



## **PCBs**

# **Health Effects and Exposure with Emphasize to Contaminated Sites**



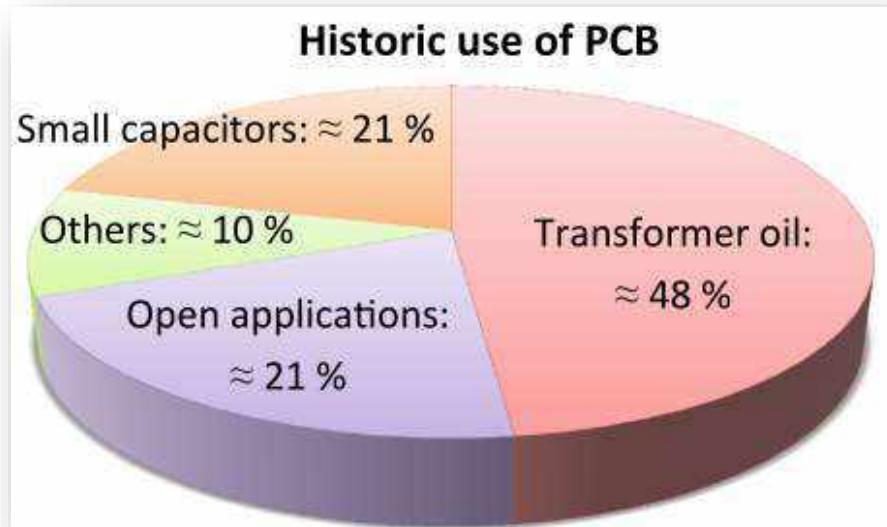
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<https://www.researchgate.net/profile/Roland-Weber-2>

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## Polychlorinated Biphenyls (PCBs) – Historic production and use

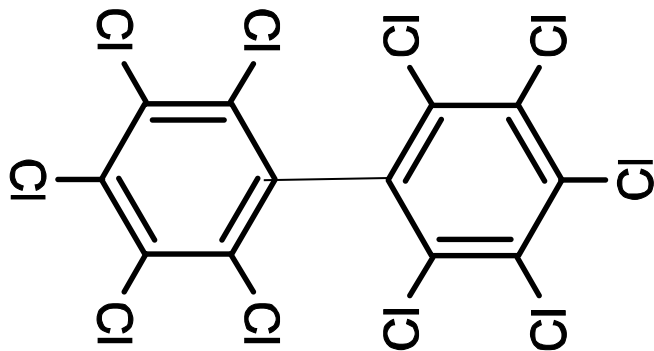
- Approx. 1.1 – 1.5 million tonnes of PCB have been produced in history.
- PCBs have been used in a wide range of closed & open applications.
- Closed applications (transformer oils, capacitors, hydraulic oils).
- Open applications (e.g. sealants, paints, cutting oils).



Bilder: Michael Müller Enviro-Consultant

## Polychlorinated Biphenyls (PCBs) – Historic production

- PCBs have been produced from at least 16 companies.
- Most companies have stopped production in 1970s to 1993.
- Today PCB production might take place in North Korea (NIP report).

