Emission Inventories for POPs and eight candidate POPs in UNECE-Europe

Emissions, projections, uncertainties, improvements

TNO | Knowledge for business

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International Conference on Intercontinental Transport of Atmospheric Mercury and Persistent Organic Pollutants in Rome, Italy, 7 to 11 April 2008

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The mantra: Emission inventories should be….

- ***Transparent***
- ***Comparable***
- ***Consistent***
- ***Complete***
- ***Accurate***

- **However, depending on the user the accents may differ. Important to realize the perspective /goal for which the EI was made!**
- **Complete - because otherwise models & policy makers can't use it**
- **Comparable & transparent & consistent – because "level playing field" and negotiations between parties**
- **Accurate? - As accurate as possible for science but comparable and transparent is more important for policy perspective…..**
- **The request for this EI was policy driven…….**

Background of the current study
Convention on Long-range Transboundary Air Pollution

- The 1998 UNECE Protocol on Persistent Organic Pollutants (POP) entered into force in 2003. Once the protocols enter into force automatically a review starts.
- TNO was asked to do a study to the effectiveness of the UNECE POP Protocol to support this review;

Choices and/or Limitations of this (policy driven) study:
no re-emissions or illegal emissions
-> underestimation of "real" emissions
No in-depth review of emission factors
-> challenge countries to give better data….and
Official emissions "overrule" expert emissions!!!!!!!

Persistent Organic Pollutants (POPs)

Most POPs are of anthropogenic origin and associated with industrial processes, product use and applications (including pesticides), waste disposal, leaks and spills, combustion of fuels, and waste incineration.

- **Major POP emission source groups**

1. **Unintentional release of unwanted by-products**
2. **Product use (e.g. Pesticides)**
3. **Release from in-use products (incorporated, slowly released)**

- **Source groups are fundamentally different: POP emissions are not correlated and (generally) independent of each other**
- **Single source vs multiple source**
- **Reduction is technically or economically limited**

Substances addressed in the present study

Persistent Organic Pollutants	Candidate POPs
Hexachlorobenzene (HCB)	Dicofol
Hexachlorocyclohexane (HCH), including lindane	Endosulfan
Polychlorinated biphenyls (PCBs)	Hexachlorobutadiene (HBU) (HCBD)
Dioxins and Furans (PCDD/F)[a)]	Pentabromodiphenyl ether (PentaBDE, PBDE)
Polycyclic aromatic hydrocarbons (PAHs)[b)]	Pentachlorobenzene (PCBe)
	Pentachlorophenol (PCP)
	Polychlorinated naftalenes (PCN)
	Short chained chlorinated paraffin's (SCCP's)

a) Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF)

b) Four indicator compounds: benzo(a)pyrene, benzo(b)fluoranthene, benzo(k) fluoranthene, and indeno(1,2,3-cd)pyrene, as specified in Annex III of the POP Protocol (ECE/EB.AIR/60).

- Aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromo-biphenyl, mirex, toxaphene, DDT, and heptachlor are thought to be no longer emitted in Europe and these substances are not further addressed in this study

The 44 UNECE countries covered by the study

Albania (ALB)	Ireland (IRL)
Armenia (ARM)	Italy (ITA)
Austria (AUT)	Kazakhstan (KZA)
Azerbaijan (AZE)	Kyrgyzstan (KGZ)
Belarus (BLR)	Latvia (LVA)
Belgium (BEL)	Lithuania (LTU)
Bosnia and Herzegovina (BIH)	Luxembourg (LUX)
Bulgaria (BGR)	Netherlands (NLD)
Croatia (HRV)	Norway (NOR)
Cyprus (CYP)	Poland (POL)
Czech Republic (CZE)	Portugal (PRT)
Denmark (DNK)	Republic of Moldova (MDA)
Estonia (EST)	Romania (ROM)
Federal Republic of Yugoslavia (YUG)	Russia (RUS)
Finland (FIN)	Slovak Republic (SVK)
Former Yugoslav Republic of Macedonia (MKD)	Slovenia (SVN)
France (FRA)	Spain (ESP)
Georgia (GEO)	Sweden (SWE)
Germany (DEU)	Switzerland (CHE)
Greece (GRC)	Turkey (TUR)
Hungary (HUN)	Ukraine (UKR)
Iceland (ISL)	United Kingdom (GBR)

