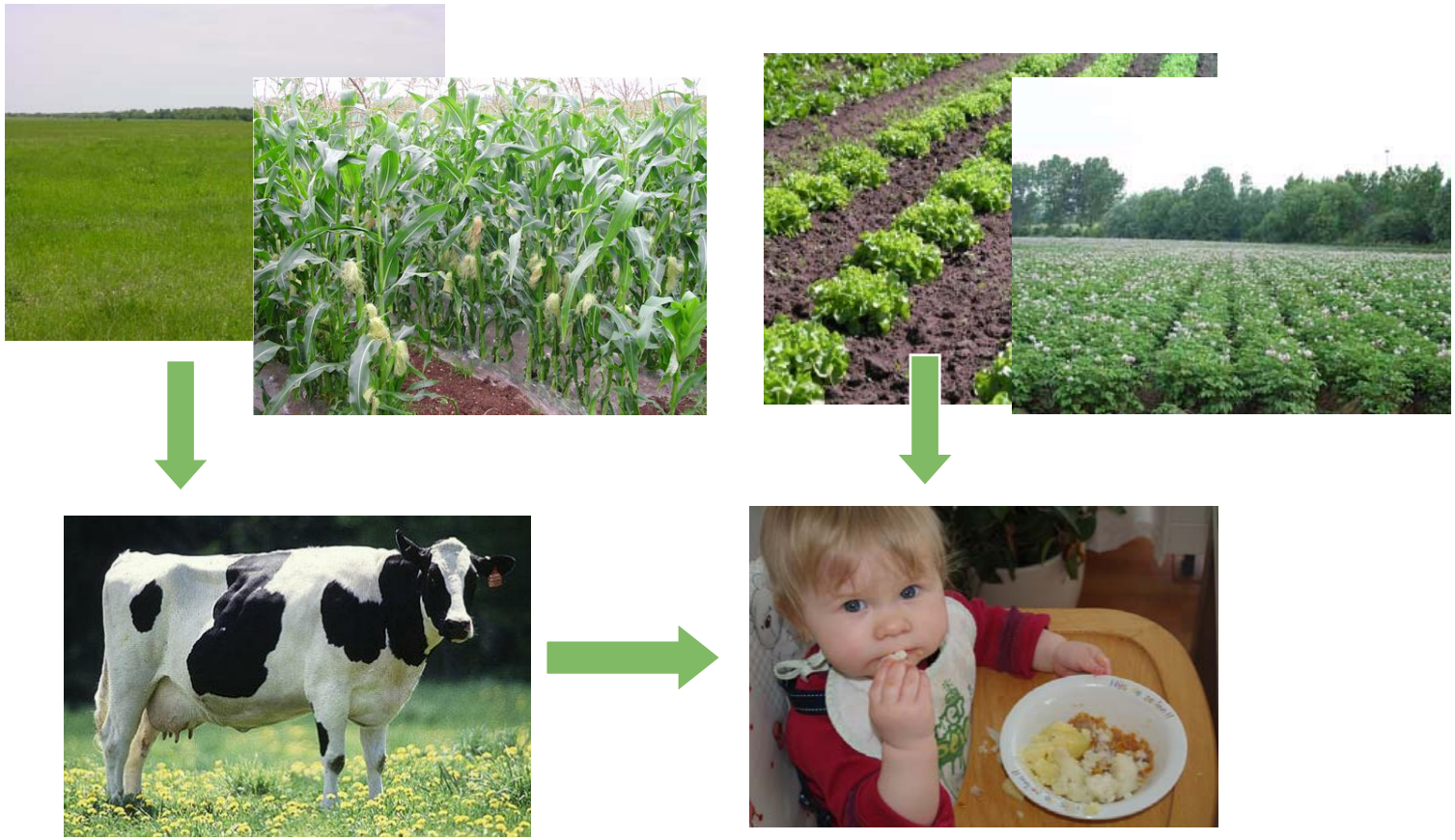
Supply chain modeling of contaminants

- Comply with maximum levels in human and animal products
  - Control in every relevant stage of the chain
  - Starting at initial point of contamination
- Quantitative supply chain modeling
  - Relative contribution various contamination routes, and their impact
  - Effectiveness of potential intervention measures
- Include all relevant contamination routes & stages

