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Modeled Environmental Concentrations of Engineered Nanomaterials (ENM) for different regions and at different resolutions

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Outline

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- Aim, concept and method of the material flow modeling
- Results of the engineered nanomaterial flow simulation studies (regional)
- Engineered nanomaterial concentrations in rivers at local resolution
- Conclusions

What's the problem?

- Engineered nanomaterials (ENM) are released to the environment.

  - Synthetic TiO_2 nanoparticle emissions from exterior facades into the aquatic environment *(Kaegi et al. 2008).*

  - Nanoparticle silver emissions into water from commercially available sock fabrics (beaker glass) *(Benn and Westerhoff, 2008)*.

  - Release of nanosilver from textiles during washing (washing machine) *(Geranio et al., 2009).*

- Some data on environmental behavior and ecotoxicology of engineered nanomaterials are available.

- Analytical methods are not (yet) available for quantitative nanomaterial detection in the environment.

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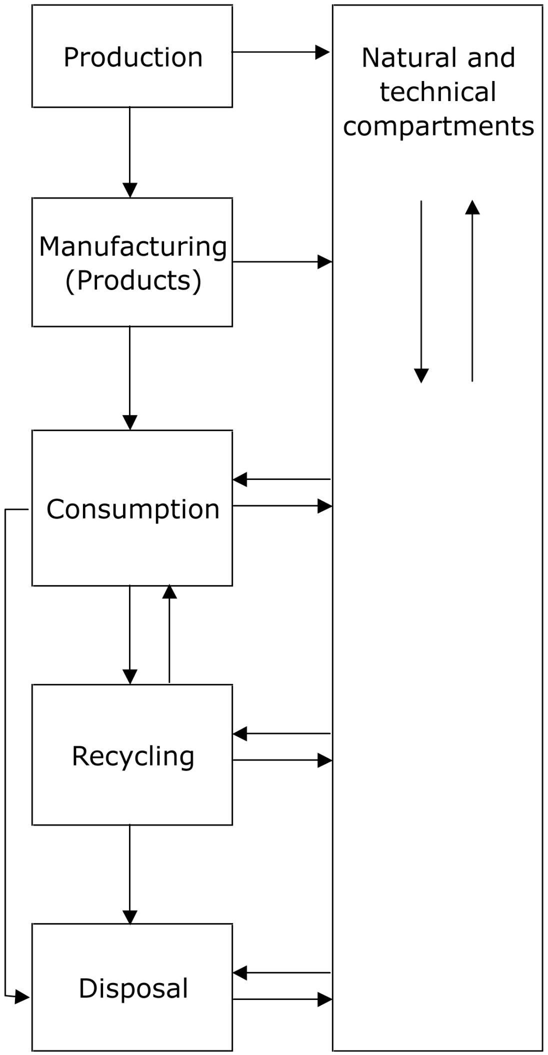
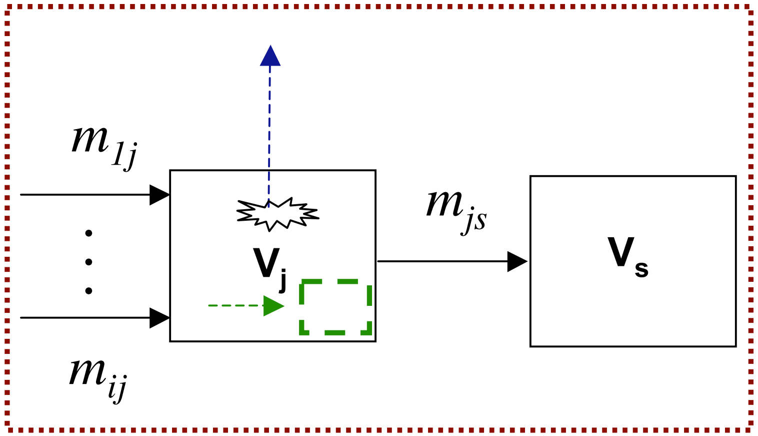
Aim, concept and method of the environmental exposure modeling

