Global NIP Update Webinar -“Introduction to polychlorinated dioxins/ furans (PCDD/PCDFs) and other unintentional POPs and inventory development and controlling emissions by an integrated approach”
19. September 2024, 15:00 -17:00 CEST, GMT+2

Introduction to polychlorinated dioxins/furans (PCDD/PCDFs) and other unintentional POPs and inventory development and controlling emissions by an integrated approach

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Content of the Web-Seminar

Part A Introduction to PCDD/PCDFs and other unintentional POPs

- Listed unintentional POPs (UPOPs) in the Stockholm Convention
- Some basic information on Dioxins/UPOPs
- Formation of unintentional POPs in thermal and chemical processes including differences
- Human exposure to Dioxins/UPOPs and link to pollution sources.

Part B PCDD/F & other UPOPs inventory development with the UNEP Toolkit

- Methodology to Establish Comparable Dioxin Inventories with the UNEP UPOPs Toolkit
- Steps for updating Dioxin/UPOPs inventories and some conclusions for development

Part C Integrated approach for pollution control of UPOPs & other major pollutants

- Releases of UPOPs & other major pollutants from some Annex C Category II/III sources
- Integrated pollutant prevention control (IPPC) promoted by the SC BAT/BEP Guidelines
- IPPC process in the EU and related BAT Reference Documents

Part A
Introduction to PCDD/PCDFs and other unintentional POPs

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Unintentional POPs listed in the Stockholm Convention

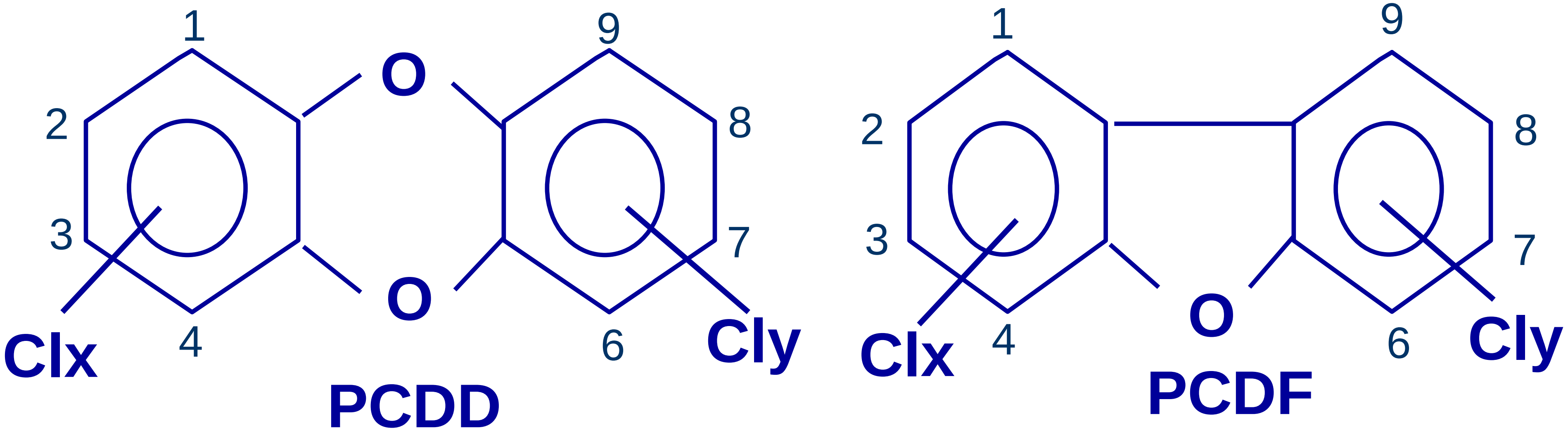
- Four of the original 12 POPs in the Stockholm Convention are unintentionally produced POPs ('UPOPs') listed in Annex C:
  - Polychlorinated dibenzo-p-dioxins (PCDDs)
  - Polychlorinated dibenzofurans (PCDFs)
  - Polychlorinated biphenyls (PCBs; main POP amount were intentional PCBs in Annex A)
  - Hexachlorobenzene (HCB)
- In 2009 Pentachlorobenzene (PeCBz) was added to Annex A/C.
- In 2015 Polychlorinated naphtalenes (PCNs) were added to Annex A/C
- In 2017: Hexachlorobutadiene (HCBD) added in Annex C and 2015 in Annex A.

These UPOPs are commonly formed as by-products in:

- The production of organochlorine chemicals,
- Processes where elemental chlorine is present,
- Thermal processes in the presence of all forms of chlorine.

In 2024, Switzerland suggested to list brominated and brominated-chlorinated dioxins and furans (PBDD/PBDF and PXDD/PXDF) in the Convention. Now assessed in the POPRC.

PCDD and PCDF molecule



PCDDs and PCDFs are the most known and best investigated unintentional POPs with the highest toxicity.

Different substitution of positions by chlorine:

- 75 PCDD congeners
- 135 PCDF congeners
- **17 congeners are substituted in 2,3,7,8-positions with the specific dioxin toxicity!**
- The **amount** of PCDD/PCDF are calculated as **Toxic Equivalency (TEQ)** from the amount of 2,3,7,8-congeners with toxic equivalency factors (TEFs).

Toxic Effects of PCDD/PCDFs

Acute effects:
- Chloracne
- Wasting syndrome
- Death (animals; humans extreme exposure)

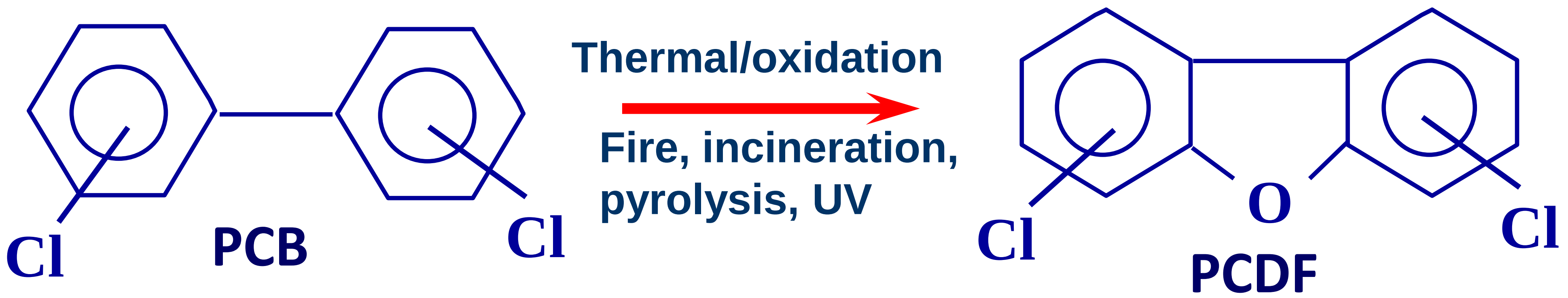
Viktor Yushchenko before (l) & after Dioxin poisoning

Chronic effects:
- Tumour promotion
- Carcinogenic (2,3,7,8-TCDD)
- Hormone system – Endocrine disruptors
- Developmental toxicity
- Reproduction (sperm quality)
- Diabetes and endometriosis
- Immune system – Immune suppressors - Immune response

See e.g.: Toxicity Review Article: Van den Berg et al. (1994) Crit. Rev. Toxicol. 24, 1; EFSA (2018) Dioxin risk assessment

PCDF Formation from PCB

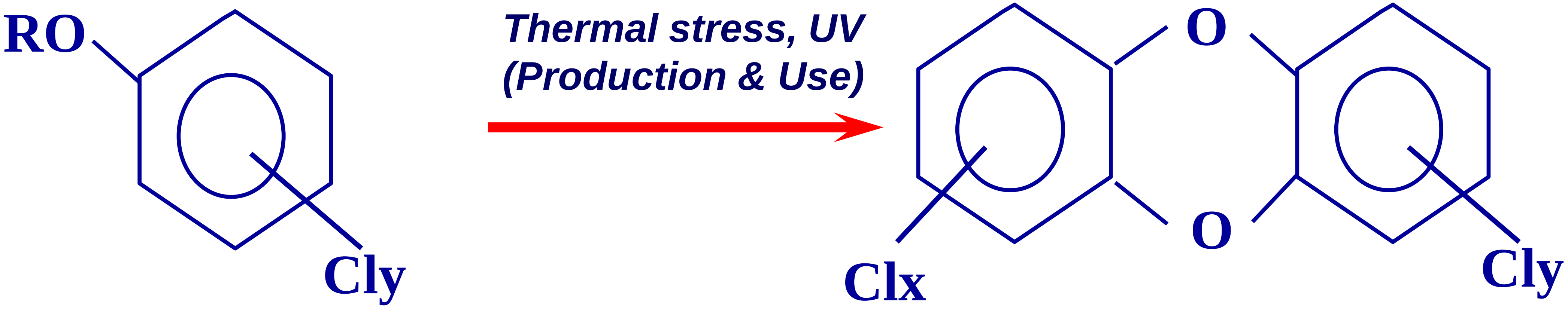
- Historic industrial 1.3 million tonnes of **PCBs had a TEQ potential ~10,000 to 16,000 kg PCB-TEQ** (TEQ in food often stem to more then 50% from dioxin-like PCBs!)
- For comparison: ~100 kg TEQ total global emission/year! (Wang et al. (2016) Chemosphere 151, 303–309).
- PCBs are PCDF precursor and can additionally form PCDF in % range in fires or other thermal stress situation (Buser et al. (1978) Chemosphere 8, 419).



- By formation of PCDF from PCB the TEQ of a mixture can increase up to 50 times (compared to the already contained PCB-TEQ!) (Weber et al ES&T 36, 1836, 2002) (see also Irish Pork crises from feed contaminated by co-incineration of PCB-oil in drying process). By open burning and the non-BAT thermal treatment of PCB containing oils.
- High PCDF formation risk when PCBs are destroyed (also other Cl/Br POPs). (Weber (2007) Chemosphere. 67(9), S109-117)

PCDD/PCDF Formation from Precursors

The history of PCDD/PCDF is closely related to the production of chlorinated aromatics.



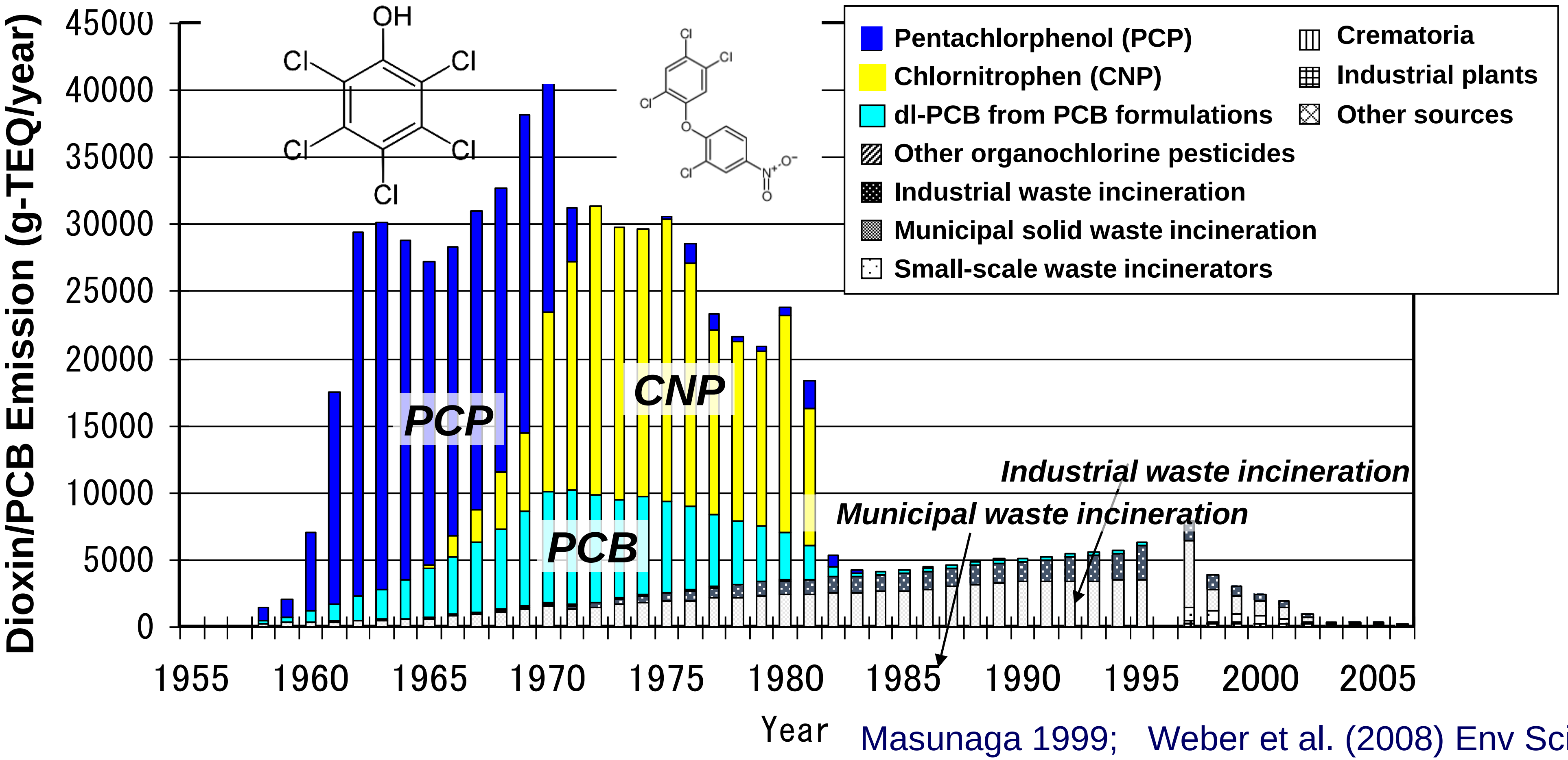
e.g. 2,4-D / 2,4,5-T (Seveso, Agent Orange), Pentachlorophenol (PCP; POP listed 2015)

A pesticide factory in Hamburg/Germany with 30 years HCH/2,4,5-T production generated 333-856 kg TEQ in residues disposed to landfills 1950s to 1980s.
(Götz et al. (2015) Env Sci Pollut Res. 20, 1925-1936)

Agent Orange & other 2,4,5-T/2,4-D mixtures sprayed in Vietnam contained estimated 366 (to 1464) kg TEQ
(Stellmann et al (2003) NATURE 422, 381-387)

(For comparison: ~100 kg TEQ total global emission/year!) Wang et al. (2016) Chemosphere 151, 303–309.

Example for Impact of Application of Chlorinated Aromatics - Historical PCDD/PCDF Inventory & Input into the Japanese Environment

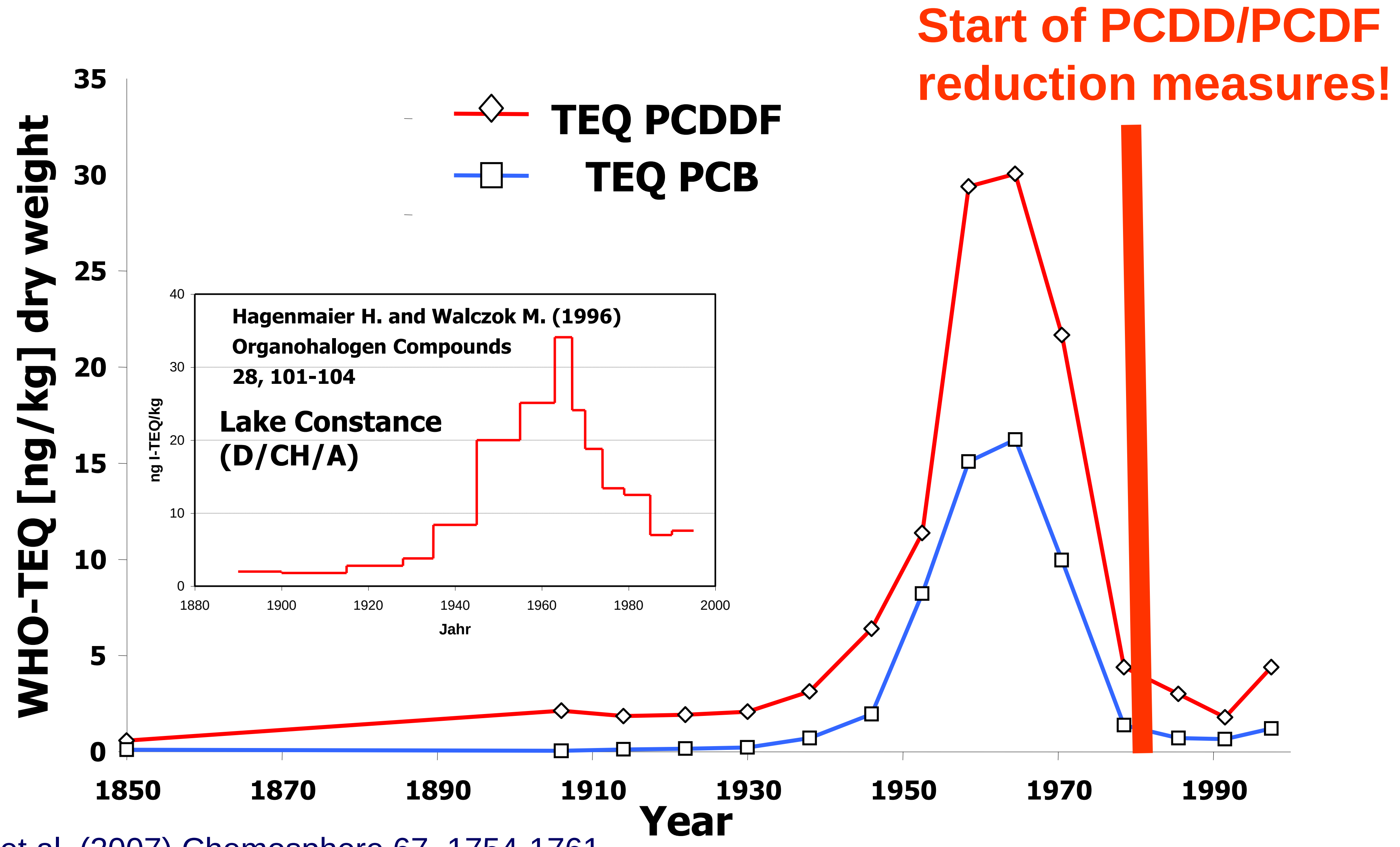


Masunaga 1999; Weber et al. (2008) Env Sci Pollut Res 15, 363-393;

- ~**460 kg TEQ** has been released into the Japanese environment **from pesticide use** and ~**120 kg TEQ from the PCB use**. This can be compared to the global dioxin release of ~100 kg/a TEQ today (Wang et al.)
- Due to the high persistence, a high share of these PCDD/PCDFs are still present in the rice fields and washed out into river sediments and sea sediments (Yao et al. (2002) Environ Toxicol Chem. 21(5), 991-998)