Application to heavy metals

- Aims of study:
  - Develop supply chain model to asses impact of soil heavy metal pollution and soil characteristics on animal and human exposure
  - Scenario analyses for soil characteristics
    - Impact of control measures
    - Regional differences
- Uptake heavy metals by crops, fodder, animals and humans depend on:
  - Soil properties, animal / plant physiology & animal and human consumption patterns
- Link: Soil – plant - animal – human

Transfer of heavy metals



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Application to Cadmium

- Relevance Cadmium
  - Accumulation in body, adverse health effects
  - EU maximum levels
    - Feeding stuffs (0.5 - 2 mg/kg)
    - Food stuffs (0.05 -0.5 mg/kg)
    - Human exposure (TWI 7 µg/kg BW; EFSA 2009 2.5 µg/kg BW)
  - Kempen area (NL/B)

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The setting

- Kempen area (NL/B):
- Input of Cadmium (and Lead and Zinc) to soil by zinc smelter, period 1882-1983
  - Affected area 350 km^2
  - Soils: sandy, acid, low organic matter
  - High mobility and (bio)availability of Cadmium in soil
  - Intake by grazing animals: animal health/quality animal products
  - Uptake by crops: quality of arable crops
  - Exposure of human

The Setting

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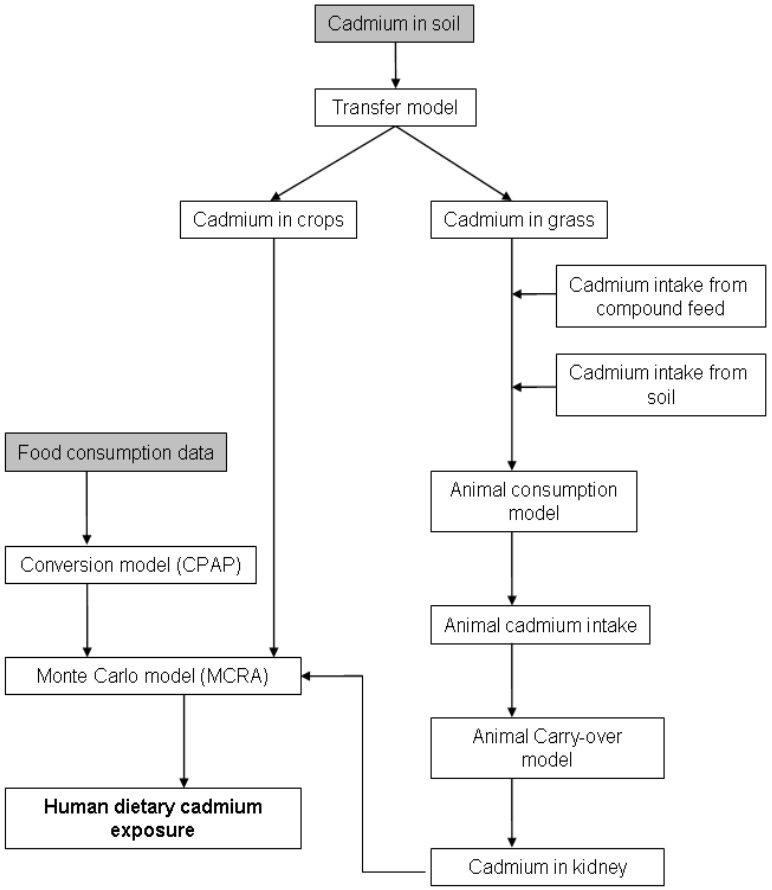
The approach: chain model



1. Soil to crop module (field data) by ALTERRA
2. Animal consumption patterns by ASG
3. Animal carry-over module by RIVM
4. Food consumption and dietary exposure module by RIKILT