Trends in POP Emissions in UNECE Europe for 1990 (Berdowski et al.) and 2000 (this study)

Year_policy scenario	HCB	HCH	PCB	PCDD/F	PAH indicator compounds			
					BaP	BbF	BkF	Indeno
1990	8.0	1326	122.2	12.89	NA [b)]	NA [b)]	NA [b)]	NA [b)]
2000	18.2	255	133.3	11.74	907	1040	459	700

(Tonnes/yr, PCDD/f in kg Teq/yr)

- HCB emissions increase strongly – Artefact of methodologies; the 1990 inventory did not include production of secondary Aluminium as a HCB source & completeness of agricultural data is better in year 2000 inventory. So, increase in HCB from 1990 – 2000 is not a real trend.
- HCH emissions declined by 81%,
- Emissions of PCB (+9%) and PCDD/F (-9% decrease) did not change much.
- No good comparison for PAH indicator compounds possible

POP Emissions UNECE Europe for 2000 and projected emissions following two policy scenarios (TNO, 2005).

Year_policy scenario[a)]	HCB	HCH (Lindane)	PCB	PCDD/F	PAH indicator compounds			
					BaP	BbF	BkF	Indeno
2000	18.2	255	133	11.7	907	1040	459	700
2010_BL_CLE_CRPOP	8.0	255	26.5	8.6	869	1006	434	657
2020_BL_CLE_FIPOP	1.5	255	7.4	3.8	597	678	222	460

(Tonnes/yr, PCDD/f in kg Teq/yr)

CR = current ratification; FI = full implementation all countries
Methodology documented in Denier van der Gon et al., TNO report 2005/194

- CLE + CRPOP: Emissions will decline substantially for HCB, PCB and PCDD/F in 2010-2020, PAHs emissions decline only slightly and no change is foreseen for HCH because occurring use appears to be allowed use.
- Full implementation (all UNECE-Europe countries) of the protocol would result in an important further reduction of HCB, PAHs and PCDD/F and will effectively address the still remaining PCB emissions.

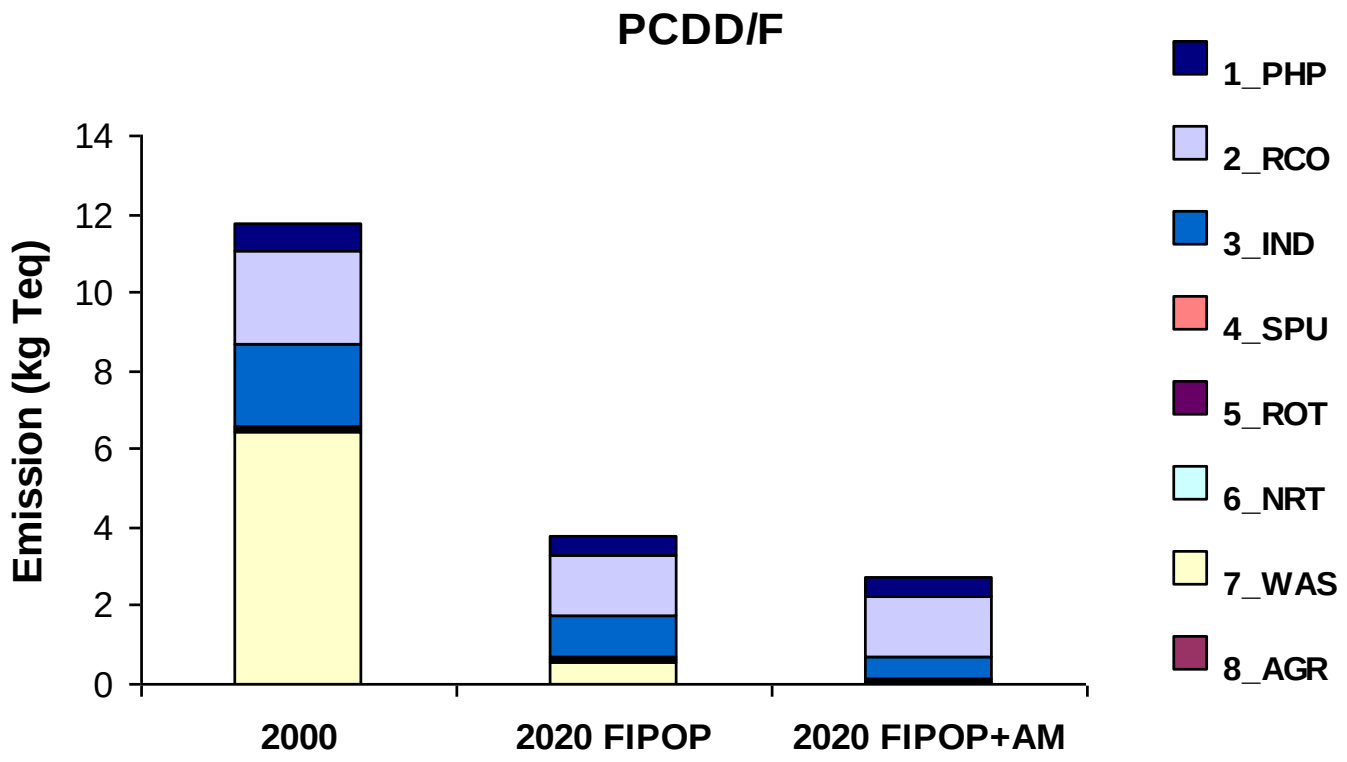
Note: Emission estimates for individual countries and projection years available in papers / reports