Time Trend of PCDD/F in Sediments Swiss/German Lakes

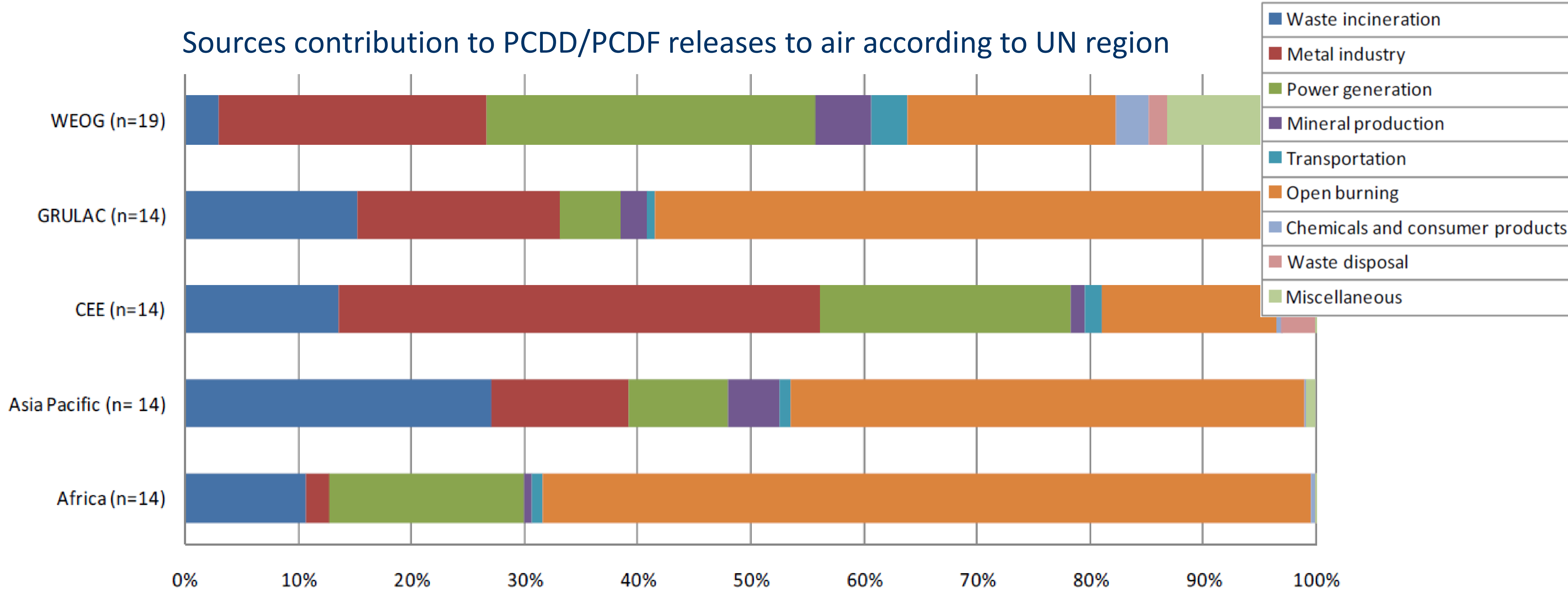
Time resolved PCDD/F Sediment contamination in Greifensee (Switzerland) or Lake Constance (D/A/CH) show the large contamination from PCDD/F contaminated chemicals until the 1970s.



Zennegg et al. (2007) Chemosphere 67, 1754-1761

Major air release sources of PCDD/F in UN regions

- The **largest contributor to PCDD/F global air releases today is open burning**, **followed by waste incineration**, the metallurgical industry, and heat and power generation.
- **Open burning *(in particular waste*) is the highly dominant source of release to air in Africa,** Asia Pacific and Latin America and the Caribbean. (UNEP/POPs/COP.8/INF40)



Trace chemistry of fire and thermal formation of PICs and PCDD/F

What is the difference of the fuels we use(d) for heating, cooking (wood, oil, gas) or we use(d) as light source (oil lamp, candle) and the materials present in waste burning?

Complete combustion of gasoline or paraffin:

$C_xH_y + O_2$ ----> CO_2 + H_2O

Elements are not destroyed by combustion they are only transformed and distributed!!

Products of incomplete combustion (PICs; all real processes!!):

$C_xH_y + O_2$ ----> $CO_2/CO + H_2O + C_xH_yO_z$ (PICs incl. PAH)

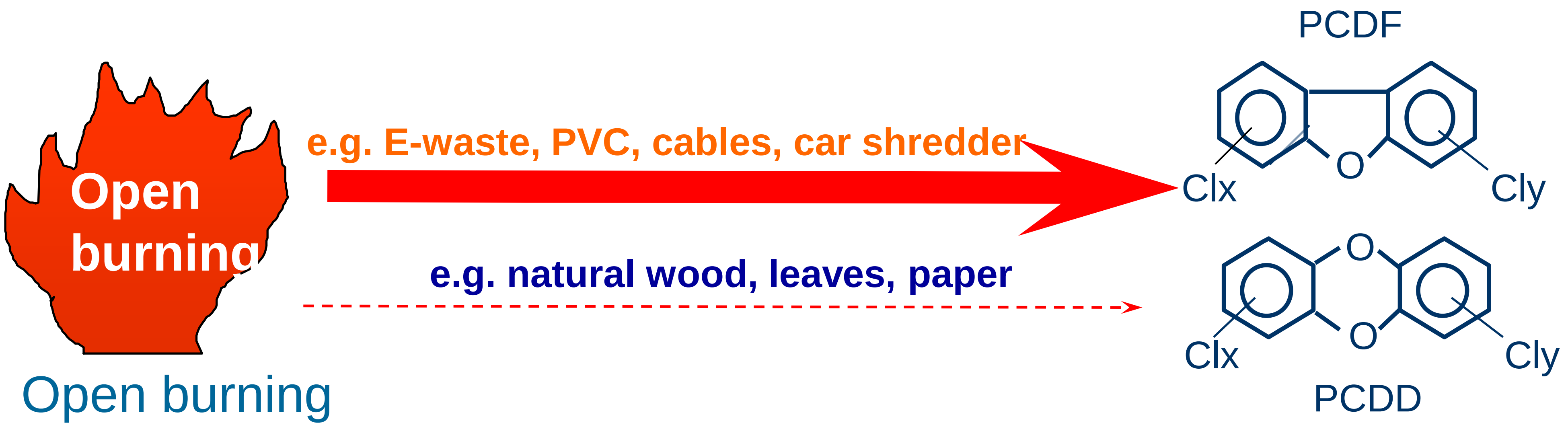
Because chlorine is present in waste combustion:

$C_xH_y + O_2 + Cl$ ----> $CO_2 + H_2O + C_xH_yO_zCl_m$ (UPOPs: PCDD/PCDFs, PCBs, PCN, HCB,PeCB)

If bromine is present Br_pCl_q----> also brominated-chlorinated PXDD/PXDF

Dioxins/UPOPs in Open Burning of Waste – Effect of Waste Types

Dioxins + other UPOPs



TEQ-Emission depends strongly on fuel/waste source (chlorine content & metal catalysts)

+ Toxic Metals in wastes: Cd, Pb, Hg, Cr, As, Cu, Ni, Co etc.

+ Inhalable patriculate matter (PM10; PM 2.5) having health impact !

Forest fires mainly redistribute adsorbed PCDD/PCDF and PCB (Prange et al. (2003) Environ. Sci. Technol. 37, 4329-4329)

PCDD/F Formation in Open Burning – effect of organic chlorine

The emission of **PCDD/F** from **open burning strongly depends** on the **chlorine content.**
High emission from burning PVC containing waste!

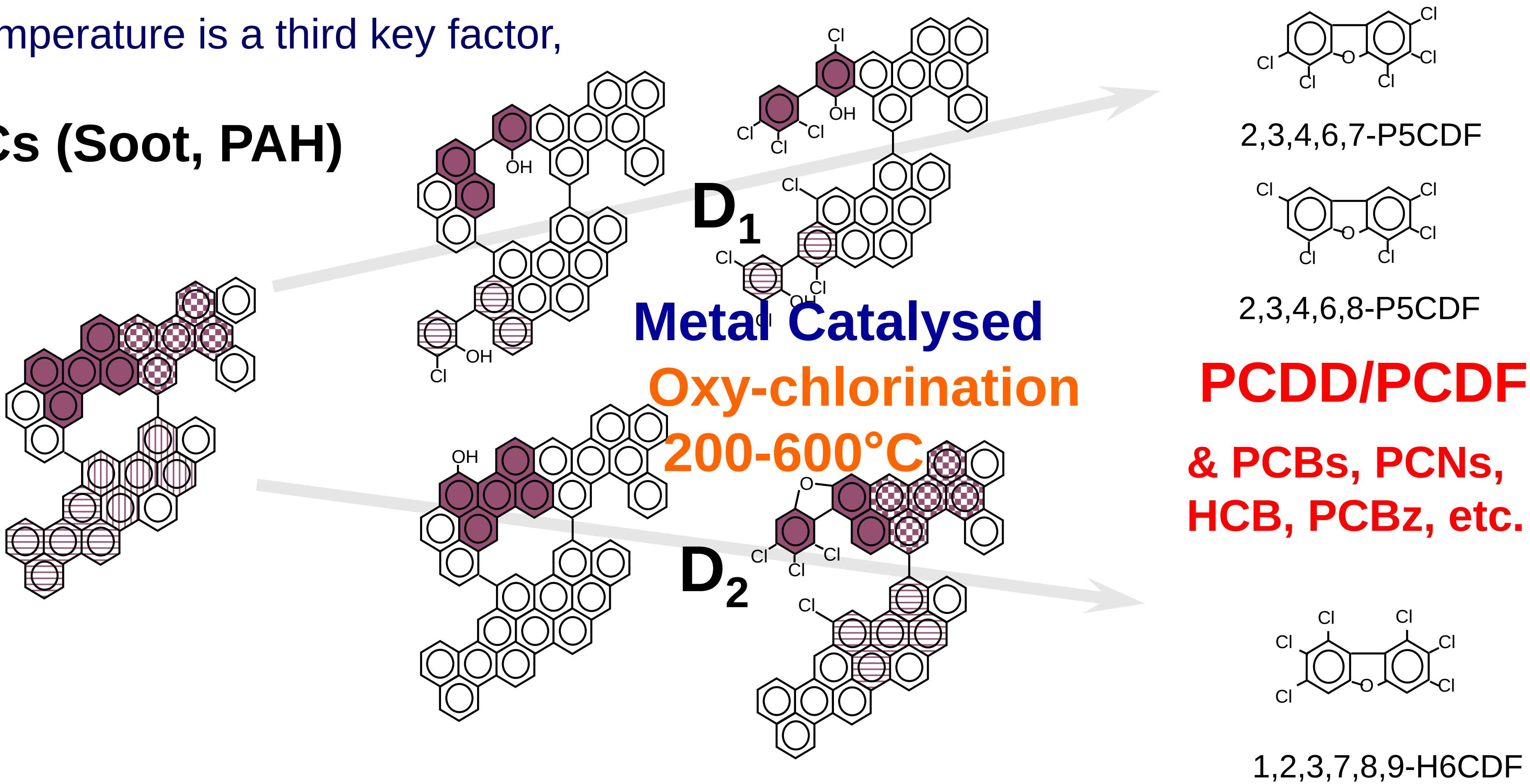
Wastes	Dioxins emissions (ng-TEQ/kg-waste)
Agricultural plastics (PVC)	6554.1
Electric wire tube	1032.6
Scrap tire	220.9
Wood (construction waste)	91.6
Rice husk	67.4
Wood (demolition waste)	26.5
Bundles of straw	20.2
Tree, Leaves	4.6

Ikeguchi and Tanake (1999) Organohalogen Compounds 41, 507-510.
https://dioxin20xx.org/wp-content/uploads/pdfs/1999/99-237.pdf

Formation of PCDD/PCDFs and other UPOPs from Soot/PAH

Oxychlorination of soot/PAHs (*de novo* synthesis) in thermal processes

- The amount of PICs (soot/PAHs) is one basic factor for PCDD/PCDF and other UPOP formation.
- The metal catalysts are the second major factor.
- The temperature is a third key factor,

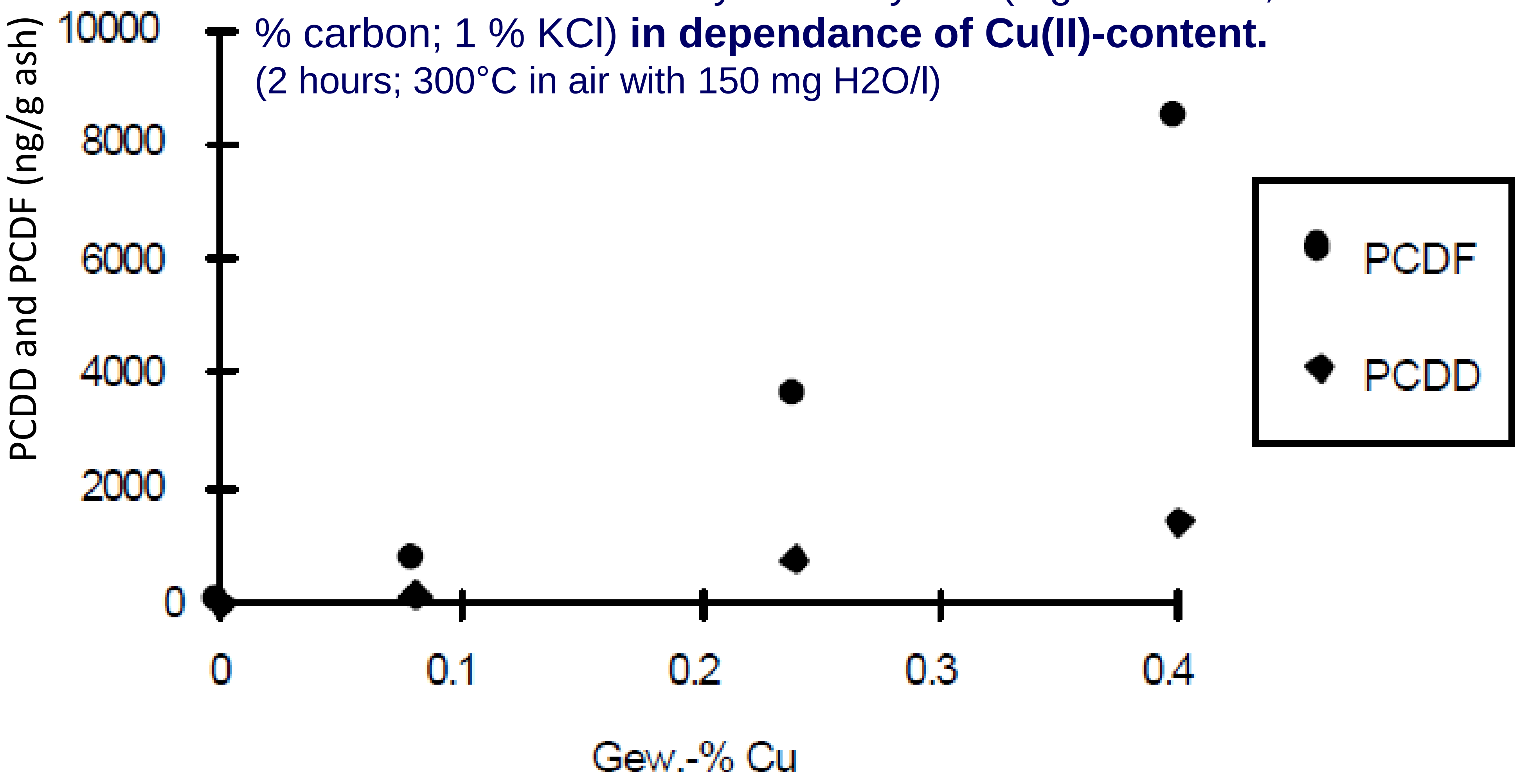


Weber, Iino et al. (2001) Chemosphere 44, 1429-1438.

Impact of Copper Content on PCDD/F Formation

- Copper is the best catalyst for PCDD/PCDF de novo formation in thermal processes.
- Other metals like iron also have an catalytic effect but lower.

***De novo* formation** on synthetic fly ash (Mg/Al-silicate; 1 % carbon; 1 % KCl) **in dependance of Cu(II)-content.**
(2 hours; 300°C in air with 150 mg H2O/l)



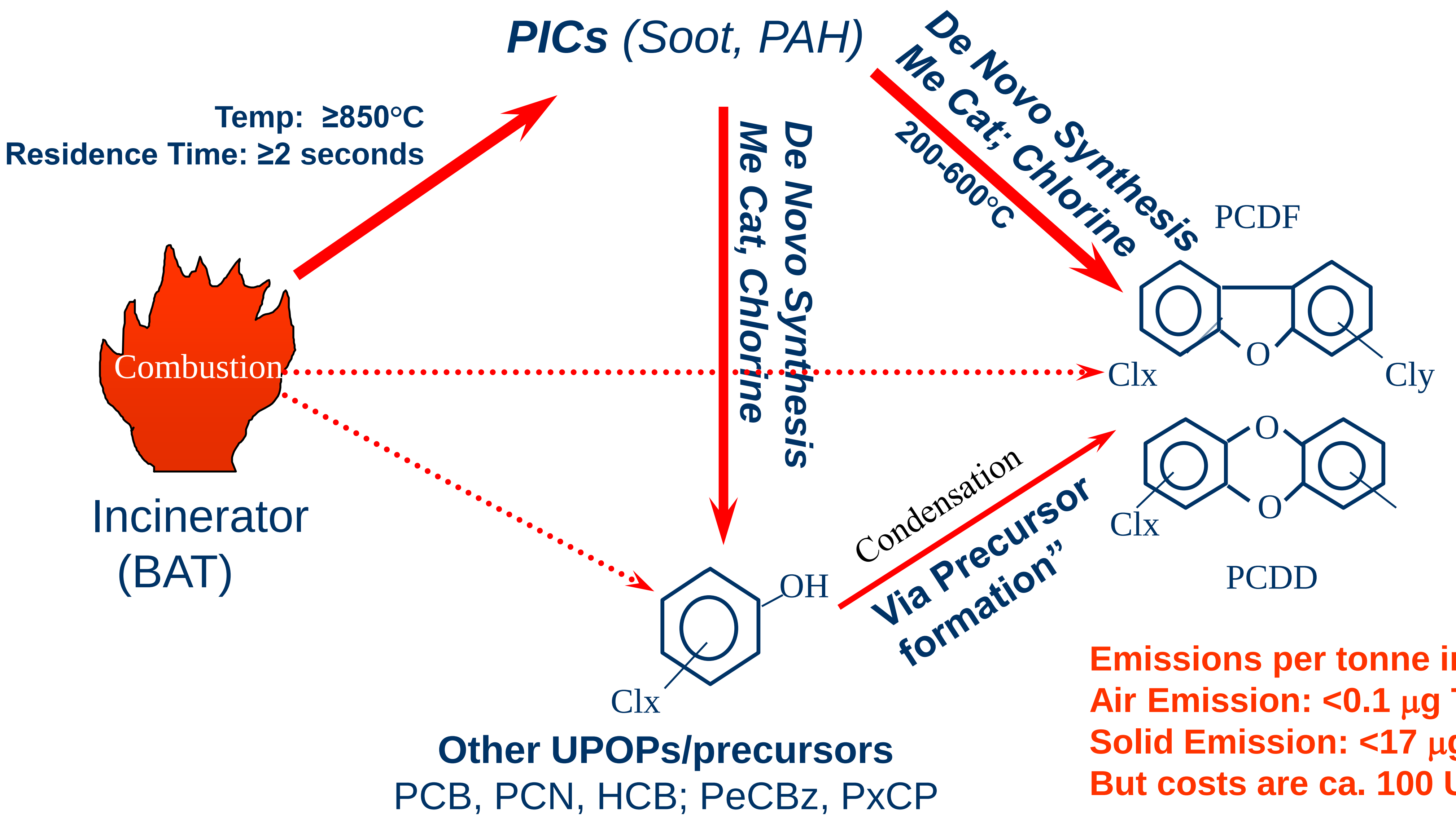
Stieglitz et al. (1989) Chemosphere 18, 1219-1226..