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Data needs

- Soil map: organic matter, pH, clay, Cadmium
- Data on consumption (incl. range) of cows of different ages; roughage and compound
- Data on consumption patterns (incl. range) of people
- Data on soil and crop quality: soil – plant module (field data!): fodder and arable products
- Data on Cadmium levels in different animal products & food products (validation)

The modules (1)

- Soil – plant module

  log Cd(plant) = a + b*pH + c*log(OM) + d*log(Cd) + e*log (clay)

  Calibrated with field data (grass, maize, potato, endive, leek, lettuce, spinach, tomato, carrots, cucumber, beans, scorzonera, celery, radish)

- Animal intake module

  DI (mg/day) = Cd(soil) * F(soil) + Cd(comp) * F(comp) + Cd(rough) * F(rough)

  For cattle up to 6 years (0-1; 1-2 and >2 yrs)

  Roughage incl maize and grass

  Water excluded

  Cd levels in compound from survey (imported)

The modules (2)

- Animal carry-over module

  Linear bioaccumulation coefficient → kidneys, liver, meat

  (conflicting results on excretion)

  For meat: ratio 134/31/1 for kidneys/liver/meat

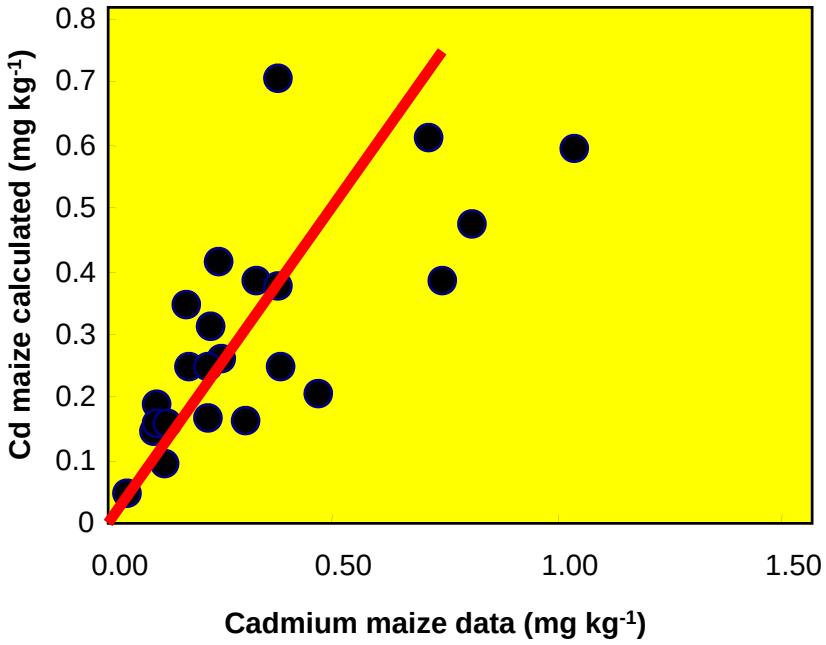
- Human exposure module

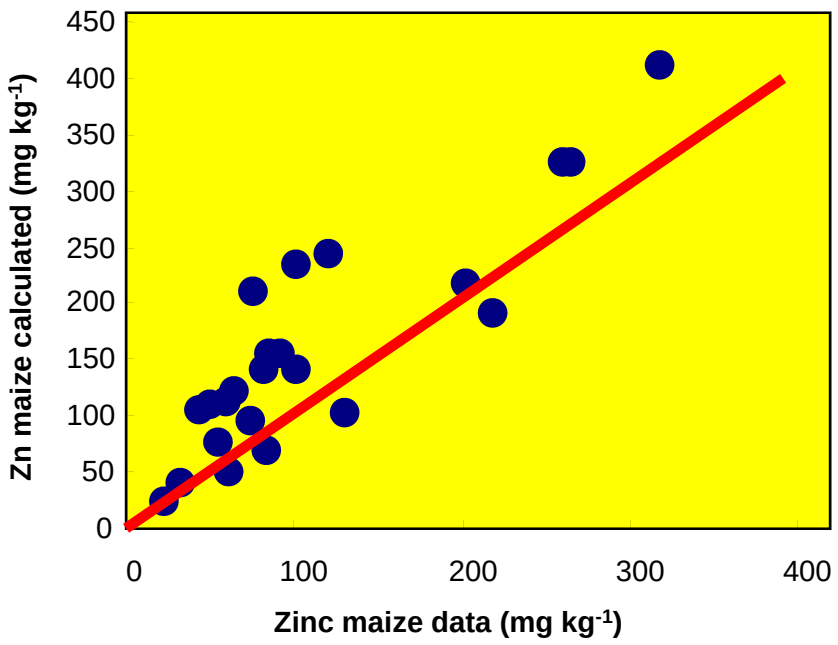
  Monte Carlo simulations based on (estimated) food Cd levels and distributions of consumptions patterns

  For 1-6 years and 1-97 years

Soil – Plant Module

Measured vs predicted levels of Cd and Zn in fodder





Human Exposure: scenarios

1. NL scenario (avg consumption from non-polluted areas)
   - Databases national food contamination & food consumption patterns
2. Kempen scenarios (100% consumption from Kempen)

Scenario	Cadmium level soil (mg kg^{-1})	pH	Description
1	0.5	4.5	Clean – low pH
2	0.5	5.5	Clean – high pH
3	1.0	4.5	Average – low pH
4	1.0	5.5	Average – high pH
5	2.5	4.5	Contaminated – low pH
6	2.5	5.5	Contaminated – low pH

Validation

- Measured Cd levels in cattle organs and crops from Kempen area
- Human exposure based on surveyed Cd levels in Kempen food products

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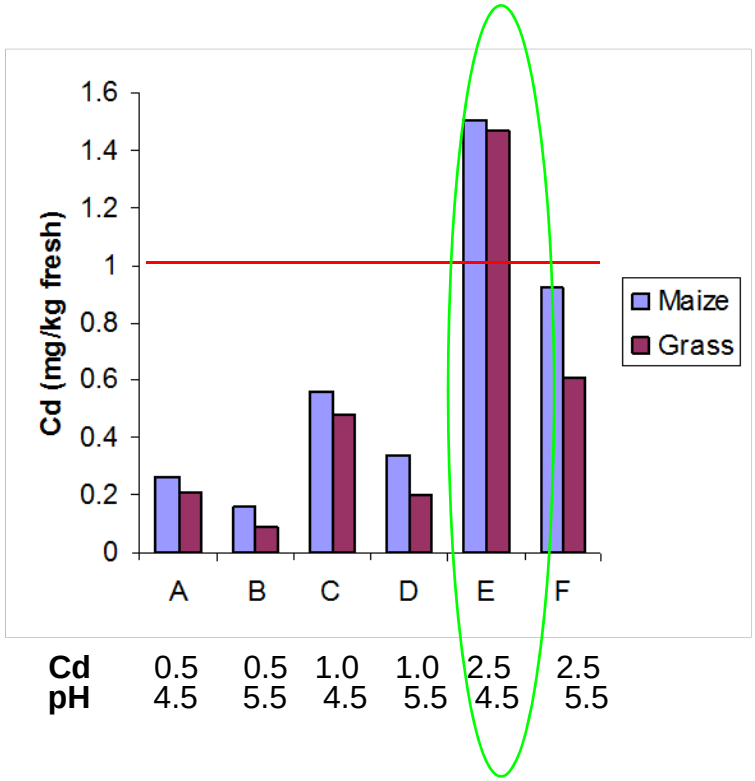
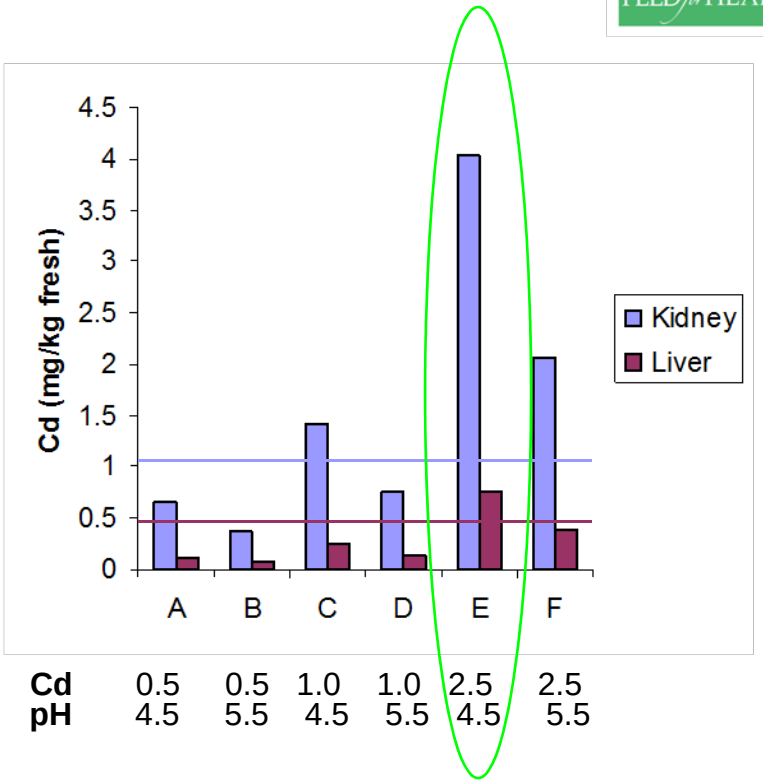
Cadmium in cattle feed + organs