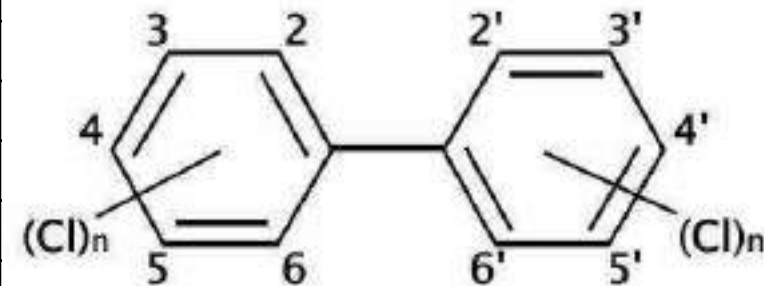


Producer	Country	Start	Stop	Amount	%
Monsanto	USA	1930	1977	641,246	48.4
Bayer AG	West Germany	1930	1983	159,062	12.0
Orgsteklo	U.S.S.R. (Russia)	1939	1990	141,800	10.7
Prodelec	France	1930	1984	134,654	10.2
Monsanto	U.K.	1954	1977	66,542	5.0
Kanegafuchi	Japan	1954	1972	56,326	4.2
Orgsintez	U.S.S.R. (Russia)	1972	1993	32,000	2.4
Caffaro	Italy	1958	1983	31,092	2.3
S.A. Cros	Spain	1955	1984	29,012	2.2
Chemko	Czechoslovakia	1959	1984	21,482	1.6
Xi'an	China	1960	1979	8,000	0.6
Mitsubishi	Japan	1969	1972	2,461	0.2
Electrochemical Company	Poland	1966	1970	1,000	<0.1
Zaklady Azotowe	Poland	1974	1977	679	<0.1
Geneva Industries	USA	1971	1973	454	<0.1
Total	Global	1930	1993	1,325,810	100

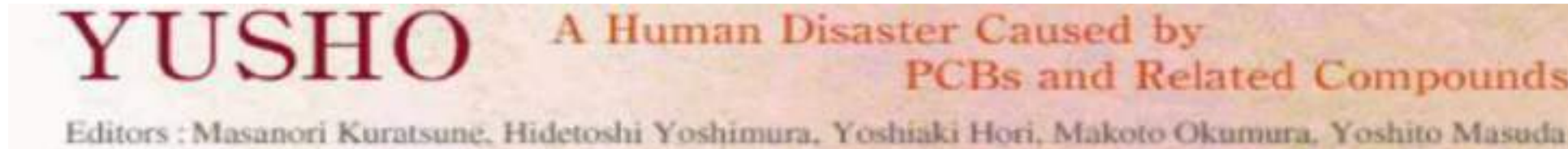
## Dioxin-like PCBs (TEF) and indicator PCBs

Art	PCB Kongener		TEF 1998	TEF 2005
	IUPAC-Nr.	Struktur		
Non-ortho PCB	77	3,3',4,4'-TetraCB	0.0001	0.0001
	81	3,4,4',5-TetraCB	0.0001	0.0003
	126	3,3',4,4',5-PentaCB	0.1	0.1
	169	3,3',4,4',5,5'-HexaCB	0.01	0.03
Mono-ortho PCB	105	2,3,3',4,4'-PentaCB	0.0001	0.000 03
	114	2,3,4,4',5-PentaCB	0.0005	0.000 03
	118	2,3',4,4',5-PentaCB	0.0001	0.000 03
	123	2',3,4,4',5-PentaCB	0.0001	0.000 03
	156	2,3,3',4,4',5-HexaCB	0.0005	0.000 03
	157	2,3,3',4,4',5'-HexaCB	0.0005	0.000 03
	167	2,3',4,4',5,5'-HexaCB	0.00001	0.000 03
	189	2,3,3',4,4',5,5'-HeptaCB	0.0001	0.000 03
Indicator PCB	28	2,4,4'-TriCB		
Ballschmitter	52	2,2',5,5'-TetraCB		
	101	2,2',4,5,5'-PentaCB		
	138	2,2',3,4,4',5'-HexaCB		
	153	2,2',4,4',5,5'-HexaCB		
	180	2,2',3,4,4',5,5'-HeptaCB		

There are 209 PCB Congenere. 12 + 6 PCBs have a special status



### Health effects of PCBs – finding from Yusho



- Rice oil contaminated with PCBs and related PCDFs from leaking heat-exchanger in rice-oil production caused severe health effects.
- This Yusho accident (1968; Japan) showed for the first time that fetuses and neonates are more sensitive to PCBs than are adults. **In utero and lactational exposure to PCBs caused severe and long-lasting or permanent effects in children.**
- Studies in several industrial countries showed that neurobehavioral and developmental deficits occur in newborns at levels found in the general population.
- Deficits continue through school-age
  - lower IQ scores,
  - lower reading comprehension,
  - difficulty paying attention (“ADHD”)