PCDD/PCDF Emission in Metal Production

Metal production (abundant catalyst!)

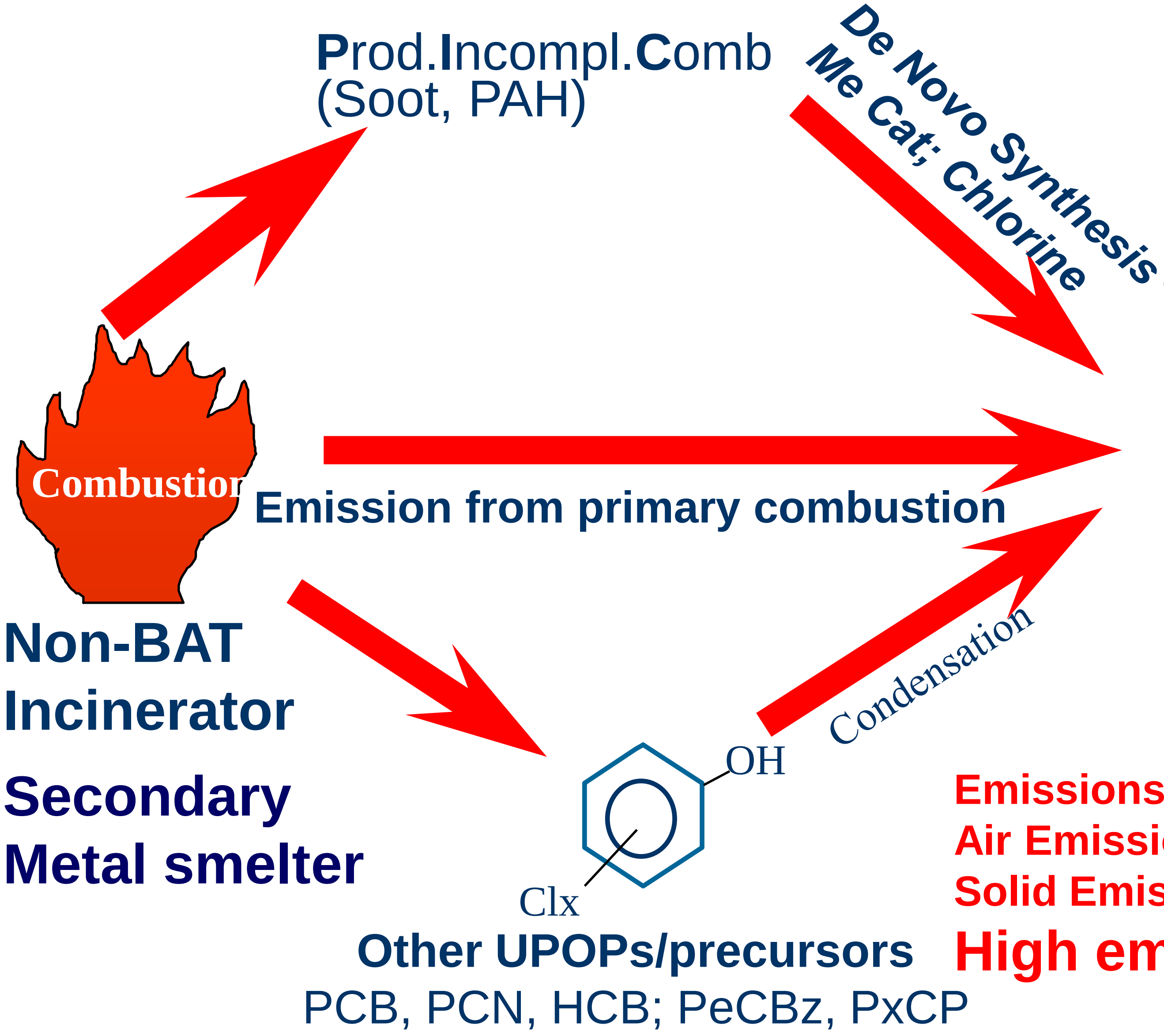
- Iron and Steel (primary) ++
- Sinterbands +++++++
- Iron and Steel (secondary) +++++++
- Copper (secondary;best catalyst) ++++++++
- Aluminum (secondary) ++++++
- Lead (secondary) ++++
- Zinc (secondary) +++++++
- Nickel (secondary) ++++
- Magnesium (primary; chlorine) +++++++++

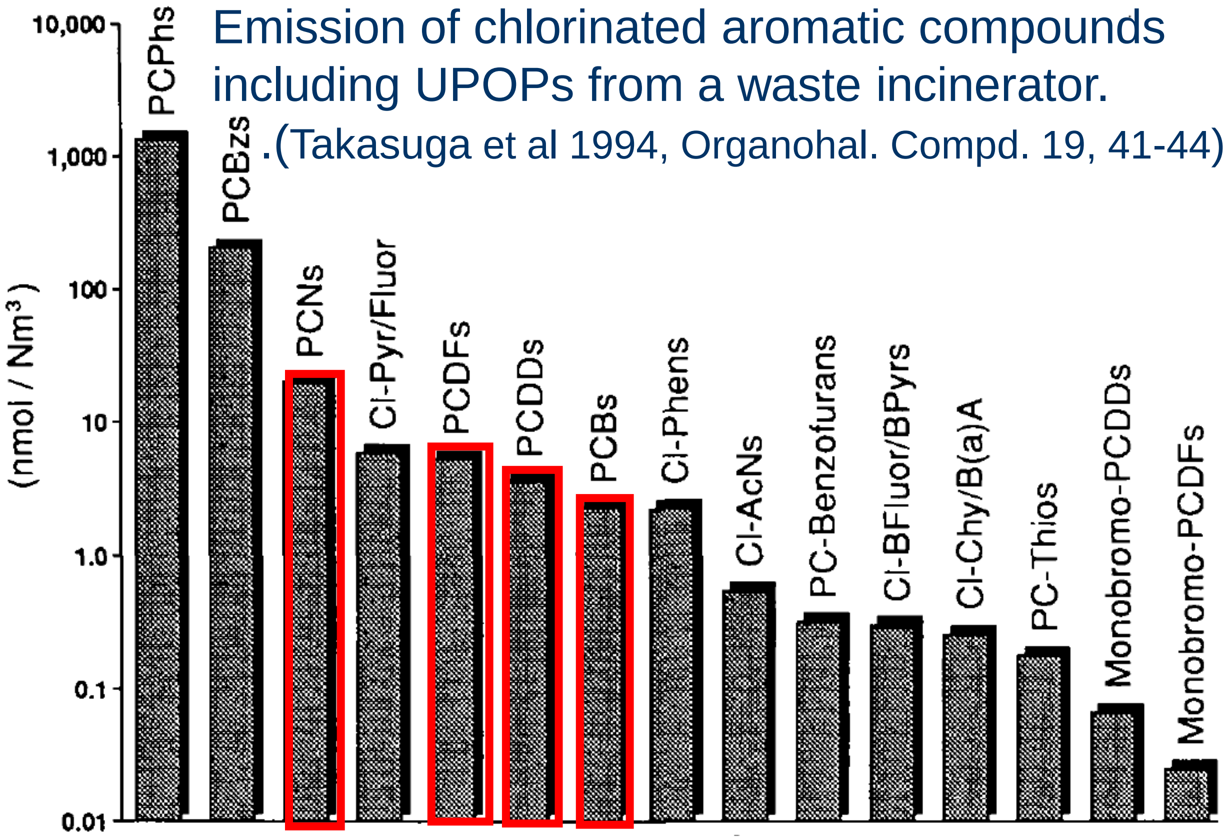
Formation of PCDD/PCDF and other UPOPs/Precursor in BAT Waste Incinerators



Emissions per tonne input material
Air Emission: <0.1 μg TEQ/ton
Solid Emission: <17 μg TEQ/ton
But costs are ca. 100 US$/t waste!

Unintentional POP formation in **non-BAT incinerators** or **other thermal processes with low combustion quality**



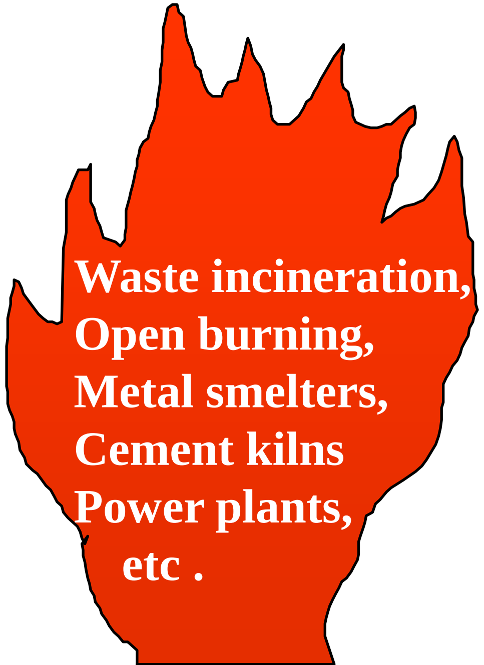


Emissions per tonne input material
Air Emission: 400-40000 µg TEQ/ton
Solid Emission: 400-40000 µg TEQ/ton

High emissions!

Unintentional POPs in **thermal processes**

- In **thermal processes PCDD/PCDF and the other unintentional POPs are formed together** within a certain concentration ratio-range between the different unintentionally POPs.
- **For these sources PCDD/PCDF and UPOPs can be minimized or eliminated by the same measures that are used to address PCDD/PCDF releases. It is thus recommended by the toolkit, for practical reasons, that inventory activities be focused on PCDD/PCDF, as these substances are indicative of the presence of other unintentional POPs for most sources.**
- For a few of the thermal sources also emission factors for PCBs and HCB have been listed in the UNEP Toolkit and can be used.
- Emission factors for PeCBz, HCBD, PCN are not listed in the UNEP Toolkit (yet).
- The **calculation of these other UPOP emission from thermal sources** is rather scientific and **not relevant for prioritization and policy making. Here the TEQ of PCDD/PCDF is sufficient. But PCDD/F is not indicative for certain chemical productions.**



Unintentional POPs in **organochlorine production**

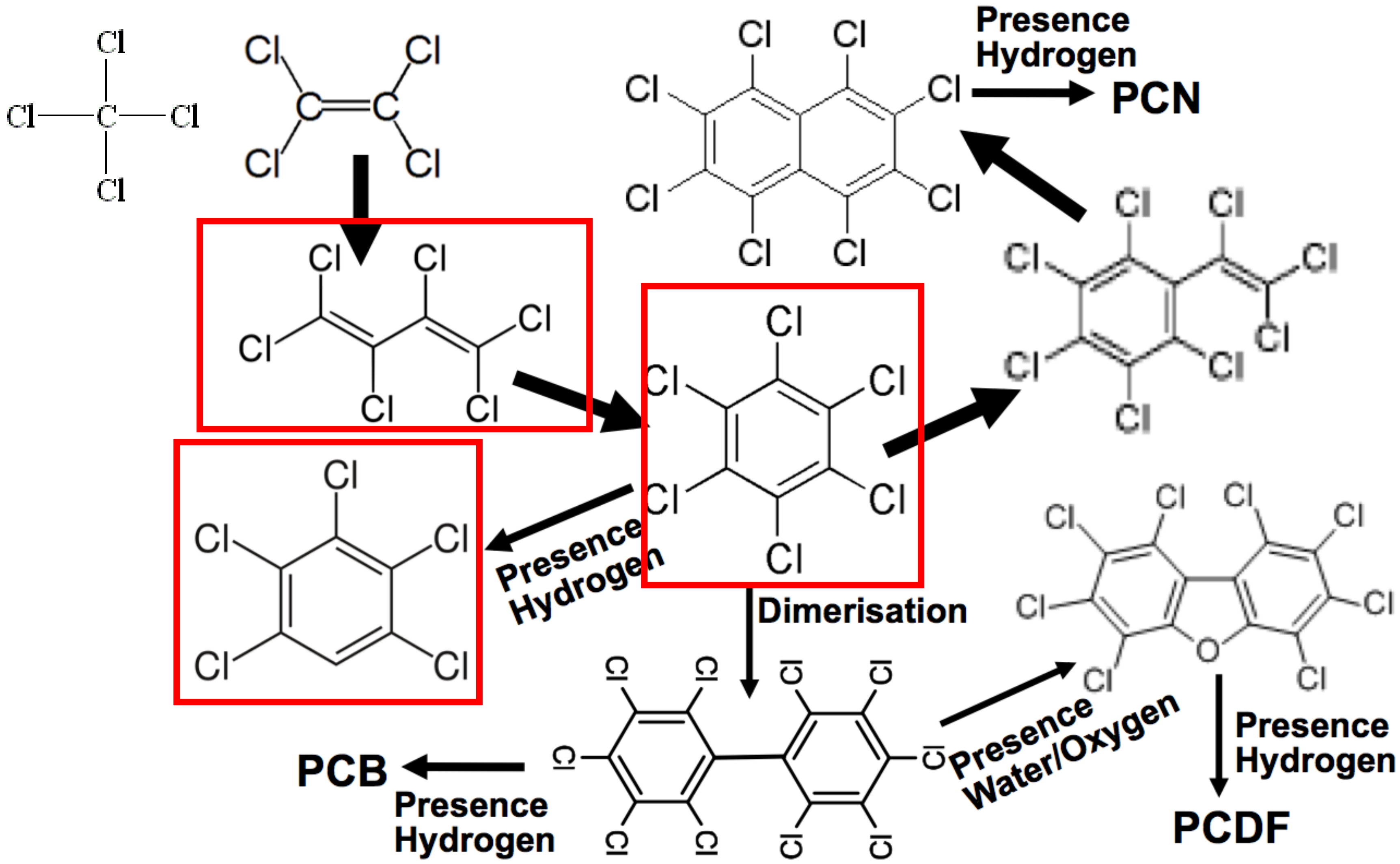
- The unintentional POPs formed **in chemical processes depend on the structure** and the **synthesis routes** of the respective **organochlorine chemical**. (Toolkit 2013; **UNEP 2024**)
- For **some production** processes the formation of **PCDD/PCDF** have **high relevance** (e.g. chlorophenols; chloranil) (Toolkit Source Cat 7).
- Some **processes have high formation** of **other UPOPs** such as **PCBs, PCNs** or chlorobenzenes (e.g. certain Cl-**solvents, pigments**) **and low/no PCDD/PCDF.**
- One example are chlorinated solvent productions (e.g. tetrachloro-methane, trichloroethene tetrachloroethene) with high volumes of HCB, HCBD, PCB, and PCNs up to 10,000 tonnes “HCB waste” for individual organochlorine solvent producers over the decades.

- For **some of these organochlorine productions some emission factors for PCBs and HCB have been listed in the UNEP Toolkit.**
- **Therefore, for some of these organochlorine sources a PCDD/PCDF inventory is not sufficient to address the release and reduction of UPOPs but other unintentional POPs need to be considered.**

- **What organochlorine product/import/use in the country?**

Formation of unintentional POPs in chlorinated solvent production

Simplified mechanism of formation of UPOPs in the production of tetrachloroethylene and tetrachloromethane with major formation of HCBD & HCB, and relevant formation of PCNs & PCB



Screening of POPs in wastes from chlorinated solvent production

- The production of chlorinated solvents results in formation of tonnes of UPOPs/year in China alone!
- The methanol-based **production of chlorinated methanes** resulted in formation of **7350 kg HCBD, 3164 kg HCB, 1119 kg PeCB, 427 kg PCN, and 167 kg PCB in China for 2010.**
- The total TEQ for **PCDD/PCDF was 32.8 g TEQ and for PCNs was 563 g TEQ!** Therefore PCDD/F was only a minor UPOP compared to PCNs.

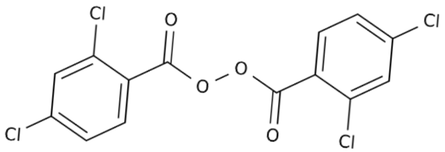
Concentrations (ng/g) of UPOPs in the carbon tetrachloride by-product of the methanol-based production of chlorinated methanes and the amounts of these classes of POPs (kg and PCDD/F in g) estimated to be emitted annually in China.