- Maize / grass / liver: exceeding max. level only when pH≤4.5, Cd ≥2.5
- Kidneys: exceeding in scenario C, E & F (pH≤4.5, Cd≥1)
- Values fall within range validation set

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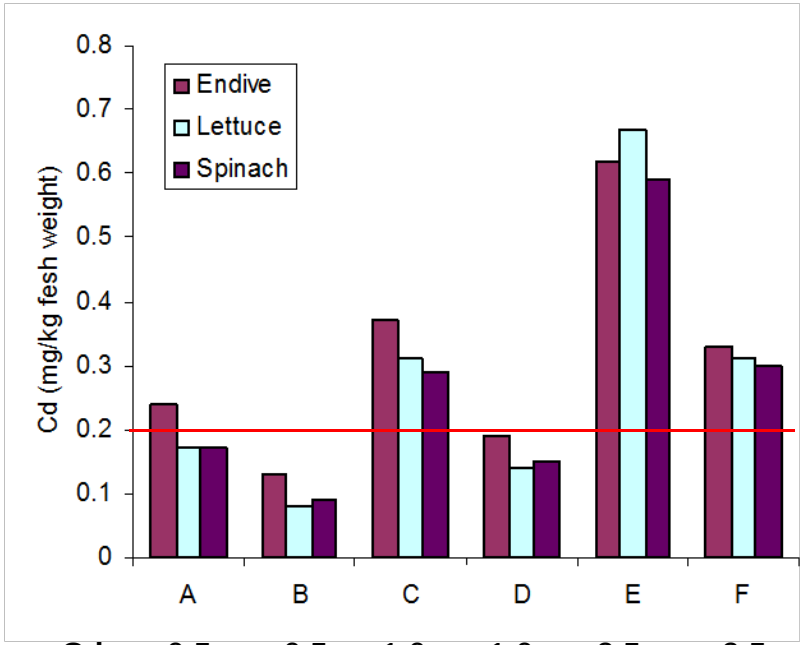
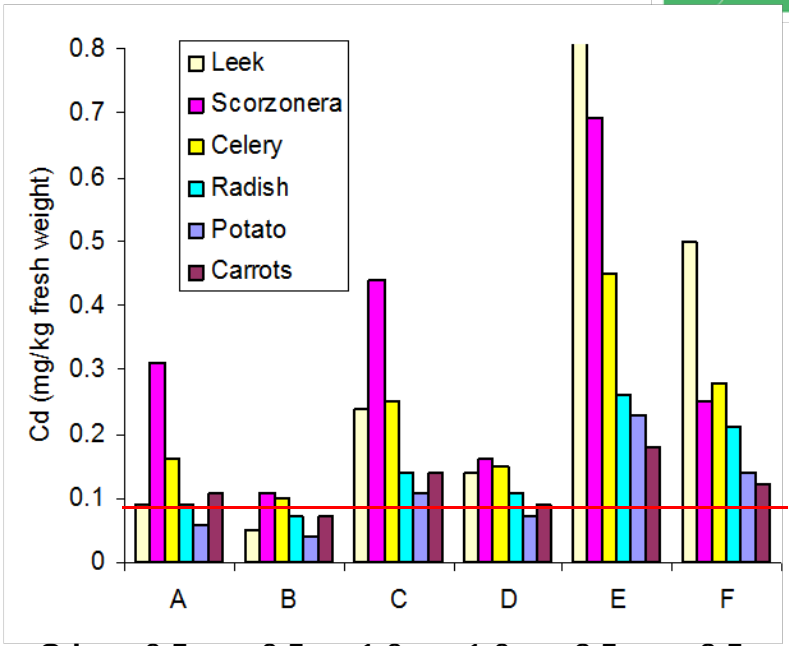
Cadmium levels in vegetables