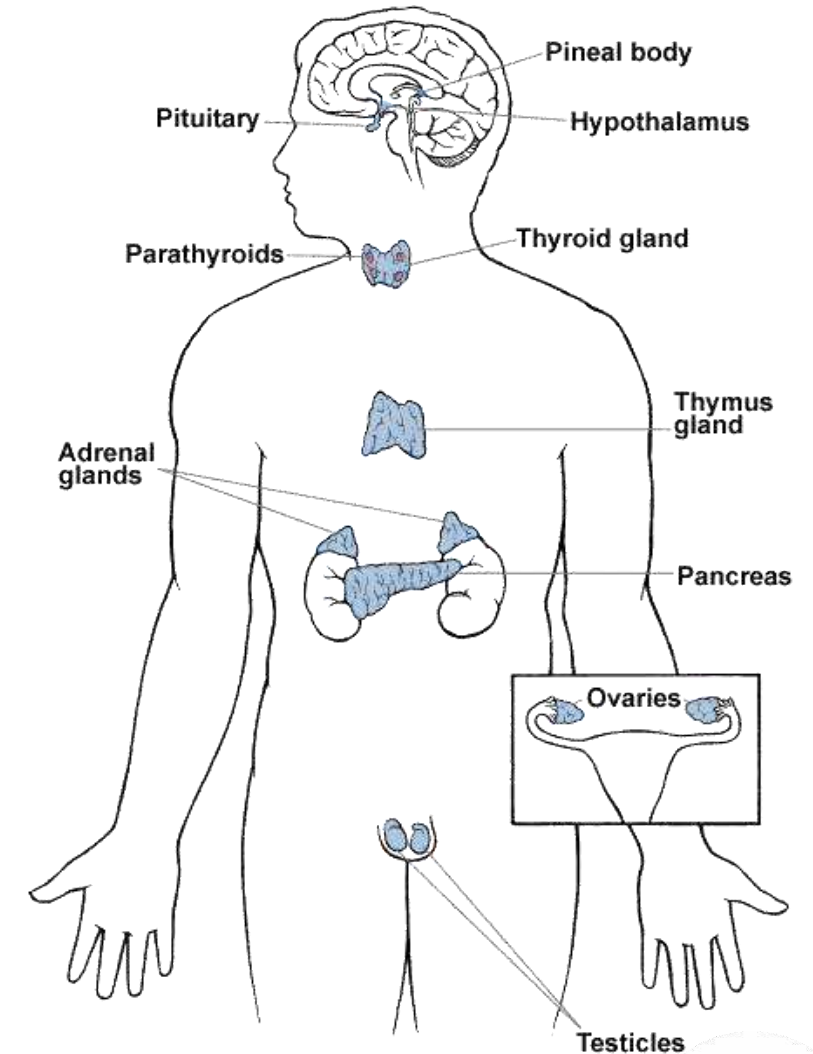
PCBs are human carcinogens.

PCBs cause cancer in humans and were classified Category 1, by the International Agency for Research on Cancer (IARC 2013)