Key sources: Relative contribution of source sectors to remaining POP emissions upon full implementation of the POP Protocol by all UNECE countries 2020

Source sector	HCB	HCH	PCB	PCDD/F	PAH indicator compound			
					BaP	BbF	BkF	Indeno
Public power and heat	0.5	0.0	55.7	13.4	0.2	0.4	0.3	0.5
Residential combustion	3.5	0.0	3.9	40.3	81.8	92.6	87.6	90.4
Industrial combustion and processes	82.4	0.0	33.9	28.0	15.7	4.5	10.4	5.8
Solvent and Product use	0.0	81.5	0.0	0.9	0.1	0.1	0.2	0.1
Road transport	2.2	0.0	1.6	1.7	1.8	2.2	0.2	2.3
Non-road transport	1.3	0.0	0.2	0.9	0.0	0.0	1.0	0.8
Waste incineration	10.2	0.0	4.7	14.7	0.3	0.2	0.3	0.2
Agriculture	0.0	18.5	0.0	0.1	0.0	0.0	0.0	0.0
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

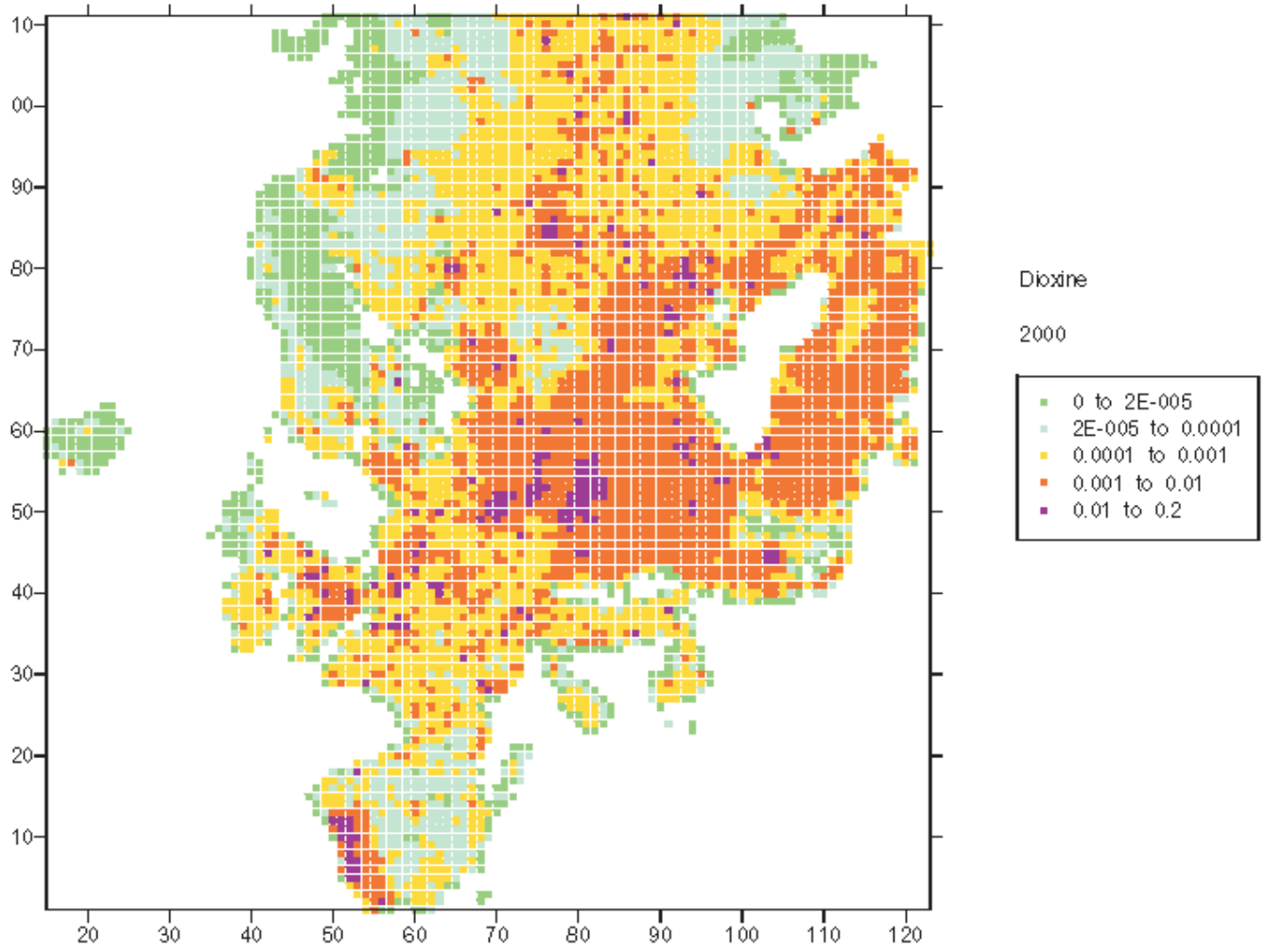
- For each POP the emissions are dominated by 1-2 source sectors (contributions > 10% are highlighted).
- The important sectors differ by POP.

PCDD/F emissions in UNECE Europe in 2000 and projected emissions in 2020 FIPOP and FIPOP+AM by source sector