No. of chlorines	PCDDs		PCDFs		PCBs		PCBz		PCNs	
	Concentration	Annual emission (g)	Concentration	Annual emission (g)	Concentration	Annual emission (kg)	Concentration	Annual emission (kg)	Concentration	Annual emission (kg)
Tri	n.d.	n.a.	n.d.	n.a.	3.77	0.339	5950	536	2.18	0.196
Tetra	0.054	4.86	0.155	14.0	14.6	1.31	6640	598	21.5	1.94
Penta	0.050	4.50	0.223	20.1	48.3	4.35	12500	1120	290	26.1
Hexa	1.11	99.9	0.882	79.4	82.5	7.42	38800	3490	1180	106
Hepta	0.074	6.66	0.628	56.5	114	10.3	n.a.	n.a.	1650	148
Octa	0.025	2.25	42.0	3780	82.5	7.42	n.a.	n.a.	1610	145
Nona	n.a.	n.a.	n.a.	n.a.	348	31.3	n.a.	n.a.	n.a.	n.a.
Deca	n.a.	n.a.	n.a.	n.a.	1170	105	n.a.	n.a.	n.a.	n.a.
Total	1.31	118	43.9	3950	1860	167	63900	5210	4750	427

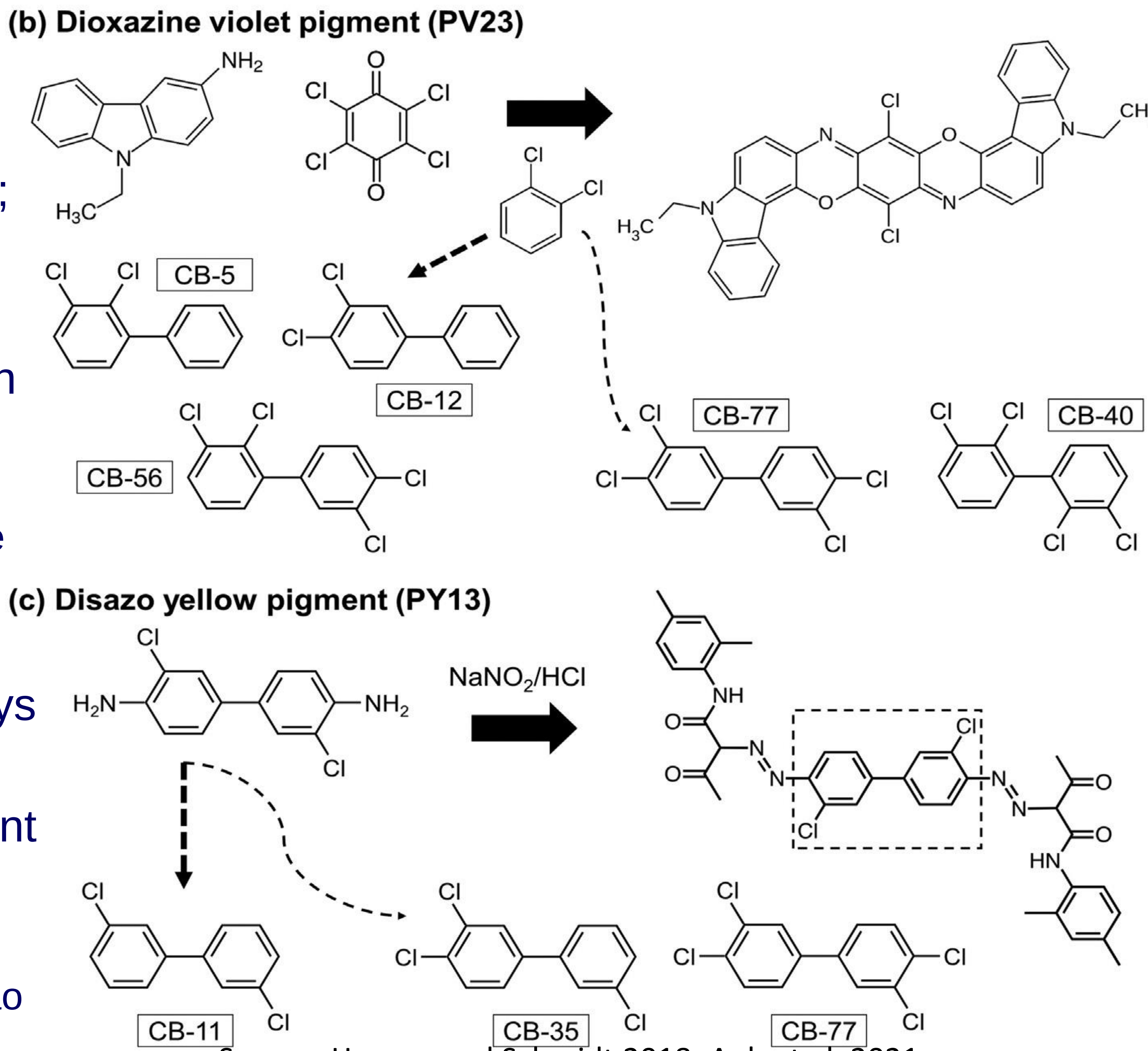
Zhang et al. (2015) Chemosphere 133, 1–5.

Unintentional PCB in chemicals

- Unintentional PCBs are formed in a range of organochlorine productions and thermally.
- This includes several colour pigments (Disazo yellow pigment (PY13); Dioxazine violet pigment PV23 using DCBz as solvent; Phthalocianine green pigment PG7)
- PCBs are also specifically unintentionally formed in production of silicone rubber when 2,4-DCBP is used as cross-linking agent (formation PCB-47, PCB-51 and PCB-68 (Herkert et al. 2018; Hombrecher et al. 2021; Kaifie et al. 2022).

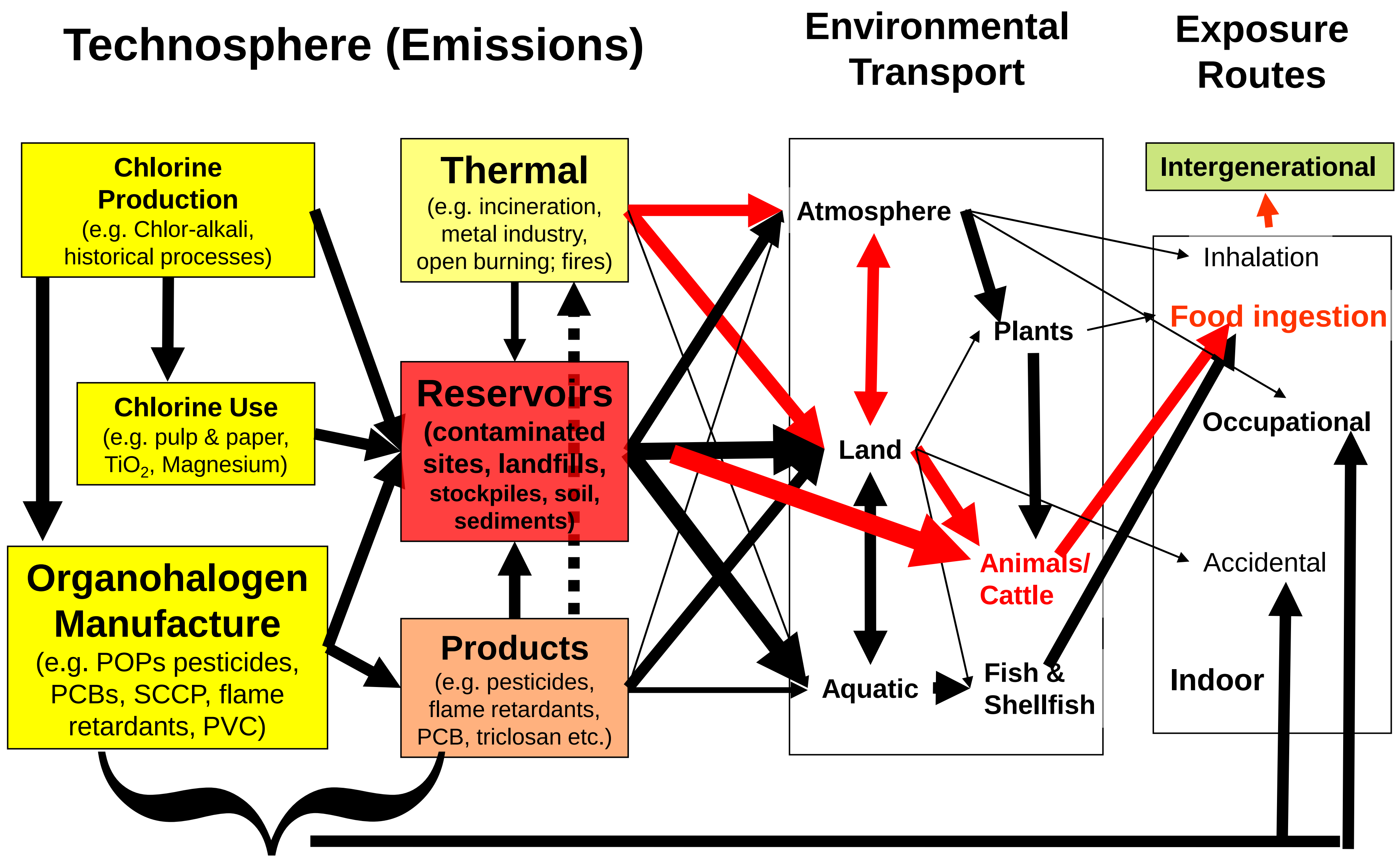


- Until 2010 environmental PCB pattern always dominated by the commercial PCB pattern.
- ~2010 UPCB11 is widespread in environment (Rodenburger et al. (2010) ES&T, 44, 2816-2821).
- Today in China UPCB is the dominant PCB source (Zhao et al. (2019) ES&T 54, 2163-71; Mao et al. (2021) Environmental pollution 271, 116171



Source: Hunger and Schmidt 2018; Anh et al. 2021

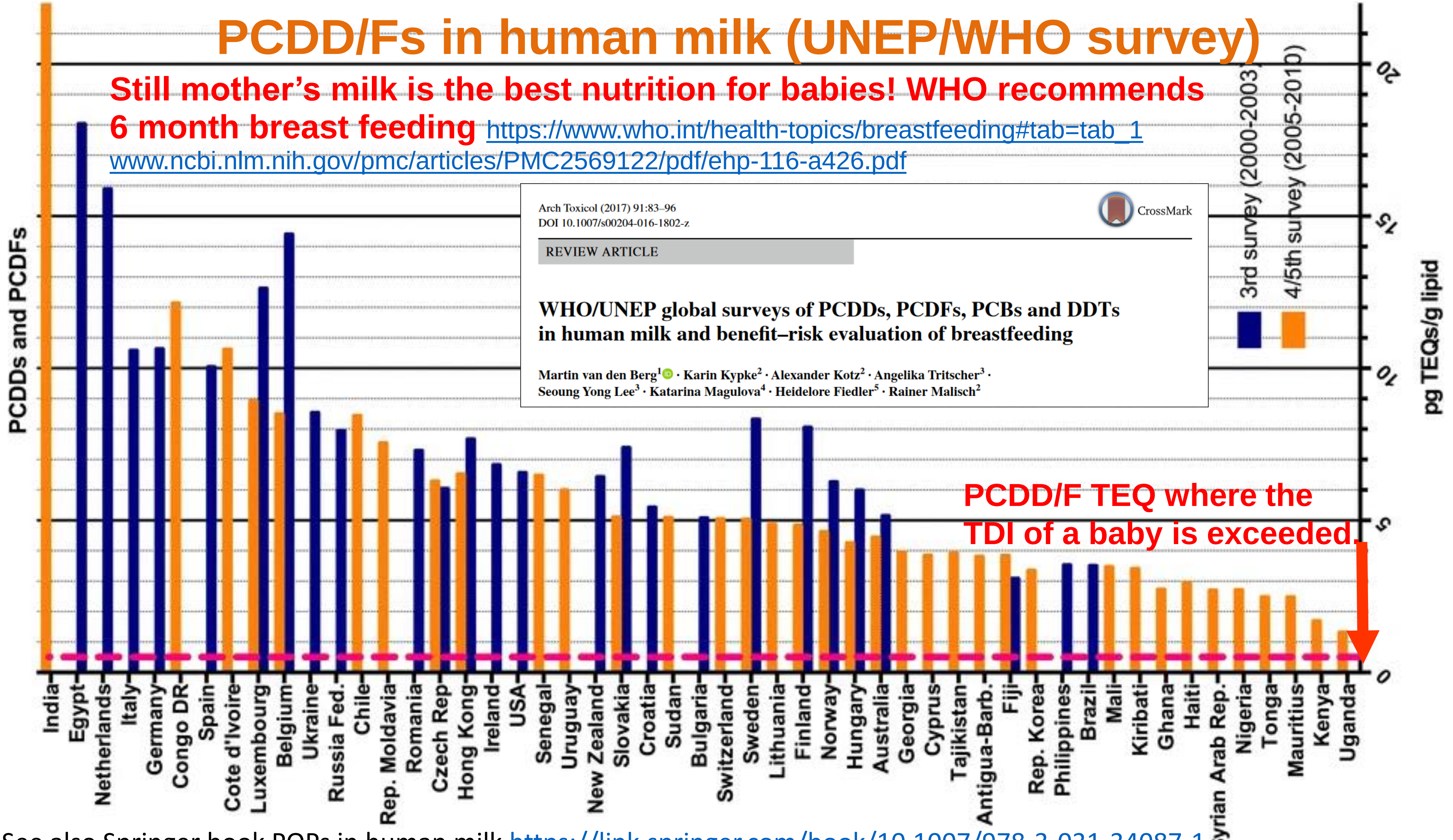
Life-Cycle of PCDD/PCDFs and other UPOPs



Weber et al. (2018) ESEU https://rdcu.be/bax79 Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

PCDD/Fs in human milk (UNEP/WHO survey)

Still mother's milk is the best nutrition for babies! WHO recommends 6 month breast feeding https://www.who.int/health-topics/breastfeeding#tab=tab_1
www.ncbi.nlm.nih.gov/pmc/articles/PMC2569122/pdf/ehp-116-a426.pdf



Arch Toxicol (2017) 91:83–96
DOI 10.1007/s00204-016-1802-z

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REVIEW ARTICLE

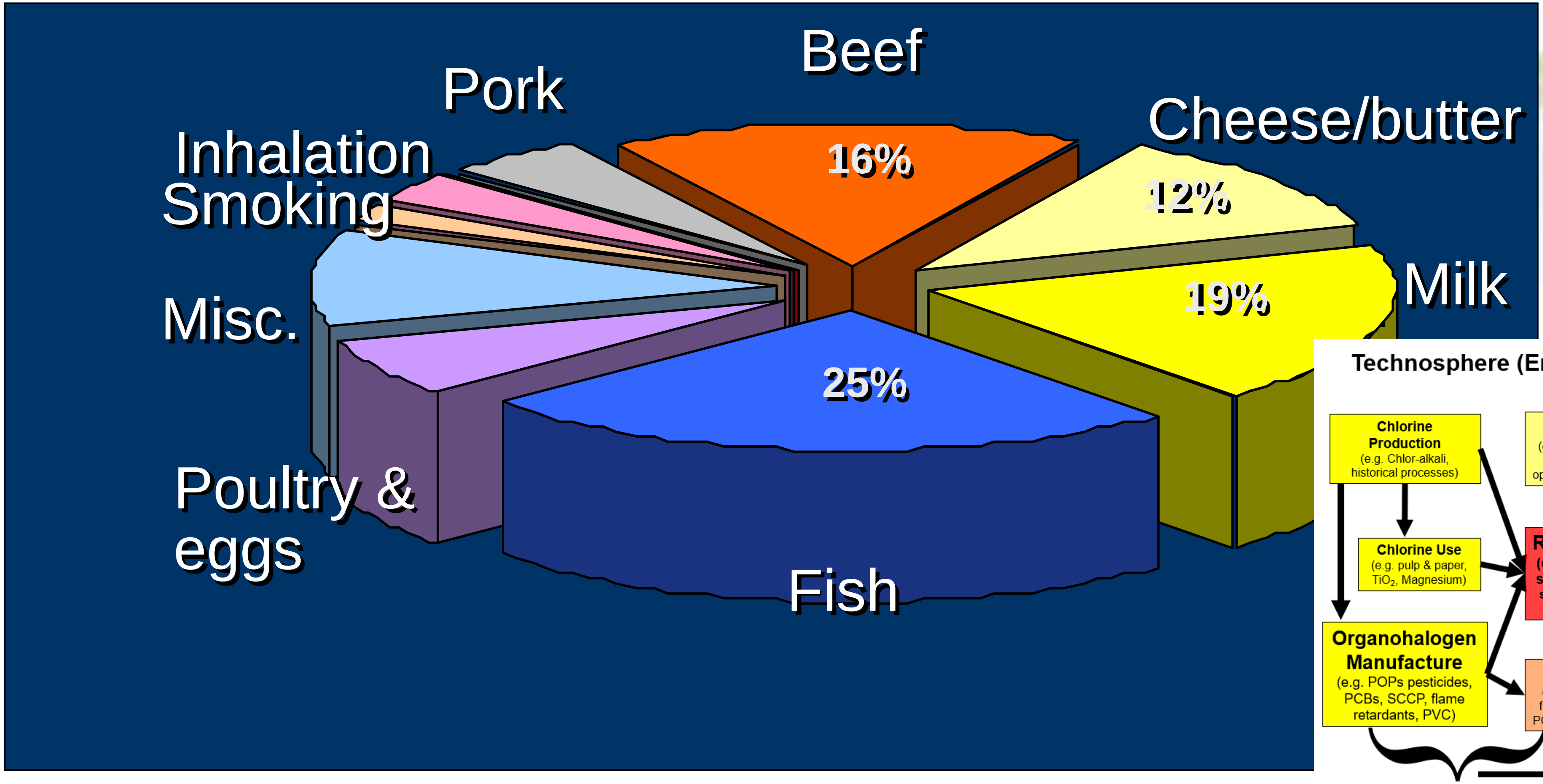
WHO/UNEP global surveys of PCDDs, PCDFs, PCBs and DDTs in human milk and benefit–risk evaluation of breastfeeding

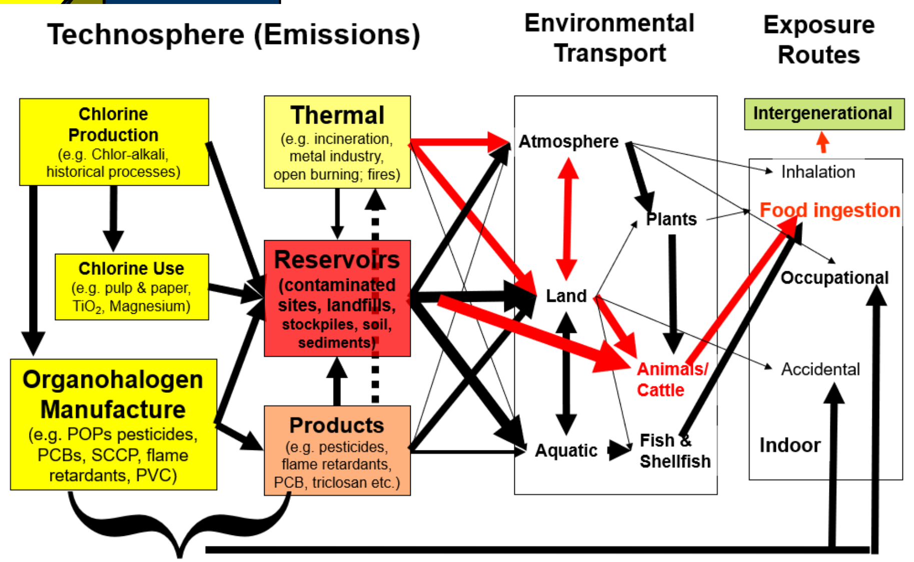
Martin van den Berg[1] · Karin Kypke[2] · Alexander Kotz[2] · Angelika Tritscher[3] · Seoung Yong Lee[3] · Katarina Magulova[4] · Heidelore Fiedler[5] · Rainer Malisch[2]

See also Springer book POPs in human milk https://link.springer.com/book/10.1007/978-3-031-34087-1

Human Dioxin Background Exposure

- **Normally >90% of PCDD/PCDF exposure come from animal based food.**
- Country example: Dioxin exposure sources for US citizens.