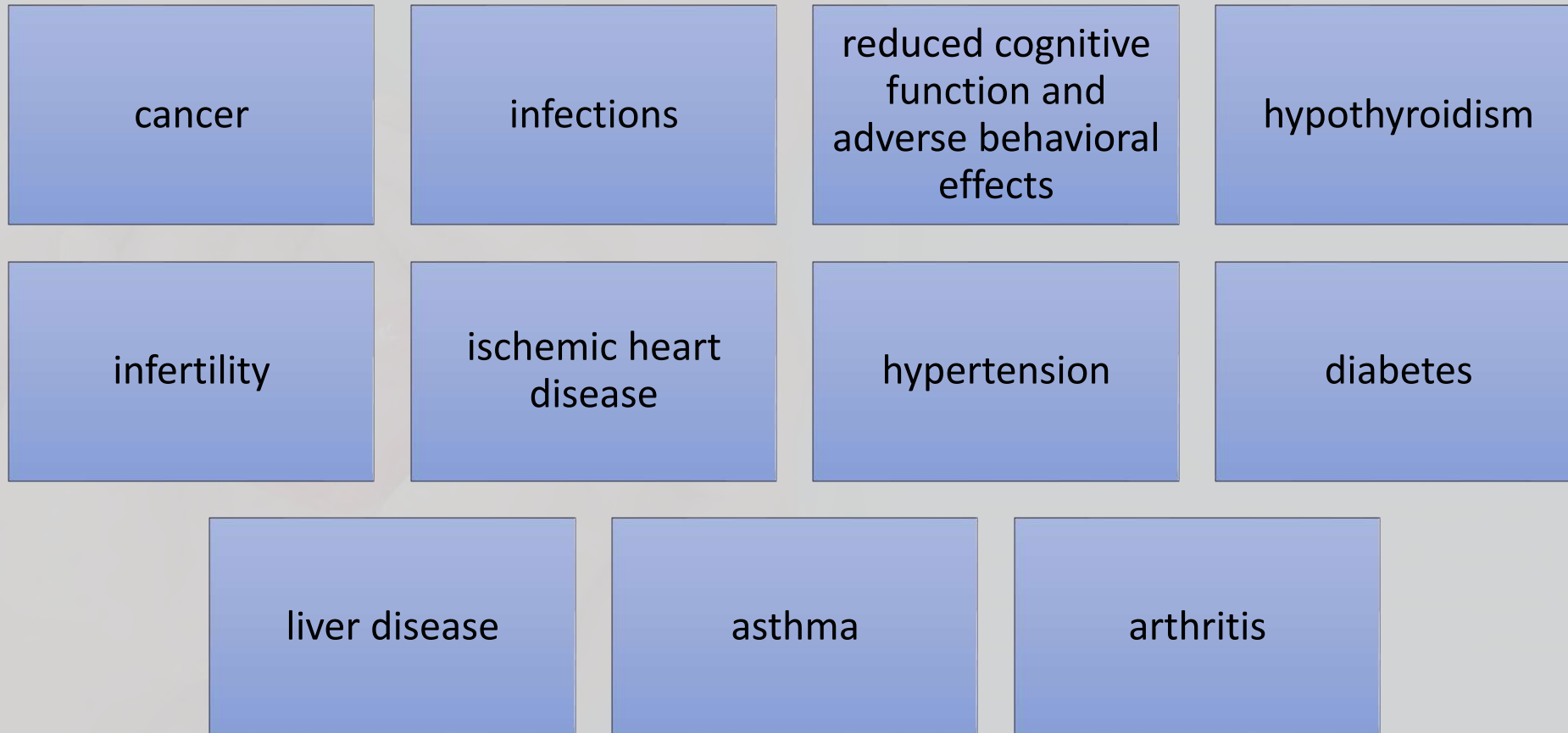
<https://monographs.iarc.who.int/list-of-classifications/>

PCBs are endocrine disrupting chemicals (EDCs).

- Endocrine disrupting chemicals (endocrine disruptors) can have harmful effects on the body's endocrine (hormone) system
- Hormones act in very small amounts and at precise moments in time to regulate the body's development, growth, reproduction, metabolism, immunity and behaviour.
- Exposure to EDCs in the womb can have life-long effects and can even have consequences for the next generation.



Humans who are exposed to PCBs are at increased risk of:



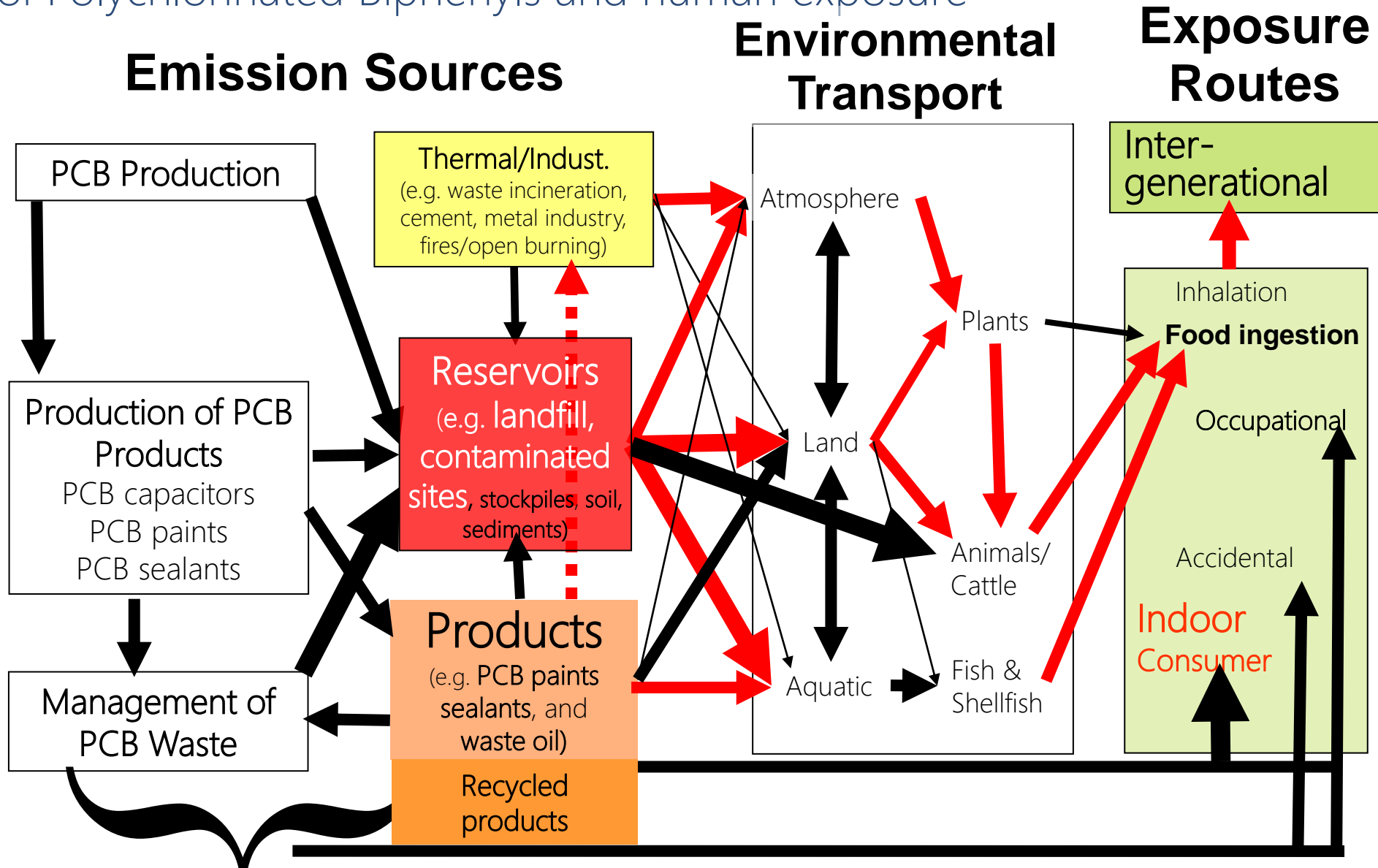
Carpenter (2006) Reviews on Environmental Health, 21, 1-23,  
[https://www.researchgate.net/profile/David\\_Carpenter2/publication/7081925\\_Polychlorinated\\_Biphenyls\\_PCBs\\_Routes\\_of\\_Exposure\\_and\\_Effects\\_on\\_Human\\_Health/links/00463513f5802b6f78000000.pdf](https://www.researchgate.net/profile/David_Carpenter2/publication/7081925_Polychlorinated_Biphenyls_PCBs_Routes_of_Exposure_and_Effects_on_Human_Health/links/00463513f5802b6f78000000.pdf)

IARC classification cancer: <https://monographs.iarc.who.int/list-of-classifications/>