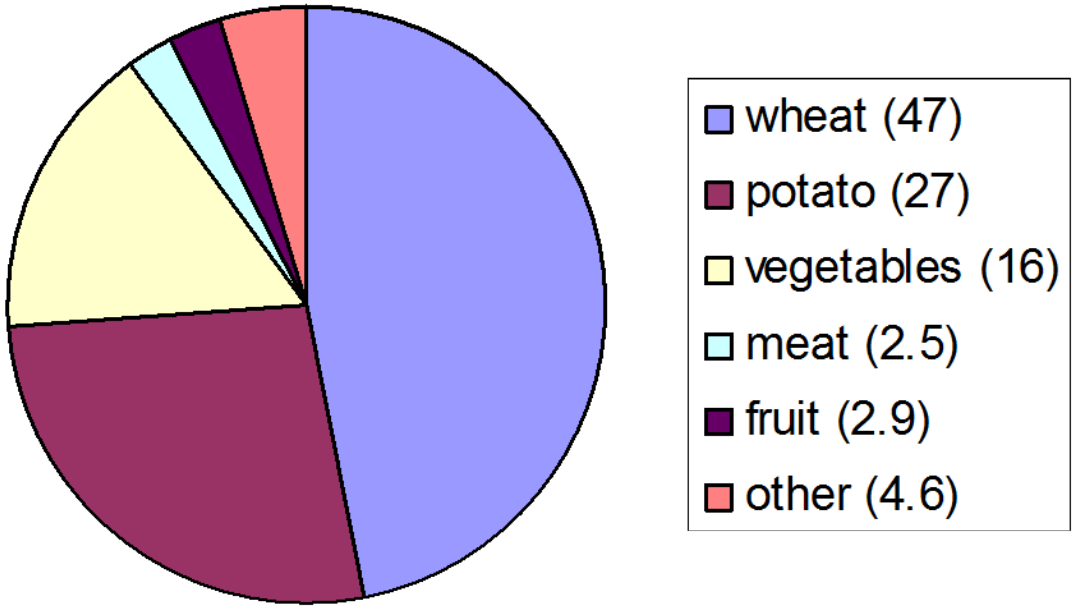




- Quality of beans and cucumbers is OK in all scenarios
- Celery & scorzonera exceed in all scenarios
- Majority vegetables exceed max. level in 3 out of 6 scenario (C, E, F)
- Values fall within range validation set

Human dietary exposure

Relative contribution to exposure:



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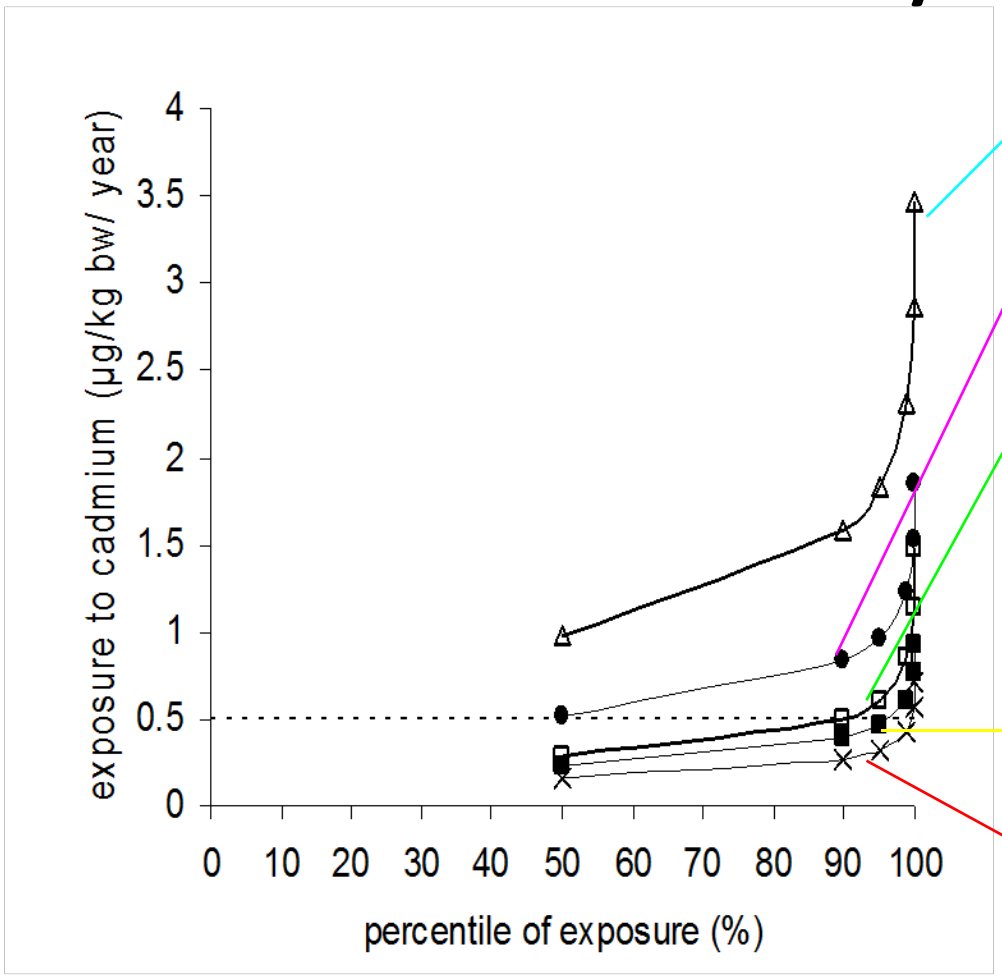
Human dietary exposure



Worst case (E: Cd 2.5, pH 4.5)

Median=0.98 µg/kg bw, 75% exceeds TDI

Average of all 6 Kempen scenarios

Validation Kempen:

median=0.28 µg/kg bw, 10% exceeds TDI*

Between scenario A en B

Minimum risk scenario Kempen

(B: Cd 0.5, pH 5.5)