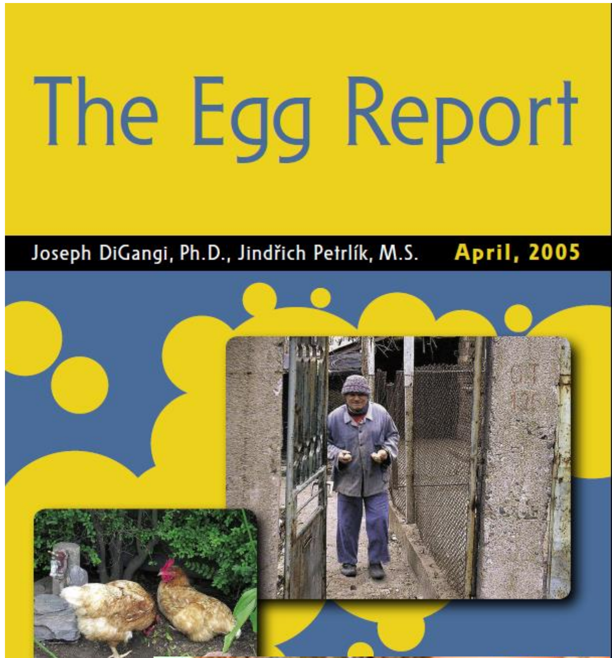


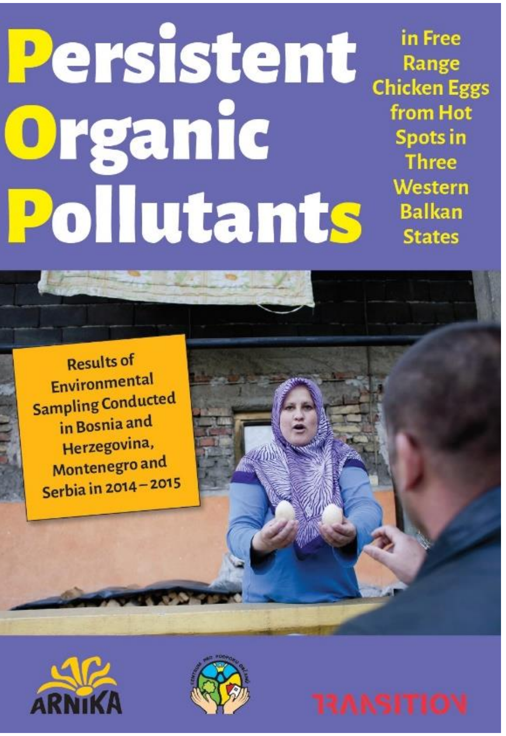


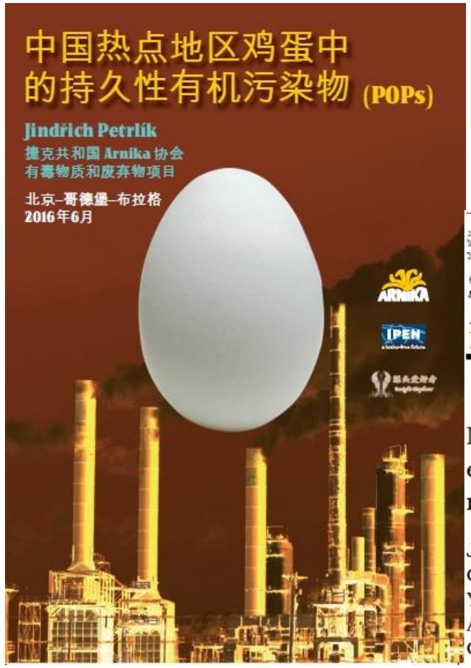
How do Dioxin/(U)POP sources result in contamination of food?

Eggs as exposure pathway of PCDD/F & PCB from contaminated soil

- Free-range eggs are sensitive indicators for PCDD/F and PCB contamination in soils and **eggs are an important exposure pathway from polluted soils to humans.**
- Chickens and eggs are therefore ideal “active samplers” and indicator species for Dioxin & PCB contaminated soils.
- Since the beginning of the Stockholm Convention the International Pollutants (POPs) Elimination Network (IPEN) monitored eggs around priority UPOP sources listed in the Stockholm Convention (e.g. waste incinerators, metal industries, chemical industry, cement plants, e-waste recycling sites, dumpsites and other open burning sites).







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Monitoring dioxins and PCBs in eggs as sensitive indicators for environmental pollution and global contaminated sites and recommendations for reducing and controlling releases and exposure

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Global egg study – Outcome of IPEN & Science for PCDD/Fs & PCBs

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Monitoring dioxins and PCBs in eggs as sensitive indicators for environmental pollution and global contaminated sites and recommendations for reducing and controlling releases and exposure

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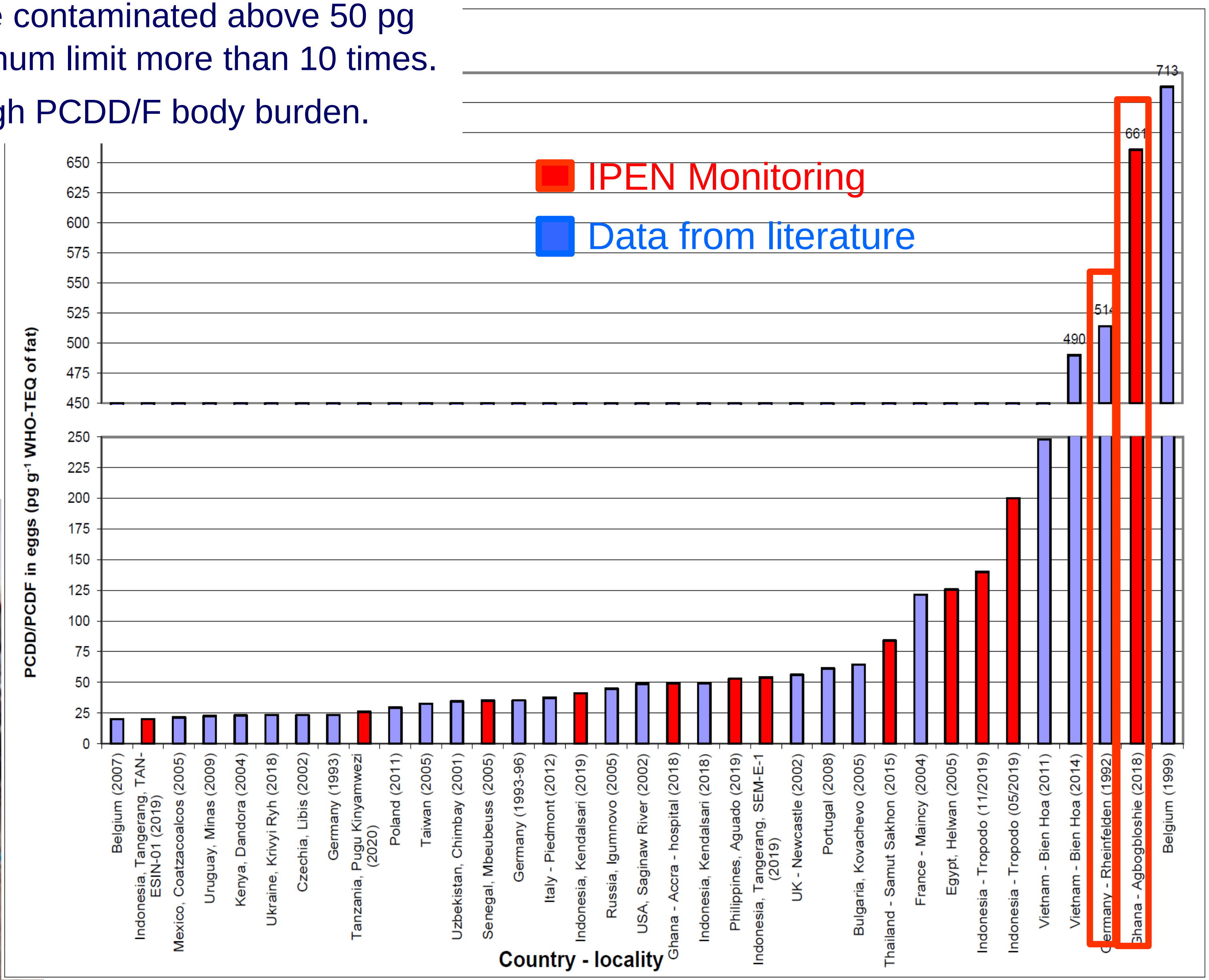
Petrlik et al. & Weber (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

- IPEN monitored 113 chicken flocks at potential PCDD/F- and PCB-contaminated sites and **88% of the pooled egg samples were above the EU maximum limits** for PCDD/Fs (2.5 pg PCDD/F-TEQ/g fat) or the sum of PCDD/Fs and dioxin-like PCBs (5 pg PCDD/F-PCB-TEQ/g fat).
- **Children consuming just one egg exceed the FAO/WHO TDI (based on 70 pg TEQ/kg month) and the EU tolerable weekly intake (TWI). This indicates that close to 90% of areas around these industrial emitters and open burning sources in low-/middle-income countries were unsafe for the consumption of free-range eggs.**

Global Dioxin Egg Review – High contaminated eggs and exposure

- Sixteen out of the 113 IPEN egg samples (14%) were contaminated above 50 pg PCDD/F-PCB TEQ/g fat and exceeded the EU maximum limit more than 10 times.
- People regularly consuming such eggs will have a high PCDD/F body burden.
- The blood level of people living in a German city contaminated by a chloralkali plant consuming eggs had up to 93 pg TEQ/g fat of PCDD/F in blood.
- For the highest contaminated eggs from Ghana containing a total of 1156 pg TEQ/g fat, a child (15 kg) ingests with one egg (7 g fat) more dioxins than the FAO/WHO consider tolerable intake for 230 days and the EU consider a tolerable intake for 5 years.





Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

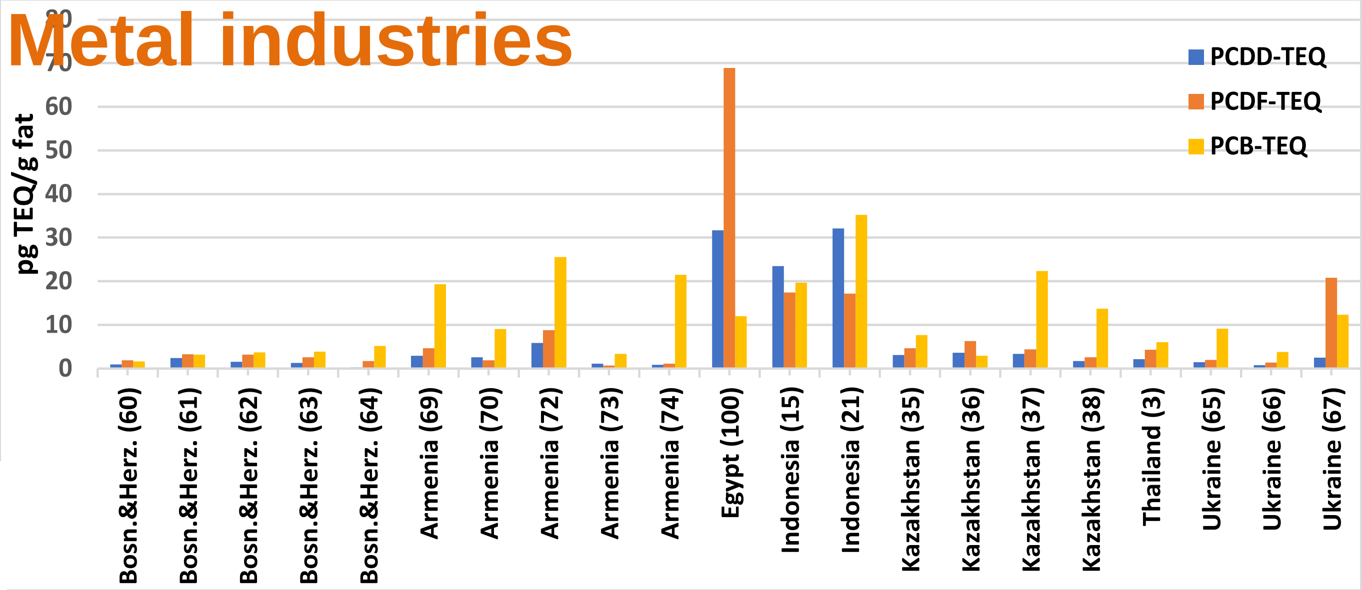
IPEN global egg study – E-waste recycling sites

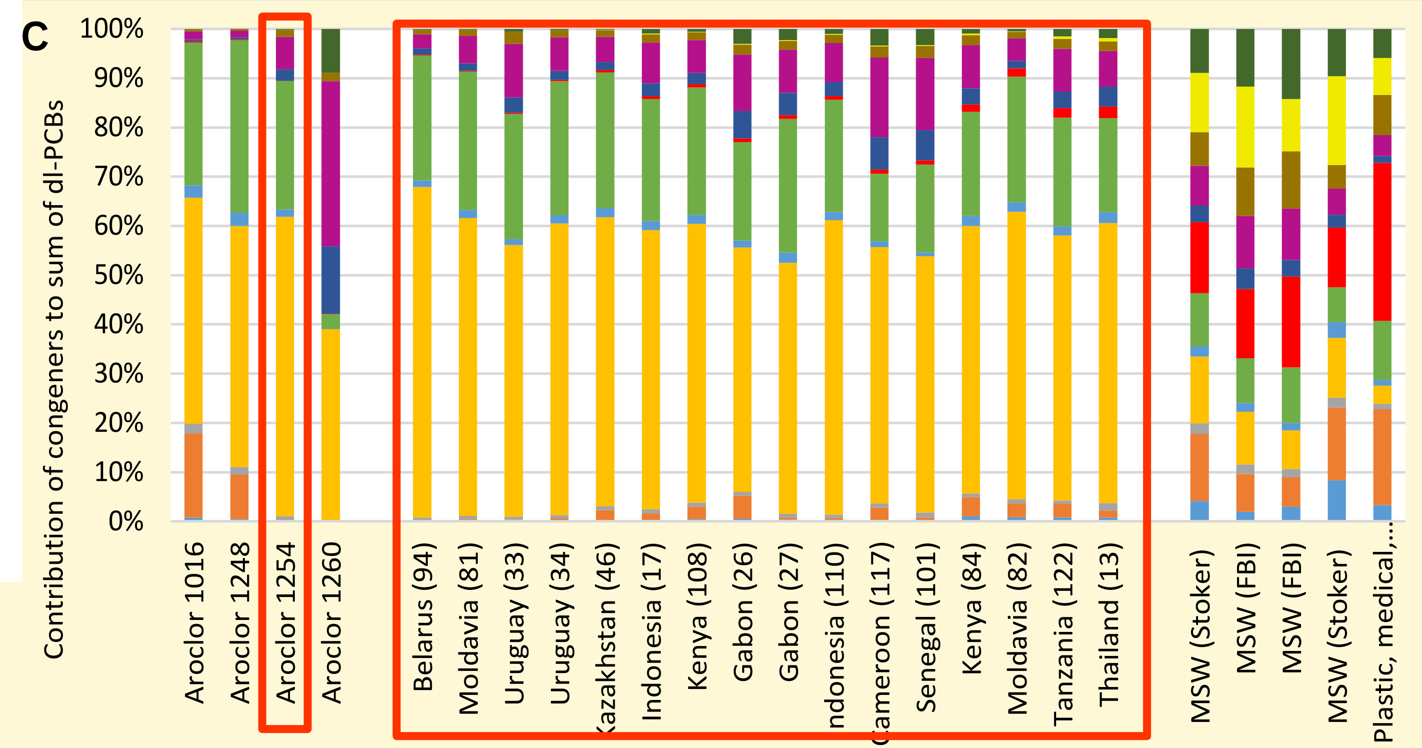
- IPEN monitored 7 pooled eggs from individual chicken flocks at e-waste sites in 5 countries (Ghana, Kenya, Indonesia, Philippines, and Thailand). The PCDD/F-PCB-TEQs were between 20.4 to 856 pg TEQ/g and therefore **all eggs exceeded the EU regulatory limit**. The **mean TEQ was 308.4 pg TEQ/kg fat** were by far the highest mean/median of all source categories.
- Three of the eggs from African sites had TEQ levels above 500 pg TEQ/g fat (more than 100 times above regulatory limits) with 856 pg TEQ/g fat in eggs from the e-waste site in Agbogbloshie (Ghana) where e-waste, including cables, is frequently burnt. Eggs at the Ngara e-waste dismantling market in Kenya were contaminated with **567.4 and 519.6 pg TEQ/g fat with 97.8 and 96.6% TEQ contribution from dl-PCB which are the highest dl-PCB levels in free-range eggs ever measured**.

Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

IPEN global egg study – Metal industries

- Recovery of metals is crucial for circular economy but secondary metal industry can have high PCDD/F emissions and contaminated ashes.
- All 21 egg samples around metal industries were above limits with mean conc. of 26.0 pg TEQ/g fat.
- Commercial PCBs (mainly Arochlor 1254) were the main TEQ contributor for most metal plants with minor unintentional PCBs from *de novo*.
- This demonstrate that over the last 40 years PCBs have entered metal smelters on metal scrap with associated pollution of surrounding soils and chicken/eggs with exposure to humans.
- This highlight that the management of metals from PCB containing equipment need a better control and better cleaning of metal parts before they enter e.g. copper or aluminum smelters.

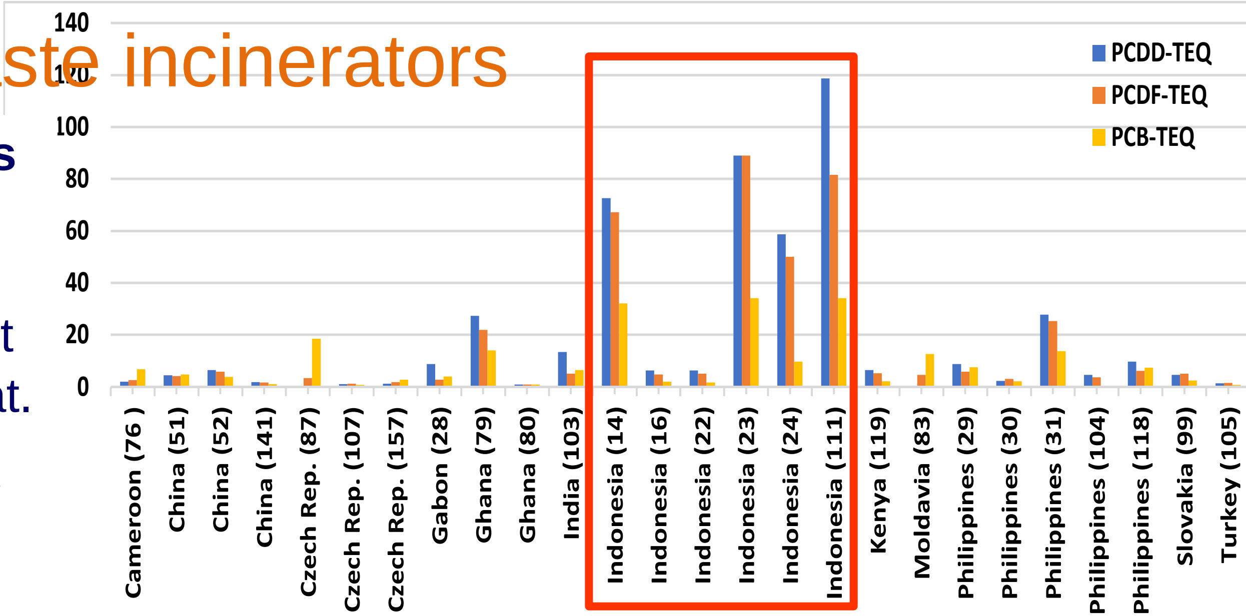




Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

IPEN global egg study – non-BAT waste incinerators

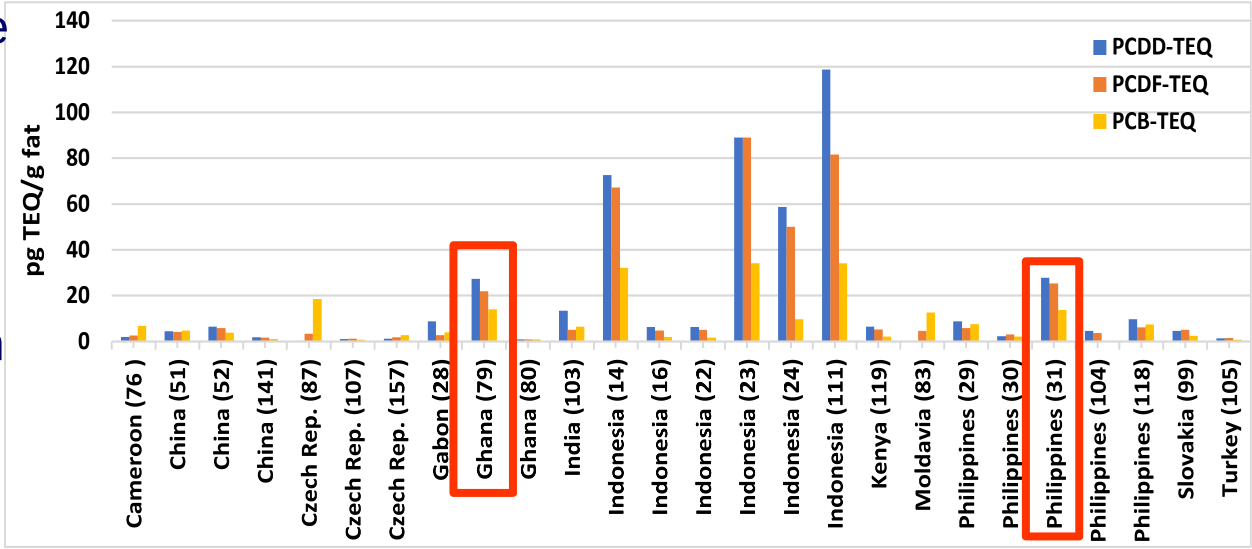
- **24 of 26 egg samples (92.3%) around waste incinerators** in 12 countries (Cameroon, China (3), Czech Republic (3), Gabon, Ghana (3), India, Indonesia (6), Kenya, Moldova, Philippines (5), Slovakia, and Turkey) exceeded the EU limit for PCDD/Fs and dl-PCBs with a mean of **43.1 pg** TEQ/g fat.
- Eggs in Tropodo/Indonesia where plastic wastes were used as fuel for tofu boilers had 234.4 and 172.0 pg TEQ/g fat. And two chicken flocks in Java, around lime kilns burning plastic waste as a fuel had 212.3 and 118.5 pg TEQ/g fat.
- The free-range chickens at both locations had access to ashes stored openly next to the kilns or used for paving sidewalks. The ashes contained PCDD/Fs at levels of 120 – 1300 ng TEQ/kg. This is up to 650 times above 2 ng TEQ/kg in soils considered acceptable for free-range chickens.
- This highlight that co-incineration of plastic waste in non-BAT facilities without air pollution control and ash management, releases high levels of PCDD/Fs in off gas and additionally via unmanaged ashes with associated environmental contamination and human exposure risk via chicken/eggs.



Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.(

IPEN global egg study – non-BAT waste incinerators

- Two other highly PCDD/F contaminated pooled egg sample **(66.8 TEQ/g fat)** were collected near a **hospital waste incinerator in Aguado, Philippines** which has been operated for more than 20 years with medical waste known to contain a high share of PVC.
- Similarly, high levels (63.1 pg TEQ/g fat) were also found in pooled eggs of a flock near a batch type hospital waste incinerator in Ghana. **The mixed bottom and fly ashes with a level of 551 ng TEQ/kg** PCDD/Fs were dumped close to the incinerator where chickens also had access (Petrlik et al. 2019a).

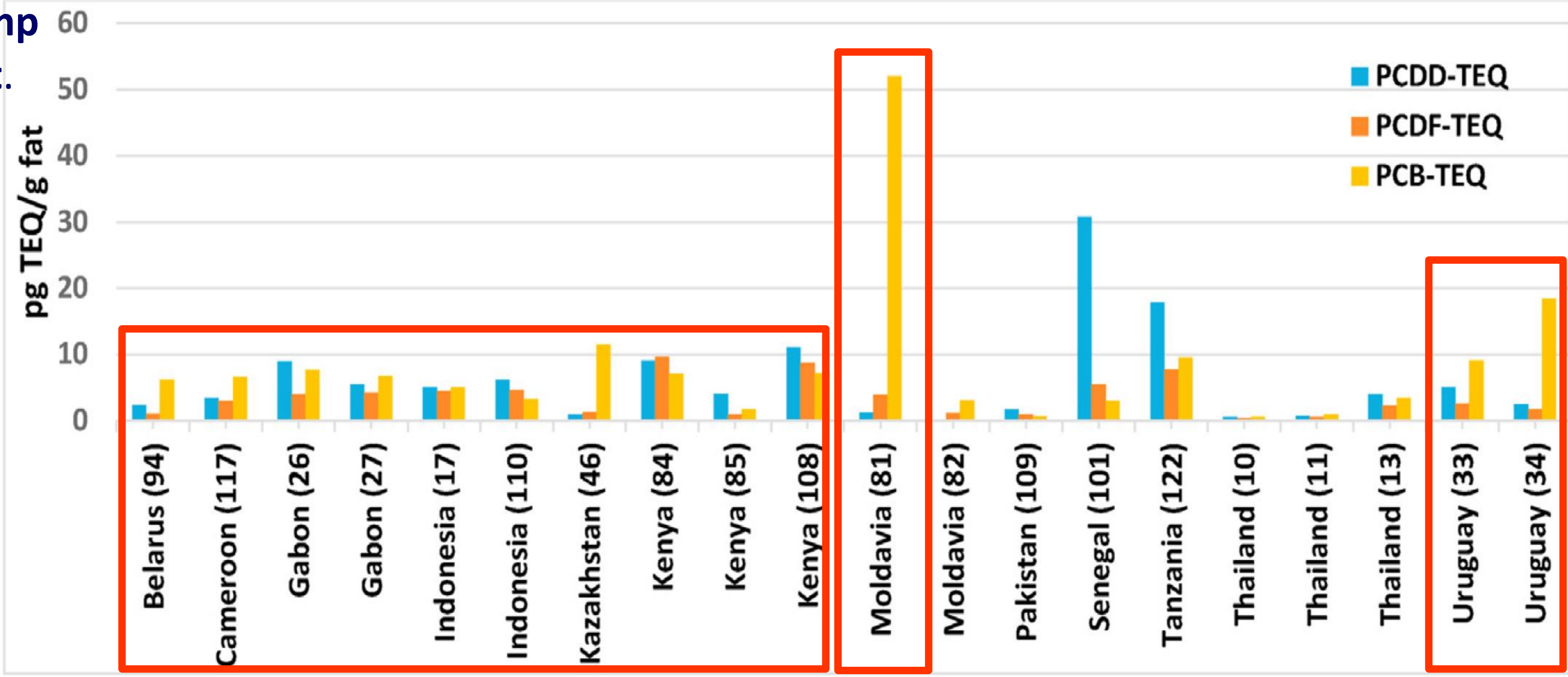


- Ash with 500 ng TEQ/kg is 30 times below the current provisional low POP limit of the Basel Convention of 15,000 ng TEQ/kg. However eggs from chickens are 30 times above regulatory limit.
- This indicates that for waste used for soil amendment like ashes from bio-mass incineration, the limit should rather be around 8 to 30 ng TEQ/kg as required by Czech regulation and the German fertilizer regulation.

Petrlik et al. (2022) Emerging Contaminants https://doi.org/10.1016/j.emcon.2022.05.001

IPEN Global Egg Study – landfills & dump sites (n=20)

- **16 of 20 pooled eggs sampled around dump sites landfills and were above the EU limit.**
- PCDD/PCDF were often above regulatory limit showing relevance of open burning.
- Eggs in Senegal & Kenya had PCP pattern
- In 12 of the 20 sites PCB-TEQ alone exceeded the EU TEQ-limit for eggs.
- The highest contaminated eggs were sampled around a landfill in Moldova with 50 pg TEQ/g fat from dl-PCB.
- Also the eggs sampled around a landfill in Kazakhstan had more than 10 pg TEQ dl-PCB/g fat contamination.



- Also in landfills in Belarus, Cameroon, Gabon and Uruguay the TEQ contribution of PCBs was higher than the contribution of PCDD/PCDF.
- The high impact of PCB contamination in eggs around dump sites highlights that dumping of PCB results in release and contamination of the surrounding with the very persistent and semivolatile PCBs.
- Also dioxin pollution from PCP seems relevant in Africa – also around dump sotes

Petrlik et al. (2022) Emerg. Contam. 8, 254-279 https://doi.org/10.1016/j.emcon.2022.05.001

Part B
Inventory development of PCDD/F and other unintentional POPs releases with the UNEP Toolkit

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Article 5 Measures to reduce or eliminate releases of UPOP

STOCKHOLM CONVENTION

(a) **Develop an action plan …..** and subsequently implement it as part of its implementation plan specified in Article 7, **designed to identify, characterize and address the release of the chemicals listed in Annex C** and to facilitate implementation of subparagraphs (b) to (e). **The action plan shall include the following elements:**

- (i) **An evaluation of current and projected releases, including the development and maintenance of source inventories and release estimates, taking into consideration the source categories identified in Annex C**;
- (ii) An evaluation of the efficacy of the laws and policies of the Party relating to the management of such releases;
- (iii) Strategies to meet the obligations of this paragraph, taking into account the evaluations in (i) and (ii);
- (iv) Steps to promote education and training with regard to, and awareness of, those strategies;
- (vi) A schedule for implementation of the action plan, including for the strategies and measures identified therein;.

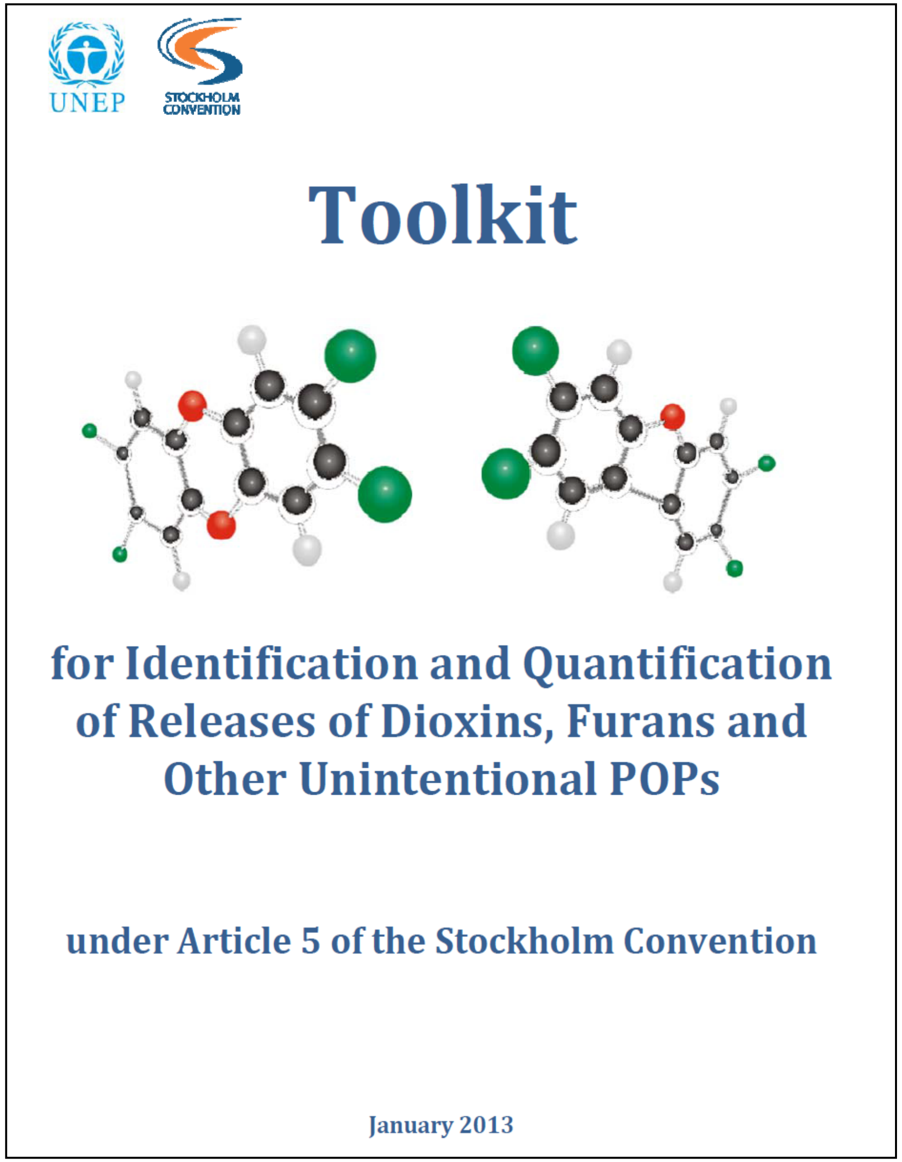
Stockholm Convention - Article 5 (a) (i) - Inventory and action plan development

- Inventory of Dioxin/UPOP sources are developed to identify, quantify and prioritize source of releases. SC: “(i) *An evaluation of current and projected releases, including the development and maintenance of source inventories and release estimates, taking into consideration the source categories identified in Annex C*”
- The inventory is the basis for the development of strategies with measures, timelines and goals to minimize these releases (Action plan in the NIP).

TOOLKIT FOR IDENTIFICATION AND QUANTIFICATION OF RELEASES OF DIOXINS, FURANS, AND OTHER UPOPs

- **Emission Factor Methodology** for Identification and Quantification of Releases of PCDDs, PCDFs and other unintentionally produced POPs

- **Aim to assist Parties in establishing release inventories that are consistent in format and content**, ensuring that it is possible to compare results, **identify priorities, mark progress and follow changes over time at the country level**, as well as regional/global levels (http://toolkit.pops.int/).



Updated Toolkit for Identification and Quantification of Releases of Dioxins, Furans, and Other Unintentional POPs

Part I General Guidance

- Data Quality and QA/QC of inventory results
- Guidance on updating and revising source inventories
- Reporting of inventory results

Part II Default Emission Factors

- New/revised PCDD/F emission factors
- Guidance on estimating activity rates, classification of sources and assigning appropriate emission factors

Part III Annexes and Example Inventories

- Complementary information on the derivation of EF
- PCB & HCB emission factors for sources with available data
- Example inventories for each source group

http://toolkit.pops.int/ Go to the toolkit 1

5-Step Approach for Establishment of a PCDD/PCDF Inventory considering the UNEP Toolkit

1. Use Screening Matrix as a guide to identify Source Groups present in the country;
2. Use the Source Category list to identify specific sources and activities in the country's respective Source Groups;
3. Obtain information on individual sources (activity rates; technology level) to classify these and select the emission factors;
4. Quantify identified sources by applying default/measured emission factors;
5. Apply nation-wide to establish full inventory.

Step 1: Main Source Groups

The **first step** is assessing & identifying the **Main Source Groups present in a country**.

No.*	Main Source Groupes	Air	Water	Land	Prod.	Residue
1	Waste Incineration	X				X
2	Ferrous/Non-Ferrous Metal Prod	X				X
3	Power Generation and Heating	X		X		X
4	Production of Mineral Products	X				
5	Transport	X				
6	Uncontrolled Combustion Proc.	X	X	X		X
7	Prod./Use Chem.&Cons. Goods	X	X		X	X
8	Miscellaneous	X	X	X	X	
9	Disposal	X	X	X		X
10	Identification of Potential Hot-Spots			X		

The sources are also major releases of heavy metals (Hg, Pb), PAH and GHG emission

*Sequence does not imply any ranking of Source Groups (importance of sources will vary from country to country);

Toolkit Source Groups and Associated Source Categories

Source Group		1. Waste Incineration	2. Ferrous and Non-Ferrous Metal Production	3. Heat and Power Generation	4. Production of Mineral Products	5. Transport
Source Categories	a	Municipal solid waste incineration	Iron ore sintering	Fossil fuel power plants	Cement production	4-Stroke engines
	b	Hazardous waste incineration	Coke production	Biomass power plants	Lime production	2-Stroke engines
	c	Medical waste incineration	Iron/steel production; foundries	Landfill, biogas combustion	Brick production	Diesel engines
	d	Light-fraction shredder waste incineration	Copper production	Household heating and cooking (biomass)	Glass production	Heavy oil fired engines
	e	Sewage sludge incineration	Aluminum production	Domestic heating (fossil fuels)	Ceramics production	
	f	Waste wood and waste biomass incineration	Lead production		Asphalt mixing	
	g	Destruction of animal carcasses	Zinc production		Oil Shale Processing	
	h		Brass and bronze production			
	i		Magnesium production			
	j		Other non-ferrous metal production			
	k		Shredders			
	l		Thermal wire reclamation			

Source Group		6. Open Burning Processes	7. Production and Use of Chemicals and Consumer Goods	8. Miscellaneous	9. Disposal and Landfill	10. Contaminated Sites and Hotspots
Source Categories	a	Biomass burning	Pulp and paper production	Drying of biomass	Landfills, Waste Dumps and Landfill Mining	Sites used for the production of chlorine
	b	Waste burning and accidental fires	Chlorinated inorganic chemicals	Crematoria	Sewage and sewage treatment	Production sites of chlorinated organics and related deposits
	c		Chlorinated aliphatic chemicals	Smoke houses	Open water dumping	Application sites of PCDD/PCDF containing pesticides and chemicals
	d		Chlorinated aromatic chemicals	Dry cleaning	Composting	Timber manufacture and treatment sites
	e		Other chlorinated and non-chlorinated chemicals	Tobacco smoking	Waste oil treatment (non-thermal)	Textile and leather factories
	f		Petroleum refining			Use of PCB
	g		Textile production			Use of chlorine for production of metals and inorganic chemicals
	h		Leather refining			Waste incinerators
						Metal industries
						Fire Accidents
						Dredging of sediments; contaminated flood plains
						Other dumps/landfills of wastes from source groups 1-9

Go to toolkit 2

Step 2: Identify for each Source Group the Source Categories/activities in the country

Step 2: Identification of Source Categories: Source Group 1 – Waste Incineration

Source categories of source group 1	Potential Release Route: Air	Water	Land	Product	Residue
1 Waste Incineration	X				X
a Municipal solid waste incineration	X	(x)			x
b Hazardous waste incineration	X	(x)			x
c Medical waste incineration	X	(x)			x
d Light-fraction shredder incineration	X				x
e Sewage sludge incineration	X	(x)			x
f Waste wood/biomass incineration	X				x
g Destruction of animal carcasses	X				x

For each of the source groups present in the country an estimate of the **activity rates of** the individual **source categories** (sub-categories of source groups) need to be made.