### 3. Lifecycle of PCBs and human exposure via food

“Life-cycle” of Polychlorinated Biphenyls and human exposure



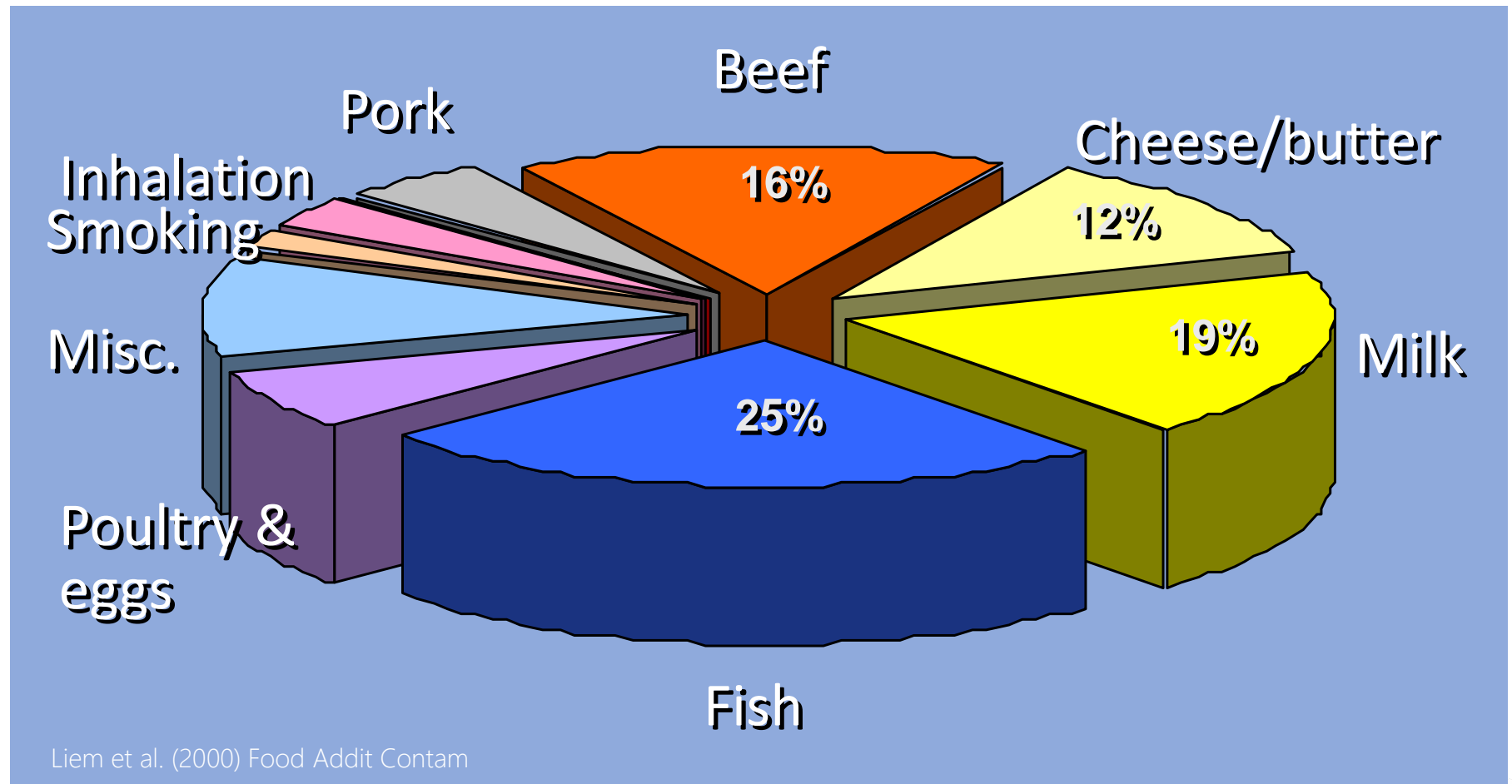
### 3. Lifecycle of PCBs and human exposure via food

#### Human background exposure Dioxin/PCBs



#### Human Dioxin/PCB exposure (U.S.A.)

- PCB/Dioxins are ubiquitous in fatty food
- Bioaccumulate in livestock/predators
- Exposure depends on the lifestyle