Basic concept: transfer coefficients modeled as contaminant specific values

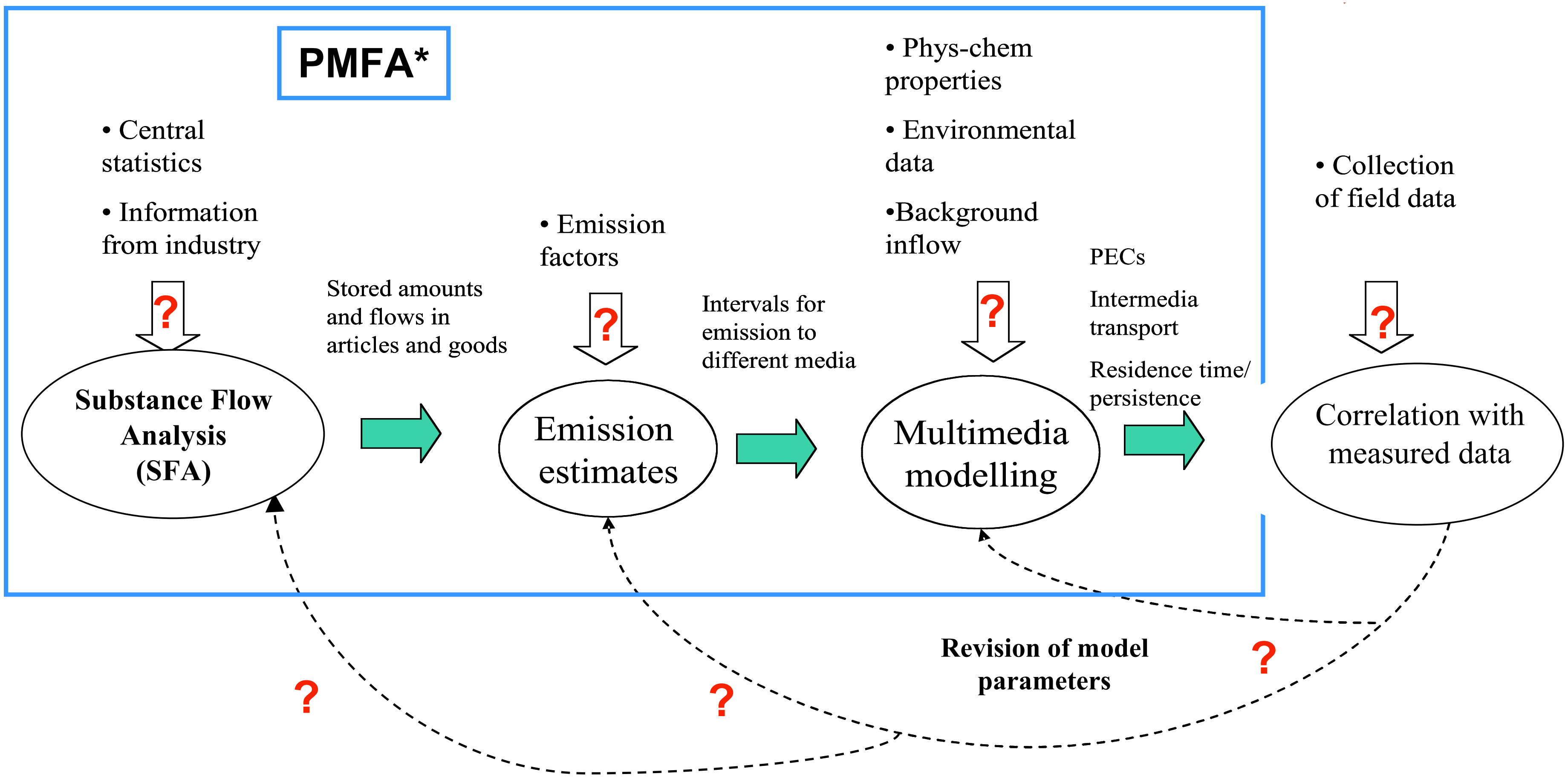




$$TC_{js} = \frac{m_{js}}{\sum_r m_{rj}}$$

$$m = m^{compound} = m^{product} \cdot c^{(i)}$$

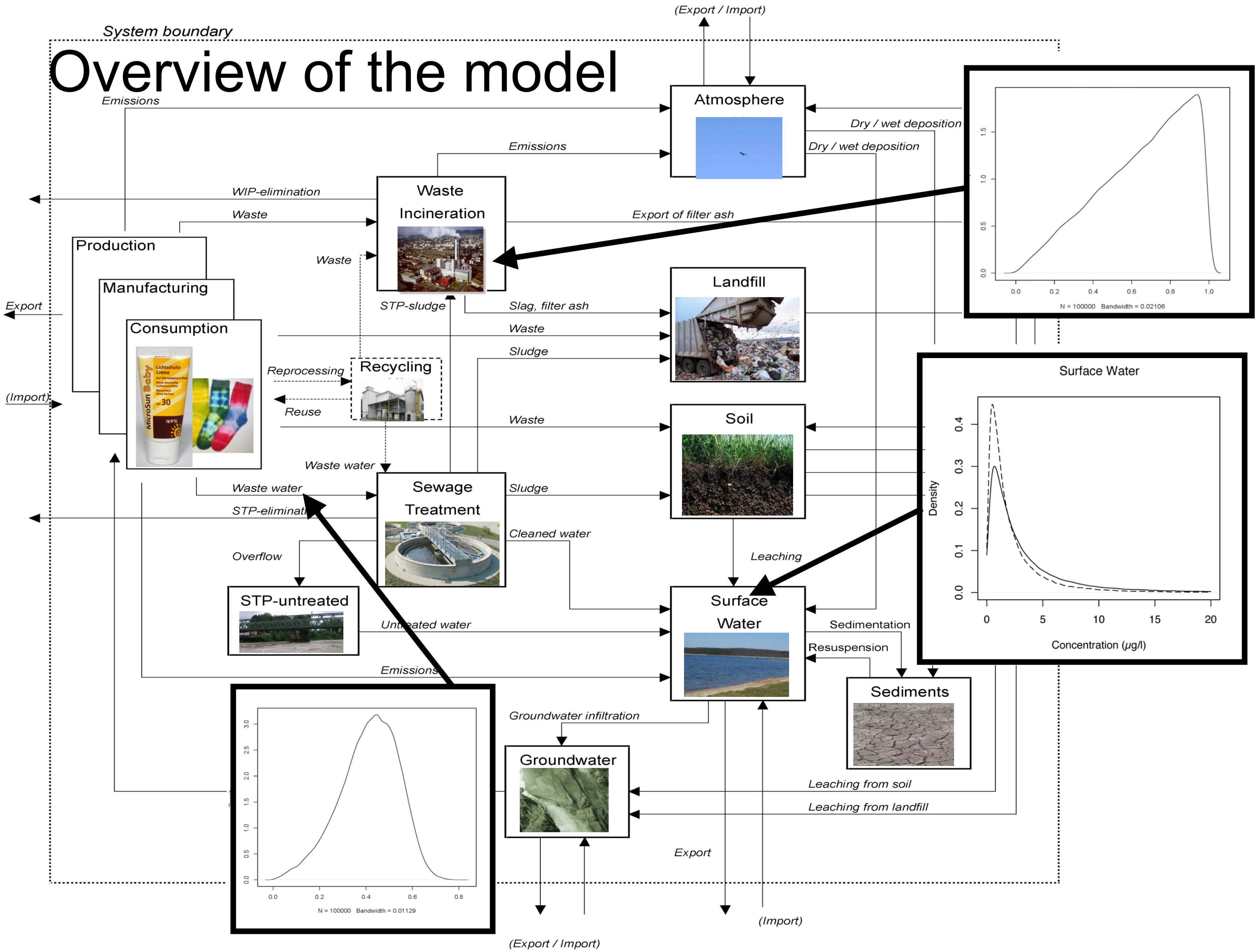
Why probabilistic/stochastic modeling?



Adapted from Föredragshallare, 2009

*PMFA: Probabilistic Material Flow Analysis

Overview of the model



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Results of the simulation studies (Switzerland, EU, USA)

Worldwide production volumes from different sources in tons/year (year of estimation)