Step 2: Identification of Source Categories: Category 2 – Ferrous/Non-Ferrous Metal Production

		Potential Release Route				
No.	Subcategories of Main Category	Air	Water	Land	Product	Residue
2	Ferrous and Non-Ferrous Metal Production	X				X
a	**Iron ore sintering**	**X**				**x**
b	**Coke production**	**X**	**x**	**x**	**x**	**x**
c	**Iron/steel production and foundries**	**X**				**x**
d	**Copper production**	**X**				**x**
e	**Aluminum production**	**X**				**x**
f	**Lead production**	**X**				**x**
g	**Zinc production**	**X**				**x**
h	**Brass and bronze production**	**X**				**x**
i	**Magnesium production**	**x**	**x**			**x**
j	**Other non-ferrous metal production**	**x**	**x**			**x**
k	**Shredders**	**X**				**x**
l	**Thermal wire reclamation**	**X**	**(x)**	**x**		**x**

Step 3 Get information & Step 4 Quantify sources UNEP Toolkit Calculation Methodology

Calculation of Source Strength (Dioxin release/year):

The basic principle is to gather "Activity Rates" which describe quantities of a process (e.g., tonnes incinerated; tonnes steel produced per year), and **select "Emission Factors" (EF)** which describe release of UPOPs/**pollutant** to each medium per unit of activity (e.g., µg TEQ/tonne). **Multiplying EF and Activity Rate yields annual releases of a Source (Source Strength).**

Annual PCDD/PCDF emission estimate:

Source Strength (gram TEQ Dioxin emission per year)

= Emission Factor x Activity Rate (1)

(Emission factor = amount PCDD/PCDF/UPOP per tonne of feed processed or product produced).

For a country or region: Total annual PCDD/PCDF release =
Σannual releases from all source groups & over all release vectors

Toolkit Calculation Methodology

Activity rates (Amount/Flux from a activity per year: tonnes produced; amount waste burned; or m^3 emitted):

- "non-dioxin-like"
- Country-specific
- Economic data, statistics, plant/facility data
- The data the task team will gather.

Emission factors (gram TEQ Dioxin/tonne product or; $/m^3$):

- Identical for similar technology
- Default emission factors (provided in Toolkit). But the team needs to gather information on individual plants like individual incinerators to decide what category of the Toolkit to select.
- Own measured data (quality requirement !)

Step 3: Selection of Emission Factors

For each source category, a range of default emission factors is given reflecting different levels of technology or other parameters controlling Dioxin/UPOP releases.

Go to Toolkit

Category 1c Hospital Waste Incineration

Emission Factors - µg TEQ/t waste

	Air	Residues
Low Technology combustion; No APC	40,000	200*
Controlled combustion, min. APCD	3,000	20*
Controlled combustion, good APCD	525	920**
High Tech. combustion, continuos, controlled combustion, soph. APCD	1	150**

***Refers only to bottom ash left in combustion chamber**

**** Refers to combined bottom ash and fly ash**

Questionnaires Annex 3

Step 4: Calculation of Releases from Source Categories

Source Category	EF Air (µg/t)	Flux (t/a)	g TEQ/a
1a) Municipal Waste Incineration			22
No control	3,500	5,000	17.5
Low technology	350	10,000	3.4
Good comb, APC	30	20,000	0.6
1c) Hospital Waste Incineration			433
Batch, no APC	40,000	10,000	400
Control. batch, APC	3,000	10,000	30
Controlled, APC	525	5,000	2.6
Total release from Waste Incineration to Air			**455**

Go to excel table for calculation

Updating and Revising Inventories and examples

Baseline Release Estimates

- The baseline release estimate is the first inventory of sources and releases of Annex C POPs elaborated by a Party, usually as part of the first National Implementation Plan developed under Article 7.

- This serves as a baseline against which subsequent updated release estimates are assessed in order to establish trends in releases over time and evaluate efficacy/effectiveness of the strategies adopted. Article 5 SC: **"…*achieve a realistic and meaningful level of release reduction or source elimination*"**

- Baseline inventory need an update with new Toolkit emission factors. Also sometimes in the first inventory some sources might have been missing or have been under/overestimated.

Updating Dioxin/UPOP Inventory & Establishing Trends in Release

FACTORS INFLUENCING CHANGES IN RELEASES OVER TIME, *e.g.*:
- Economic/demographic growth
- Changes in technology e.g. phasing in BAT&BEP
- Building, reconstruction, or close down of production facilities
- Substitution of fuels and/or raw material
- Introduction or reconstruction of abatement techniques

Updating of the inventory (for a particular reference year)

1. Examine initial/ previous inventory

Identify the approach:
- Classification of sources and EF used
- Information sources on activity rates
- Assumptions and expert judgment applied to fill the gaps

2. Review changes in data as compared with initial/ previous inventory
- Check for factors influencing changes in releases over time
- Check for revised/new Toolkit EF
- Reclassify sources according to the present situation
- Establish activity rates for the reference year

3. Calculate releases
- If sources are reclassified and/or EF have been revised: assign new EF accordingly
- If source classification unchanged: use the same EF
- Multiply EF with new activity rates

NEED TO REVISE

FACTORS TRIGGERING THE NEED TO REVISE INITIAL/PREVIOUS INVENTORIES, *e.g.*:
- Toolkit EF have been changed or new EF added
- Approach has been changed (e.g. assumptions/expert judgment)
- Activities/sources:
  - were not identified in the baseline
  - were incorrectly classified

NEED TO REVISE

Revision of the initial/previous inventory

1. Correct and/or adjust initial/previous inventory
- Include missing information/ fill gaps
- Use the revised set of EF for computing releases / apply the same assumptions/expert judgment as in the updated inventory

CONSISTENT TIME TRENDS

Source: Stockholm Convention Secretariat Animate version/film; http://toolkit.pops.int/Publish/Popups/Figure1UpdateRevisionInventories/Figure1.html

Update baseline inventory: Revised Emission Factor

Baseline inventory
[2003 data, Toolkit 2005]

Source group: Open burning
Source category: Waste burning
Source class: Uncontrolled domestic waste burning

Activity rate [2003]: **60'000 t/yr**
EFAir [Toolkit 2005]: 300 µg TEQ/t

Release to air from open burning of waste: **18 g TEQ/yr**

Updated inventory
[2013 data, Toolkit 2013]

Source group: Open burning
Source category: Waste burning
Source class: Uncontrolled domestic waste burning

Activity rate [2013]: **20'000 t/yr**
EFAir [Toolkit 2013]: 40 µg TEQ/t

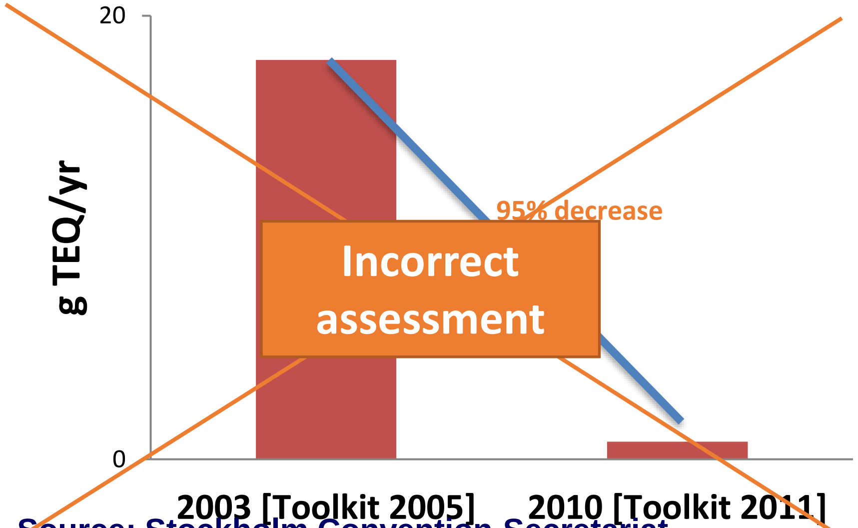
Release to air from open burning of waste: **0.8 g TEQ/yr**

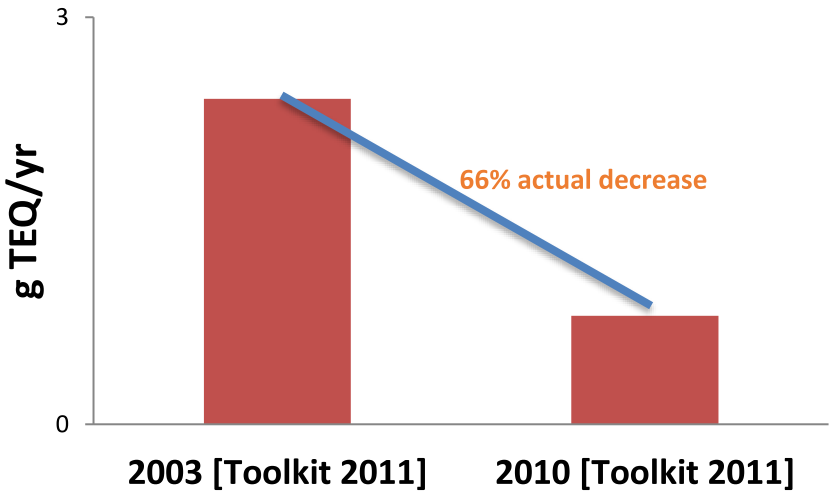
Revised inventory
[2003 data, Toolkit 2013]

Source group: Open burning
Source category: Waste burning
Source class: Uncontrolled domestic waste burning

Activity rate[2003]: **60'000 t/yr**
EFAir [Toolkit 2011]: 40 µg TEQ/t

Release to air from open burning of waste: **2.4 g TEQ/yr**





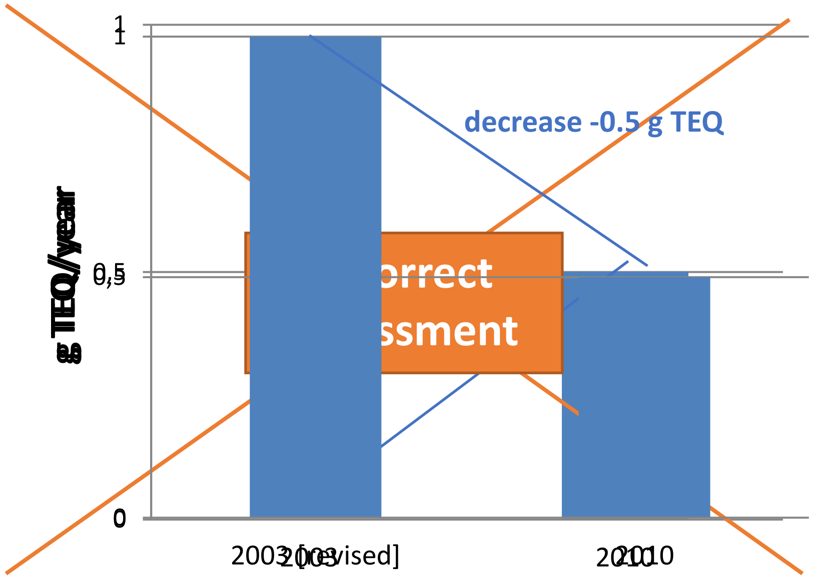
Source: Stockholm Convention Secretariat

Update baseline inventory: Missing Source in the 1st Inventory

Baseline inventory
[2003 data, Toolkit 2005]

Source group: Waste incineration
Source category: Destruction of animal carcasses

-no information
-releases considered negligible



Source: Stockholm Convention Secretariat

Updated inventory
[2010 data, Toolkit 2013]

Source group: Waste incineration
Source category: Destruction of animal carcasses
Source class: Old facility, no APCS
New information discovered
Activity rate [2010]: **1'000 t/yr**
EFAir [Toolkit 2013]: **500 µg TEQ/t**

Release to air from destruction animal carcasses: **0.5 g TEQ/yr**

Revised inventory
[2003 data, Toolkit 2013]

Source group: Waste incineration
Source category: Destruction of animal carcasses
Source class: Old facility, no APCS

Activity rate [2003]: **2'000t/yr**
EFAir [Toolkit 2013]: **500 µg TEQ/t**

Release to air from destruction of animal carcasses: **1 g TEQ/yr**

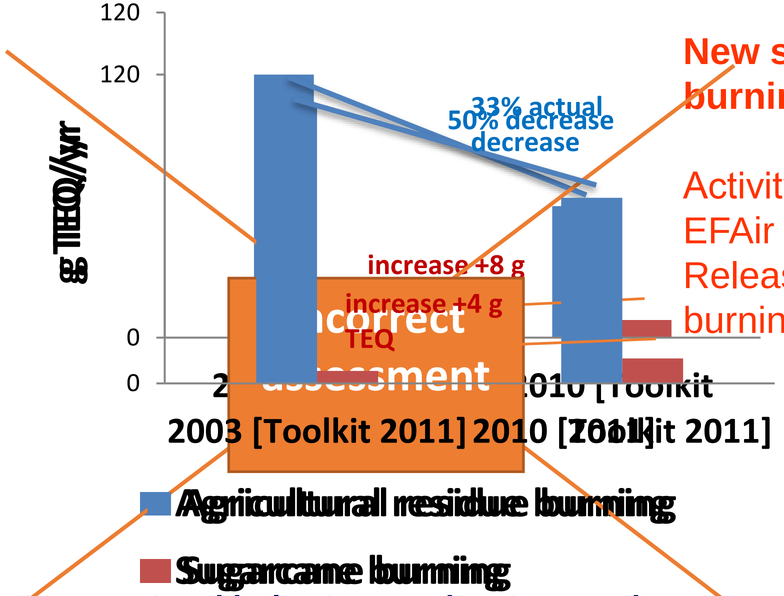
Update baseline inventory: Additional Class added to Toolkit

Baseline inventory [2003 data, Toolkit 2005]

Source group: Open burning
Source category: Biomass burning
Source class: Agricultural residue burning, impacted

Activity rate [2003]: **4’000’000 t/yr**
EFAir [Toolkit 2005]: **30 µg TEQ/t**

Release to air from agricultural residue burning: **120 g TEQ/yr**



Source: Stockholm Convention Secretariat

Updated inventory [2013 data, Toolkit 2013]

Source group: Open burning
Source category: Biomass burn
Source class: Agricultural residue burning, impacted

Activity rate [2013]: **2’000’000 t/yr**
EFAir [Toolkit 2013]: **30 µg TEQ/t**

Release to air from agricultural residue burning: **60 g TEQ/yr**

New source class: sugarcane burning

Activity rate [2013]: 2’000’000 t/yr
EFAir [Toolkit 2013]: 4 µg TEQ/t
Release to air from sugarcane burning: 8 g TEQ/yr

Revised inventory [2003 data, Toolkit 2013]

Source group: Open burning
Source category: Biomass burn
Source class: Agricultural residue burning, impacted

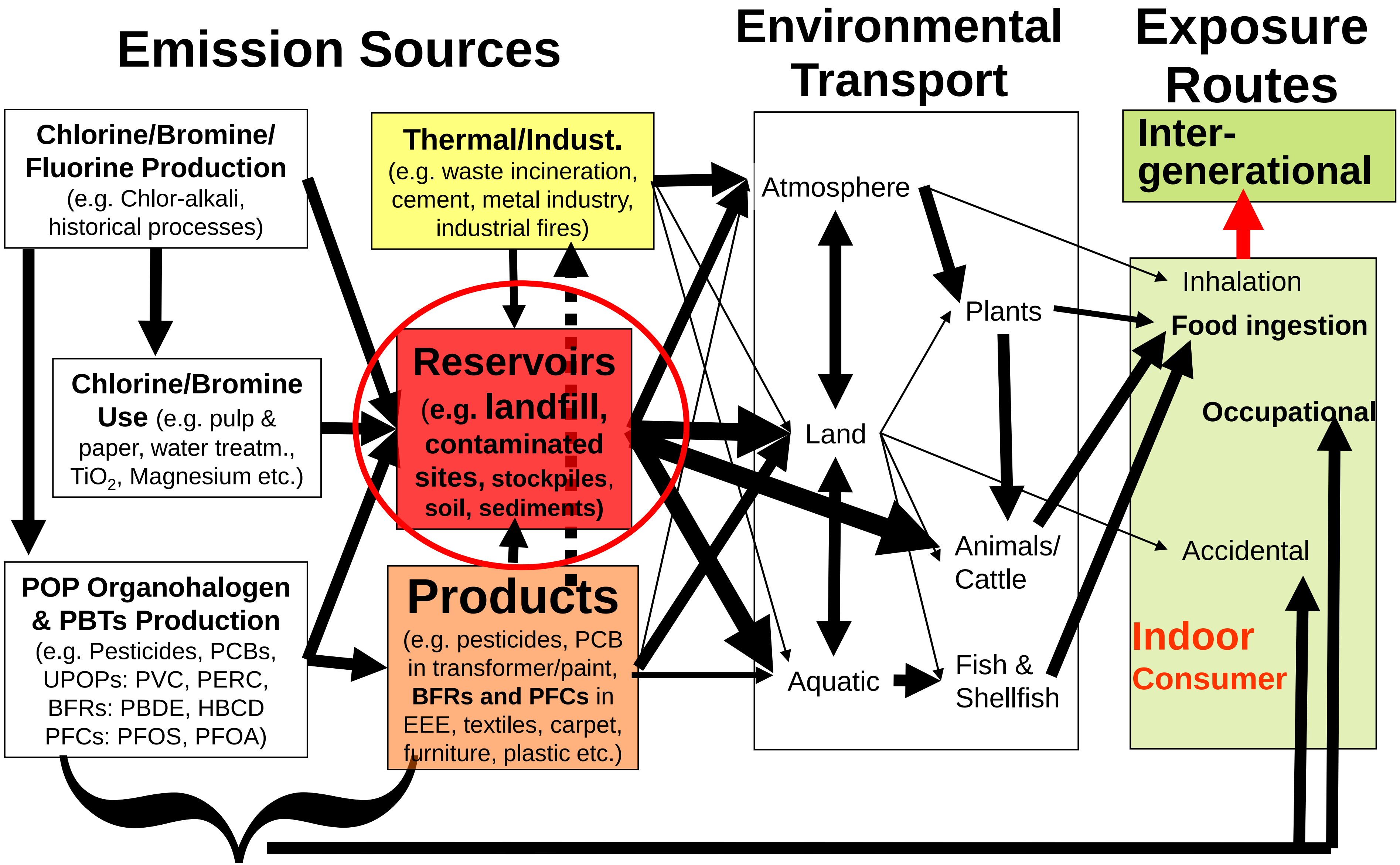
Activity rate [2003]: **3’000’000 t/yr**
EFAir [Toolkit 2013]: **30 µg TEQ/t**

Release to air from agricultural residue burning: **90 g TEQ/yr**

New source class: sugarcane burning

Activity rate [2003]: 1’000’000 t/yr
EFAir [Toolkit 2013]: 4 µg TEQ/t
Release to air from sugarcane burning: 4 g TEQ/yr

"Life-Cycle" of POPs/PBT, Environmental Transport and Exposure: Contaminated Sites



Weber et al. (2008) ESPR15, 363-93;. (2018) ESEU https://rdcu.be/bax79 Petrlik et al.(2022) Emer Contamihttps://doi.org/10.1016/j.emcon.2022.05.001

Source Group10 – Contaminated sites/hotspots

- Article 6 of the Stockholm Convention encourages parties to **develop strategies to identify sites contaminated with unintentional POPs.**
- This source group includes an indicative list of activities that might have resulted in the contamination of soils and sediments with PCDD/PCDF and other unintentional POPs.
- PCDD/PCDF from reservoirs including contaminated sites and hotspots represent nowadays an important source of human exposure, often through food contamination.