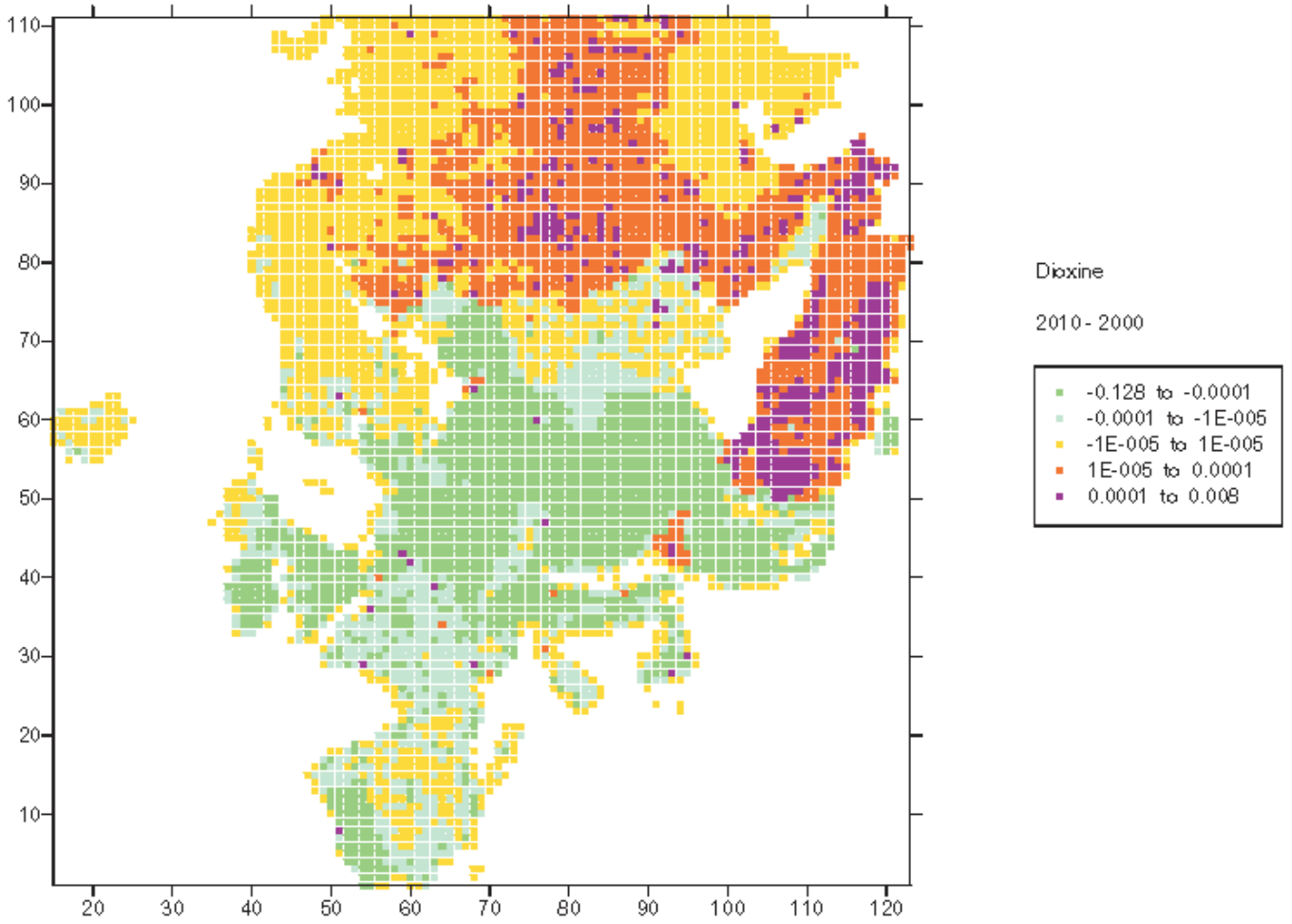


- Major reduction PCDD/F through FIPOP
- Waste incineration as a source is effectively addressed
- Most important remaining source will be residential combustion

Distribution of the emissions of Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) over the 50 x 50 km^2 EMEP grid for UNECE-Europe in 2000 (kg Teq/gridcell)



The difference between projected PCDD/F emissions from UNECE-Europe in the year 2010 with current legislation and the the year 2000 (negative values indicate an emission reduction) (kg Teq/gridcell)



Eight Substances (possibly) proposed for addition to UNECE POP protocol

Candidate POPs
Dicofol
Endosulfan
Hexachlorobutadiene (HBU) (HCBD)
Pentabromodiphenyl ether (PentaBDE, PBDE)
Pentachlorobenzene (PCBe)
Pentachlorophenol (PCP)
Polychlorinated naftalenes (PCN)
Short chained chlorinated paraffin's (SCCP's)

emission of substances (possibly) proposed for addition in 2000, 2020 before and after possible revision of the POP Protocol, and costs

Substance scenario	2000	Projected Emission 2020		Costs
		FIPOP	FIPOP+AM	
		Tonnes/yr		(M€/yr)
HCBD	2.6	2.6	0.19	3.4
PBDE	94	94	0 [c)]	0
PCN	1.0	0.28	0.11	0 [e)]
PeCB	0	0	0	0
SCCP	114	114	0	7-170
Dicofol	32	32	0	28-129
Endosulfan	775	775	0	31-160
PCP	262	262	80 [c)]	0

c) Implementation of additional measures is assumed to start in 2010.
e) No costs; Emission reduction is side-effect of measures aimed at other substances

Much interest (low costs – big impacts) but how to continue?