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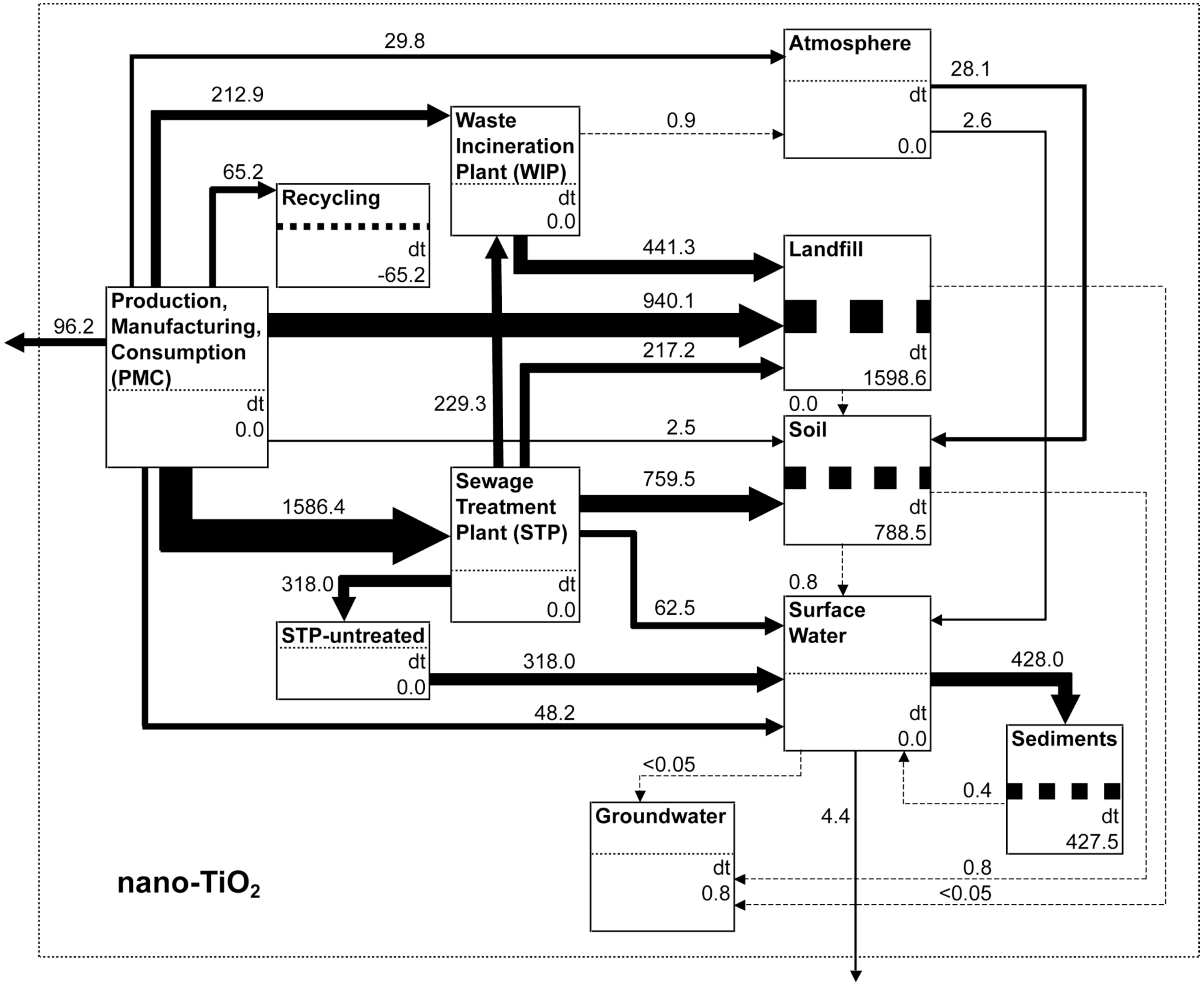
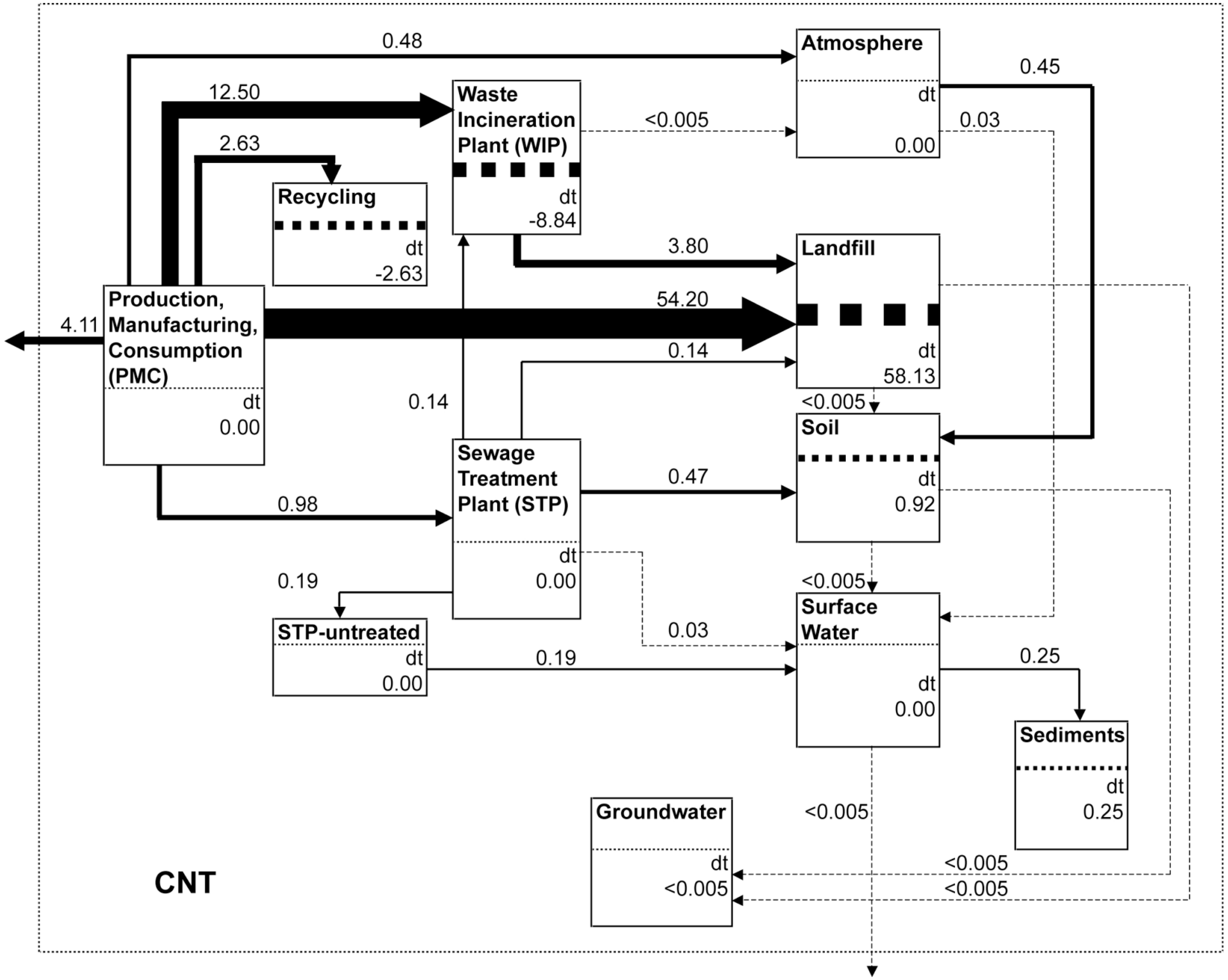
TiO_2	Ag	ZnO	CNT	Fullerenes
679 (2007)	4 (2005)	18 (2008)	140 (2008)	0.15 (2002)
3‘000 (2008)	5 (2008)	20 (2007)	278 (2007)	5 (2008)
5‘000 (2007)	434 (2008)	528 (2007)	295 (2008)	10 (2005)
60‘926 (2008)	563 (2008)	1‘800 (2008)	426 (2008)	
		9‘845 (2008)	473 (2004)	
			500 (2006)	