Median=0.24 µg/kg bw, 3% exceeds TDI

National level

median=0.16 µg/kg bw

0.25% of population exceeds TDI*

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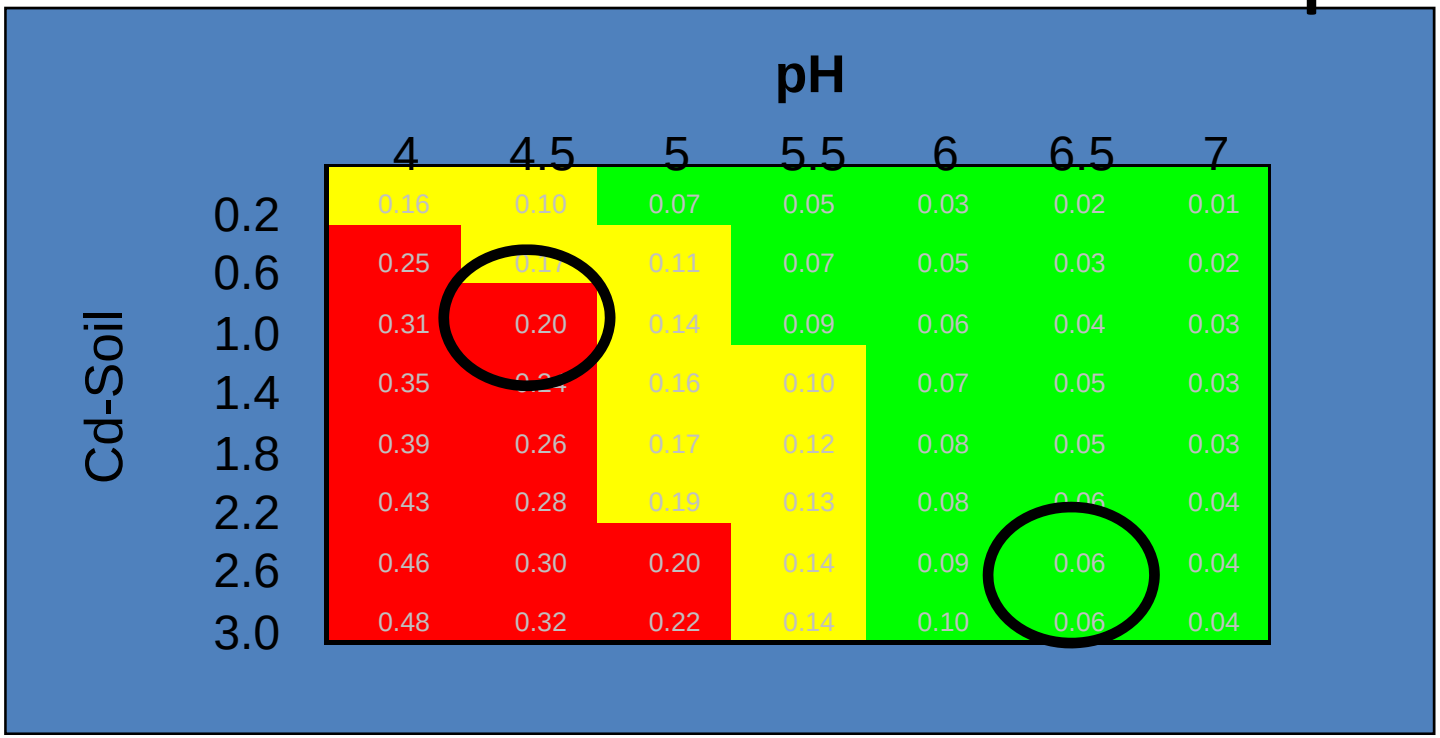
0.5 µg /kg bw/day-1

Conclusions

- Current chain model linking soil, plants, animal & human exposure
  - Successful demonstration of a supply chain risk assessment model
  - Close agreement model and validation data
  - Gives relatively fast insight in feed & food chain risks
  - Relatively fast regional assessment
  - Easily adapted to local/regional conditions, (inter)national levels, and other contaminants
  - Assessment of efficiency intervention strategies
- Some model parts uncertain, esp. transfer into animal organs

Practical Solutions: Look-up Tables



Example 1: Cd-soil 1.0, pH 4.5 **Quality insufficient**

Example 2: Cd-soil 3.0, pH 6.5 **Quality Sufficient**

Acknowledgements

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Thank you for your attention!

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