Note; gridded maps for modelling available

Uncertainties in POP Emission Inventory

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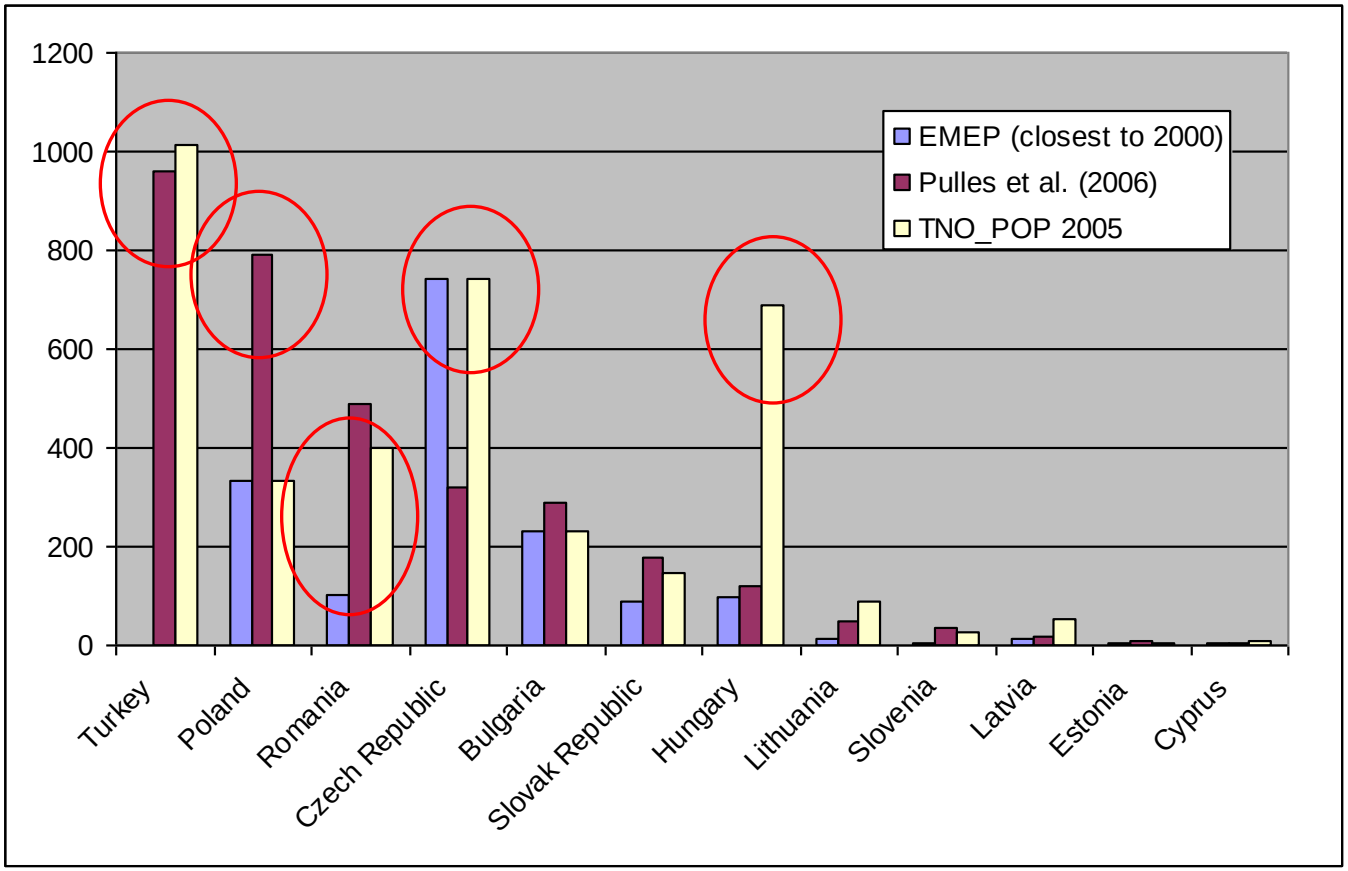
- **see also POP section in:** "*Evaluation of inventories of HMs and POPs"* (in: *Vestreng et al., MSC-W Technical Report, 2006*.)