Material-flow model for nano-TiO_2 for the US (mode values in tons/year)



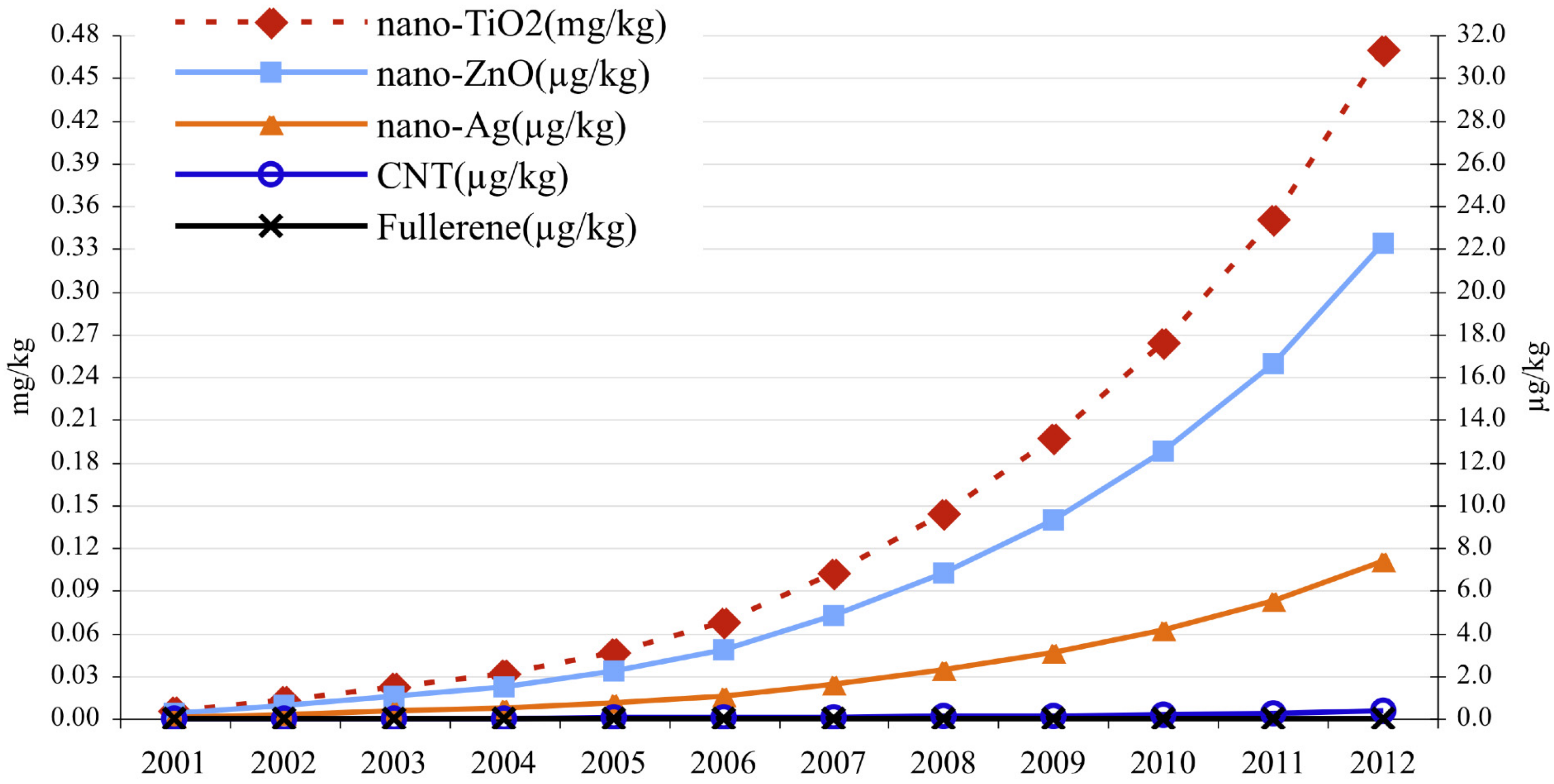
Material-flow model for CNT for the US (mode values in tons/year)



Modeled concentrations in waters for the EU (mode and 15 and 85% quantiles in ng/L)

	TiO_2	Ag	ZnO	CNT	fullerenes
Surface water	15 (12-57)	0.76 (0.59-2.16)	10 (8-55)	0.004 (0.0035-0.02)	<0.0005 (<0.0005-0.2)
Treated wastewater	3’470 (2’500-10’800)	43 (33-111)	432 (340-1’420)	15 (11-32)	4 (4-26)

Concentrations in sludge treated soil in the US between 2001 and 2012



Risk evaluation: PEC_{modal}/PNEC (for Europe)

	TiO_2	Ag	ZnO	CNT	fullerenes
Surface water	0.02	1	0.3	<0.0005	<0.0005
Cleaned wastewater	4	61	11	<0.0005	0.02
Sediment	na	na	na	<0.0005	na
Soil	0.004	na	na	<0.0005	<0.0005
Sludge treated soil	0.3	na	na	<0.0005	<0.0005

PEC: Predicted environmental concentrations
PNEC: Predicted no effect concentrations