The following steps are recommended for assessing:

- Identifying historical activities that could have caused Dioxin/UPOP contamination and identifying the potentially contaminated sites;
- Assessing these sites for the likely magnitude of the contamination and ranking by their exposure risk;
- Assessing the degree of contamination of the most significant sites by detailed analysis.

http://toolkit.pops.int/Publish/Main/II_10_HotSpots.html
https://chm.pops.int/Implementation/BATandBEP/POPscontaminatedsites/Guidance/tabid/9649/Default.aspx

Contaminated Sites (Dioxin/UPOPs; other POPs; Heavy Metals, PAHs, BTX etc.)

- **One of the big environmental problems in industrial countries are contaminated sites** (contaminated soils and sediments; hazardous landfills etc.) **often due to lack of waste management and lack of BAT/BEP decades ago.**
  - US Superfund project since 45 years (multi billion $)
  - Germany started ca. 40 years and will continue (recently PFAS site activities)…….
  - Sweden have projected their remediation activities to 2050.
  - UNEP BAT/BEP guidance for POPs contaminated site assessment. (https://chm.pops.int/Implementation/BATandBEP/POPscontaminatedsites/Guidance/tabid/9649/Default.aspx)

Series on Dioxin/POPs contaminated sites in Environ. Sci Pollution Research (2008 to 2015)

Review: Weber et al. (2008) ESPR 15, 363-393 https://www.researchgate.net/publication/43496844_Dioxin-_and_POP-contaminated_sites-contemporary_and_future_relevance_and_challenges

Editorial Dioxin contaminated sites: https://link.springer.com/article/10.1065/espr2008.01.473#page-1

Editorial: Better POPs management https://link.springer.com/content/pdf/10.1007/s11356-012-1247-8.pdf

Review relevance for PCDD/PCDF/PCB in soils for food production & exposure: https://rdcu.be/bax79

Review dioxins & PCBs in eggs: https://doi.org/10.1016/j.emcon.2022.05.001

Dioxin/PCB contamination of meat/milk around a metal (sinter) plant in the EU

L'Ilva di Taranto ci avvelena e io perdo le pecore

http://city.corriere.it/interviste.shtml

Intervista ad un allevatore pugliese.

«La sua azienda si occupa di allevamento ovicaprino. Senza le pecore che fate?

Niente, siamo fermi da settembre, da quando la Regione Puglia ci ha fatto notificare il decreto di abbattimento. E così, dopo aver perso la vendita pasquale di agnelli, perderemo quella di Natale. Siamo stufi di essere sempre noi, i piccoli, a farne le spese. Ma qualcuno di queste tre industrie intorno, che sia l'Ilva, l'Eni, la Cementir o tutte e tre insieme, dovrà pagare. E non in tempi biblici.

Around steel plant in Italy PCDD/F & PCB contaminated meat & milk (sheep/goat).
(Diletti et al, Giua et al; Org. Hal Compounds 71; 2009)

- **1600 sheeps and goats needed to be slaughtered**
- **2012: 20 km restriction zone for cattle.**
- **Higher cancer rates in area**

Conclusions on PCDD/PCDF & other UPOPs inventory update

- **Most countries have a baseline PCDD/PCDDF inventory.**
- Update the baseline PCDD/PCDF/UPOPs inventory with UNEP 2013 Toolkit.
- Assessment what source groups and source categories are present.
- Gathering of activity rates of individual source categories.
- Classify individual sources according to the situation of individual plants and industries (appropriate selection of emission factors).
- Assessment of Source Group 10 contaminated sites and related risk and exposure for humans, livestock and wildlife.
- Dioxin Toolkit has included some release estimates for other UPOPs (PCBs, HCB, PeCBz) which can also be calculated. Relevant for some chemical production.
- **Please make sure that the data of your inventory is kept in an appropriate database that it is available when updating the baseline inventory (including the filled Toolkit Excel)**.

Part C
Integrated Approach for Pollution Prevention and Control of Unintentional POPs and other Major Pollutants

Dr. Roland Weber
POPs Environmental Consulting,
73527 Schwäbisch Gmünd, Germany
https://www.researchgate.net/profile/Roland-Weber-2
https://scholar.google.com/citations?user=-Cexto4AAAAJ&hl=en

BAT Electric Arc Furnace in an African Country

- BAT flue gas cleaning (bagfilter)
- Possible UPOP BAT improvements:
  - Post combustion
  - Carbon spray

➢ However no waste management in place! Ashes were blown by the wind and used for pavement.

➢ Therefore all BAT measures were meaningless here!

➢ One basis is a propper waste management.

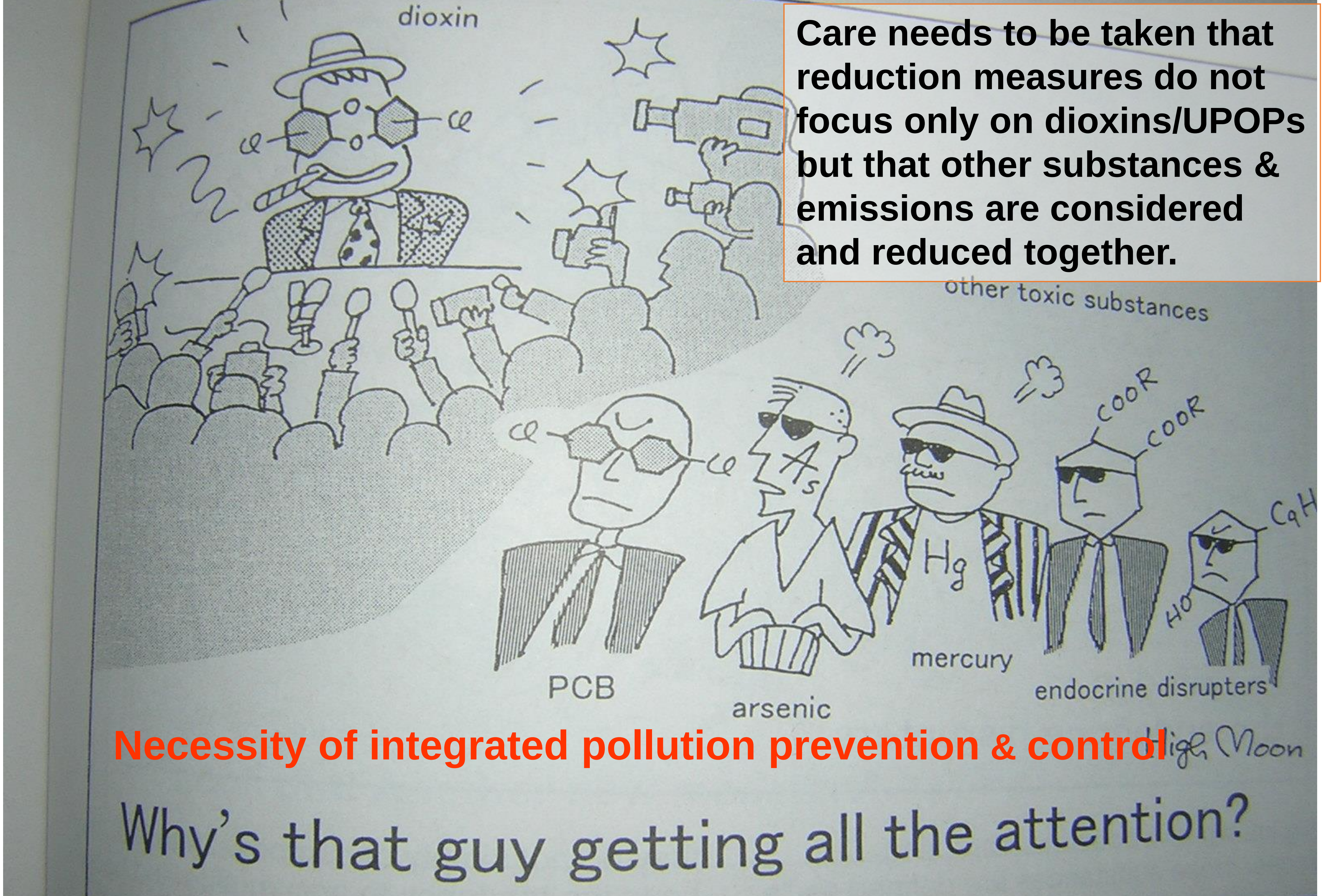
BAT Electric Arc Furnace in an African country (2005)

- Company was interested in solution of waste management.
- No support oder pressure from the government.

- Cement industry was interested in the slag.
- Fly Ash could be recycled by global zink industry.

Therefore solutions are there – facilitating cooperation!

Care needs to be taken that reduction measures do not focus only on dioxins/UPOPs but that other substances & emissions are considered and reduced together.



Necessity of integrated pollution prevention & control

Dioxin/PCB contamination of meat/milk around a metal (sinter) plant in the EU

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- 1600 sheeps and goats needed to be slaughtered
- 2012: 20 km restriction zone for cattle.
- Higher cancer rates in area

Air emissions of a primary steel plant (non-BAT; EU E-PRTR data)

	Release to air (per year)
PCDD/PCDF	99.6 g TEQ
PCB	0.13 tonnes
Benzene	237 tonnes
PAH	33.6 tonnes
Lead and compounds	79.2 tonnes
Chromium	3.87 tonnes
Mercury	1.5 tonnes
Cadmium and compounds	0.4 tonnes
Nickel	0.6 tonnes
PM10	5380 tonnes
HCN	3.94 tonnes
SOx	40,800 tonnes
NOx	28,100 tonnes
HF	568 tonnes
Carbon dioxide	11,300,000 tonnes
Carbon monoxide	569,000 tonnes
Ammonia	33.5 tonnes

Capacity of the facility:
10-12 Mio tonnes steel

Water emissions of a steel plant (non-BAT; EU E-PRTR data)

	Release to water (per year)
PAH	3.32 tonnes
Phenols	12.8 tonnes
Arsenic	0.88 tonnes
Copper	14.9 tonnes
Lead and compounds	0.91 tonnes
Chromium	10.9 tonnes
Mercury	0.46 tonnes
Cadmium and compounds	0.37 tonnes
Nickel	8,32 tonnes
Zinc	33.8 tonnes
Cyanides (as CN)	41.6 tonnes
Phosphourous	16.1 tonnes
TOC (as COD/3)	1250 tonnes
Total nitrogen	2140 tonnes

Capacity: 10-12 Mio tonnes

BAT Electric Arc Furnace (Germany): Emissions to air

(1.8 Mio t steel/a)

1,800,000 m^3/h;

Parameter	Concentration	unit	Emission factor	unit	Annual load	unit
Dust	0,6	mg/Nm^3	4.8	g/t	8640	kg/a
Cadmium	0,0005	mg/Nm^3	4.0	mg/t	7.2	kg/a
Mercury	0,044	mg/Nm^3	352	mg/t	633.6	kg/a
Thallium	< 0.0005	mg/Nm^3	< 4.0	mg/t	< 7.2	kg/a
Arsenic	0,0016	mg/Nm^3	12.8	mg/t	23	kg/a
Cobalt	< 0.0005	mg/Nm^3	< 4.0	mg/t	< 7.2	kg/a
Nickel	0,0005	mg/Nm^3	4.0	mg/t	7.2	kg/a
Lead	0,0095	mg/Nm^3	76	mg/t	136.8	kg/a
Chromium	0,0037	mg/Nm^3	29.6	mg/t	53.3	kg/a
Copper	0,0016	mg/Nm^3	12.8	mg/t	23.0	kg/a
Tin	0,0011	mg/Nm^3	8.8	mg/t	15.8	kg/a
HCl	1,21	mg/Nm^3	9.7	g/t	17.5	t/a
HF	0,115	mg/Nm^3	0.9	g/t	1.6	t/a
NO_x	12	mg/Nm^3	96	g/t	172.8	t/a
CO	284	mg/Nm^3	2272	g/t	4089.6	t/a
Organic carbon	5,4	mg/Nm^3	43.2	g/t	77.8	t/a
Benzene	0,58	mg/Nm^3	4640	mg/t	8352	kg/a
Nickeltetracarbonyl	0,078	mg/Nm^3	624	mg/t	1123.2	kg/a
Benzo(a)pyrene	< 0.00001	$\mu g/Nm^3$	< 0.08	µg/t	< 0.14	g/a
Dibenz(a,h)anthracen	< 0.00001	$\mu g/Nm^3$	< 0.08	µg/t	< 0.14	g/a
PCDD/F	0,068	ng TEQ/Nm^3	0.54	µg/t	1.0	g/a
PCB (LAGA)	0,65	$\mu g/Nm^3$	5.2	mg/t	9360	g/a
HCB	0,078	$\mu g/Nm^3$	0.6	mg/t	1100	g/a

Stockholm Convention BAT/BEP Guidance unintentional POPs

Section III.B – BAT/BEP Guideline:

Guidance principles and cross-cutting considerations includes:

- Sustainable Production Sustainable Consumption
- Precautionary Approach
- Internalizing environmental costs and polluter pays.
- **Cleaner Production**
- **Integrated Pollution Prevention and Control**

European Union Integrating Pollution Prevention and Control (IPPC) and Stockholm Convention BAT/BEP

Integrated Pollution Prevention and Control approach - Integrated mean „Considering all aspects“:

- **All pollutants (Particulate Mater (PM), heavy metals, Dioxin/UPOPs, acid gases etc. Dioxin/UPOP represent just one parameter)**
- **Emissions to air, water, soil/land (waste)**
- **Accidents/incidents**
- **Energy aspects**
- **Occupational health aspects and noise**
- **Monitoring of pollutants or operation parameters**

➔ **Best Available Techniques Reference Documents (BREFs) for different key industrial sectors**

European Union Integrating Pollution Prevention and Control (IPPC) and Stockholm Convention BAT/BEP

Energy: 2 sectors

Metal: 5 sectors

Mineral: 4 sectors

Chemical: 8 sectors

Waste: 2 sectors

Others: 7 sectors

28 Vertical BREFS

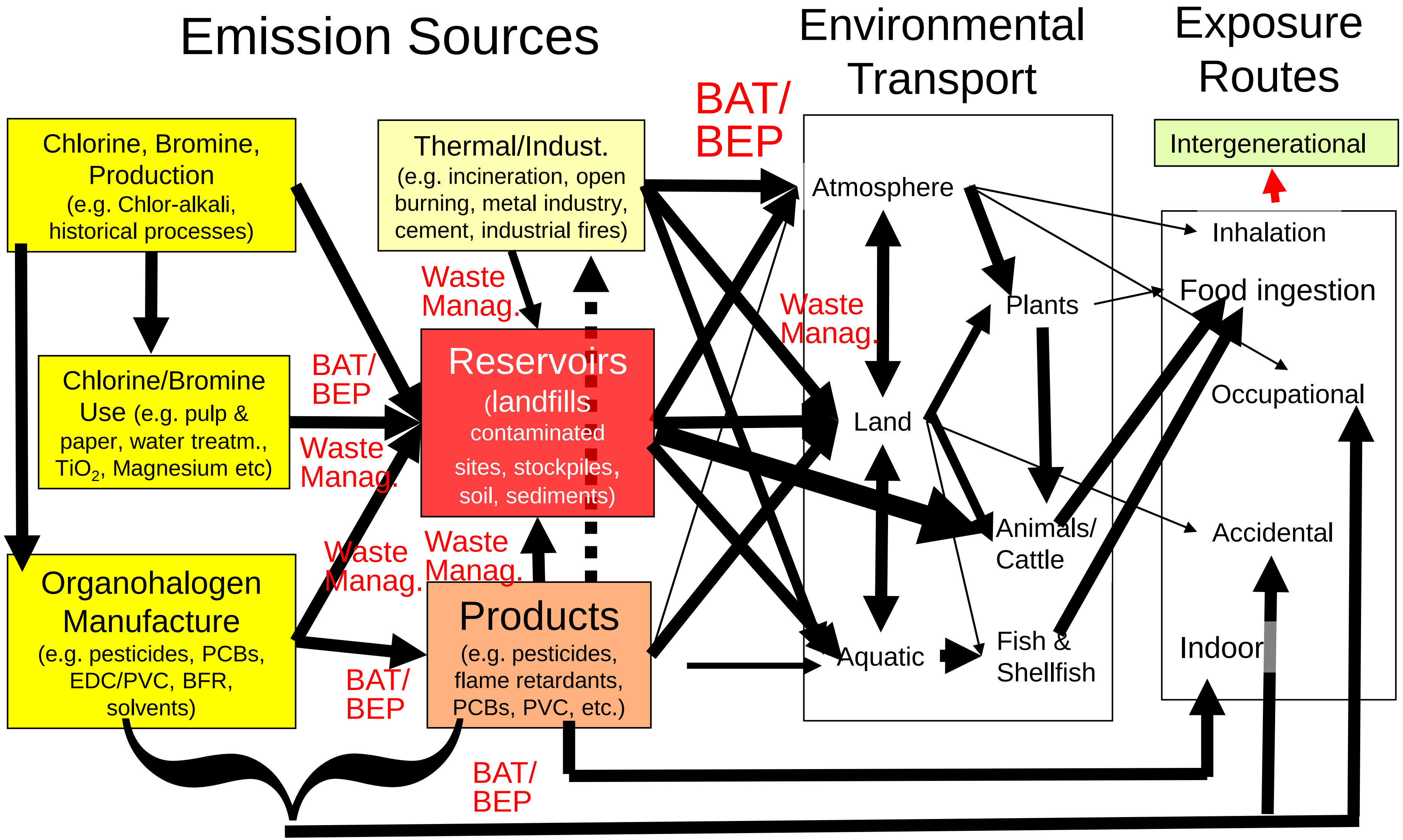
5 Horizontal BREFs

ICS MON EFS ECM ENE

33 BREFs have been published

➔ https://eippcb.jrc.ec.europa.eu/reference

Controlling UPOPs Formation and Pollutant Release – by BAT/BEP Measures including Waste Management



Therefore when developing a Dioxin/UPOP inventory it is recommended to do a thorough assessments of the facilities in respect to waste management and overall release in an integrated manner

Thank you for your attention ! Questions?

More Information https://toolkit.pops.int/

Basel Convention: www.basel.int

Rotterdam Convention: www.pic.int

Stockholm Convention: http://chm.pops.int/

Montreal Protocol/Vienna Convention: http://ozone.unep.org

FAO: www.fao.org **WHO** www.who.int/ **GFC** https://www.chemicalsframework.org

Alternatives https://www.subsportplus.eu/subsportplus/EN/Home/Home_node.html

OECD/IOMC: http://www.oecd.org/chemicalsafety/

Science: www.ipcp.ch; http://greensciencepolicy.org/; www.unep.org/oewg-spp-chemicals-waste-pollution

Industry: http://www.suschem.org/; https://icca-chem.org/; https://cefic.org/

NGO: www.ipen.org; www.ciel.org/; www.ban.org; www.chemsec.org; www.wecf.org;

Better-world-links: http://www.betterworldlinks.org/

Weber et al. (2008) ESPR 15, 363-393 https://doi.org/10.1007/s11356-008-0024-1
Weber et al. (2018) ESEU https://rdcu.be/bax79
Petrlik et al. (2022) Emer Contam https://doi.org/10.1016/j.emcon.2022.05.001

STOCKHOLM CONVENTION
BASEL CONVENTION
gef
UN environment programme
GREEN GROWTH Knowledge Partnership