Case study - Comparison of national total PCDD/F emissions



Note: Official reported data for year 2000 or closest year if 2000 emission data not available; CY -2003, EE - 2002 and LT -2003.

Comparison of national total PCDD/F emissions "unofficial /research" estimates VS official reported data

- Research estimates consistently higher than the officially submitted data (except 1 country – but after 2002 lower) but… all country estimates are within the estimated uncertainty boundaries (except 2 countries)
- Uncertainty approach gives confidence in overall quality
  - 13 countries 3.3 kg Teq/yr range (1.2 - 7.4)
  - Total UNECE-Europe 2000 = ~ 12 kg Teq/yr (TNO, 2005)
  - 12 countries: 2.3 vs 2.7 (2.1*) kg Teq / yr (Pulles et al. vs TNO 2005)
- A review of sources covered will result in identification of omitted sources and/or identification single large discrepancies; Combination of external estimates and official data may be a quick step forward if the "right" procedure could be invented

Example of uncertainty due to incomplete official reporting & “simple estimation methods”

- We gap fill in case countries do not officially report emissions. When they do, our estimate will be overwritten by the official data – no in-depth analysis!.
- TNO estimate for Italy year 2000 HCH emission of 144 ton/yr (this dominates European emissions !)
- Italy had no official HCH estimate, but is was known that Italy had asked for the possibility to use HCH for exempted uses (mostly large scale wood conservation)
- Our generic procedure to estimate exempted use of HCH is based on country's insecticide use (FAO)and the fraction of insecticide that could be HCH based on a few countries that do report exempted use and also total insecticide is known (UK was our best candidate).
- For the UK 3.1 % of the insecticide use was HCH in 2000. Next we use a partioning over compartments where in case of HCH 50% goes to air.
- The origin of the high HCH estimate for Italy is the high insecticide use in Italy of 8859 tons in 2000 (FAO Statistics Division). 3.1% of this x 50% = 137 tons.
- The remaining emission 144-137 = 7 tons is other exempted agricultural use
- The data have been submitted to national experts but no reaction was received to correct the figure….
- Italy now reports official HCH as “0” but this was submitted in 2006, when our study was finished.

Accuracy of EI could be significantly improved through targetted actions!

Suggestions for future work – Current results can be the starting point for targeted and / or concerted actions

- How to most effectively use the national expert knowledge? Action by substance? – e.g. PAHs
- Improvements in POP/ new substance emissions through more detailed country product usage data (e.g., for pesticides)
- For some substances emission factor determination should be put on the agenda (e.g., emission from in-use products)
- Emission factor determination is lagging behind but who has a problem? (e.g., emission from in-use products, fuels)
- Integrate primary emissions + re-emissions into a consistent inventory

Some Thoughts on global inventories viewed from our current work

- **Methodologies are rather simple – can be exported but approach is substance dependent;**
  - **Unintentional release; Energy stats + technological level**
  - **In-use product emissions; historical usage data**
  - **Product use; sales data – is it used at all in a country?**
- **Will give a first approximation; needs constraints and improvements**
- **By closer checking major sources / emitters**
- **Region-specific missing sources e.g. different fuel usage?**
- **Can the models constrain source regions (continents?)**
- **Nice challenge but needs a project and infrastructure**

Thank you for your attention
&
Please note:

Results published as

- Denier van der Gon et al., ***Atmospheric Environment, 41, 9245-9261, 2007***
- **TNO reports 2005 and 2006 – available as pdf (CDs)**

Or download from: www.tno.nl/HM_POP

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Acknowledgment: This work was funded by
Netherlands Ministry of Housing, Spatial Planning and Environment