Assessment factor 1000
na: not available

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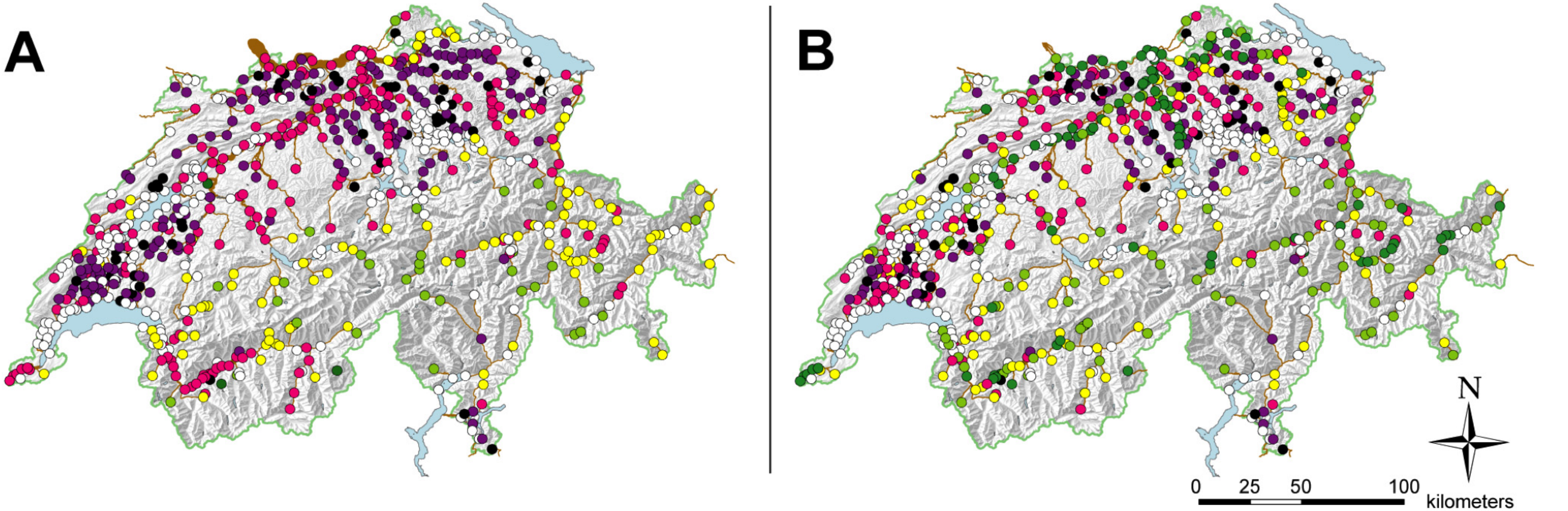
Modeled engineered nanomaterial concentrations in rivers at local resolution

PECs in Swiss rivers at water levels reached or exceeded in 95% of the time (modal ENM emission)

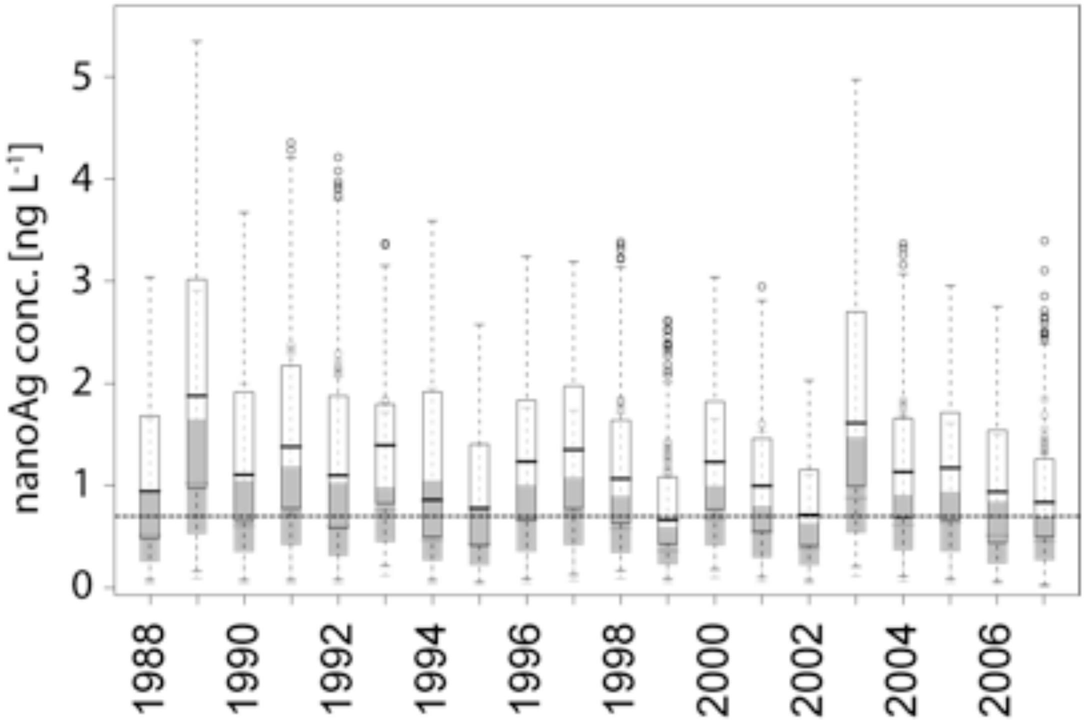
without sedimentation **with sedimentation**



Modal PEC of nano-Ag at baseflow Q_{347} [ng L^{-1}], current PNEC 0.7 ng L^{-1}

- < 0.028
- 0.028 - 0.14
- 0.14 - 0.7
- 0.7 - 3.5
- 3.5 - 17.5
- > 17.5
- discharge to lake or no Q_{347} available

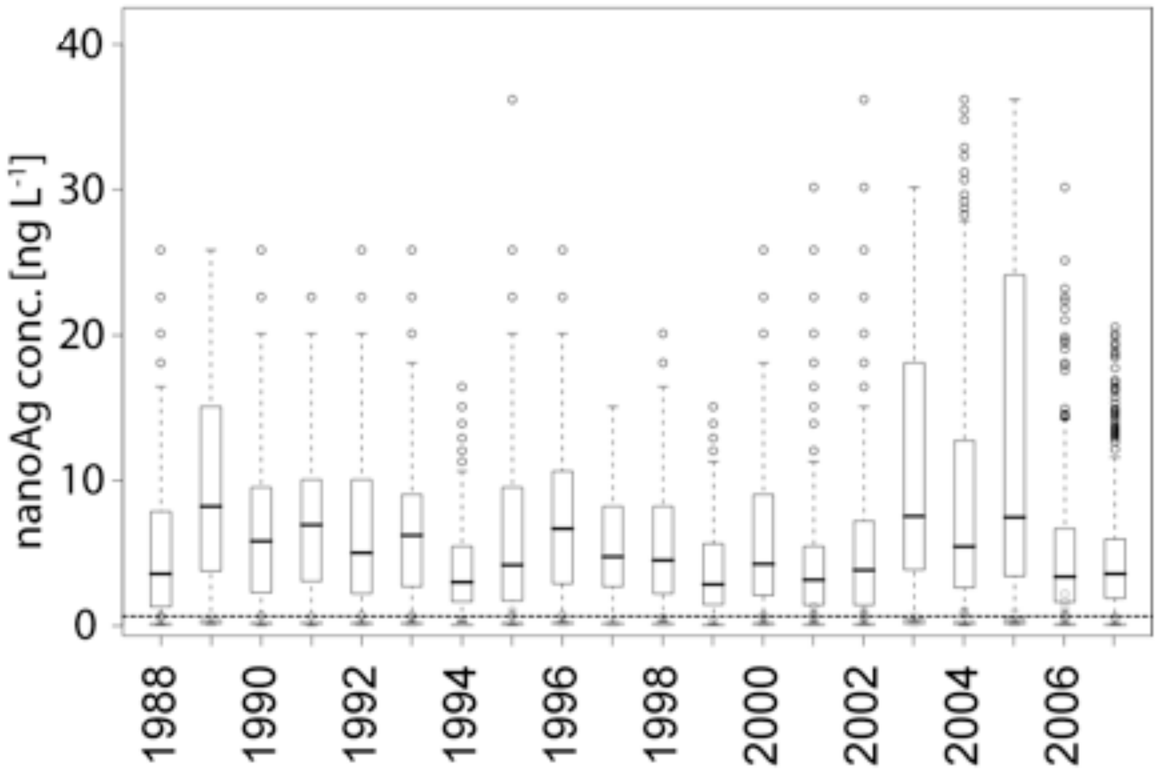
PECs and exceedances of PECs above predicted no effect concentrations (PNECs) for nano-Ag (0.7 ng L^{-1})



Gray box diagram: scenario with sedimentation

River section: Courroux (Délemont)

PECs and exceedances of PECs above predicted no effect concentrations (PNECs) for nano-Ag (0.7 ng L^{-1})



Gray box diagram: scenario with sedimentation

River section: Seyon-Valangin

Open points

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- Better data on production and use needed
- Release from products: only few studies available
- Different forms and functionalizations of nanomaterial
- Geographical and time-dependent differentiation
- Lack of ecotoxicological data for some environmental compartments and nanomaterials

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Sources

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