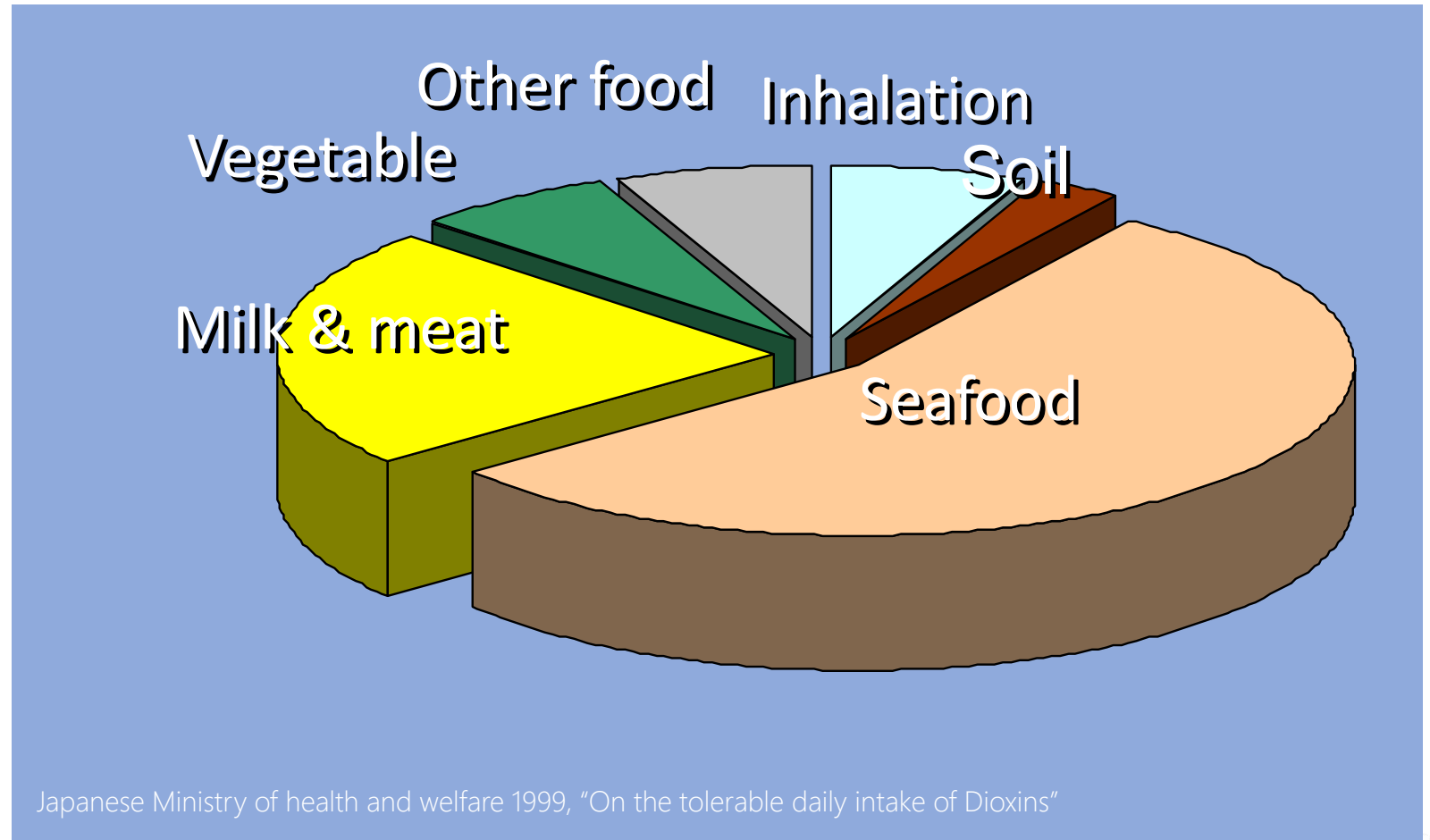
### 3. Lifecycle of PCBs and human exposure via food

#### Human background exposure Dioxin/PCBs



Major dioxin/PCB exposure path in the population of Japan.

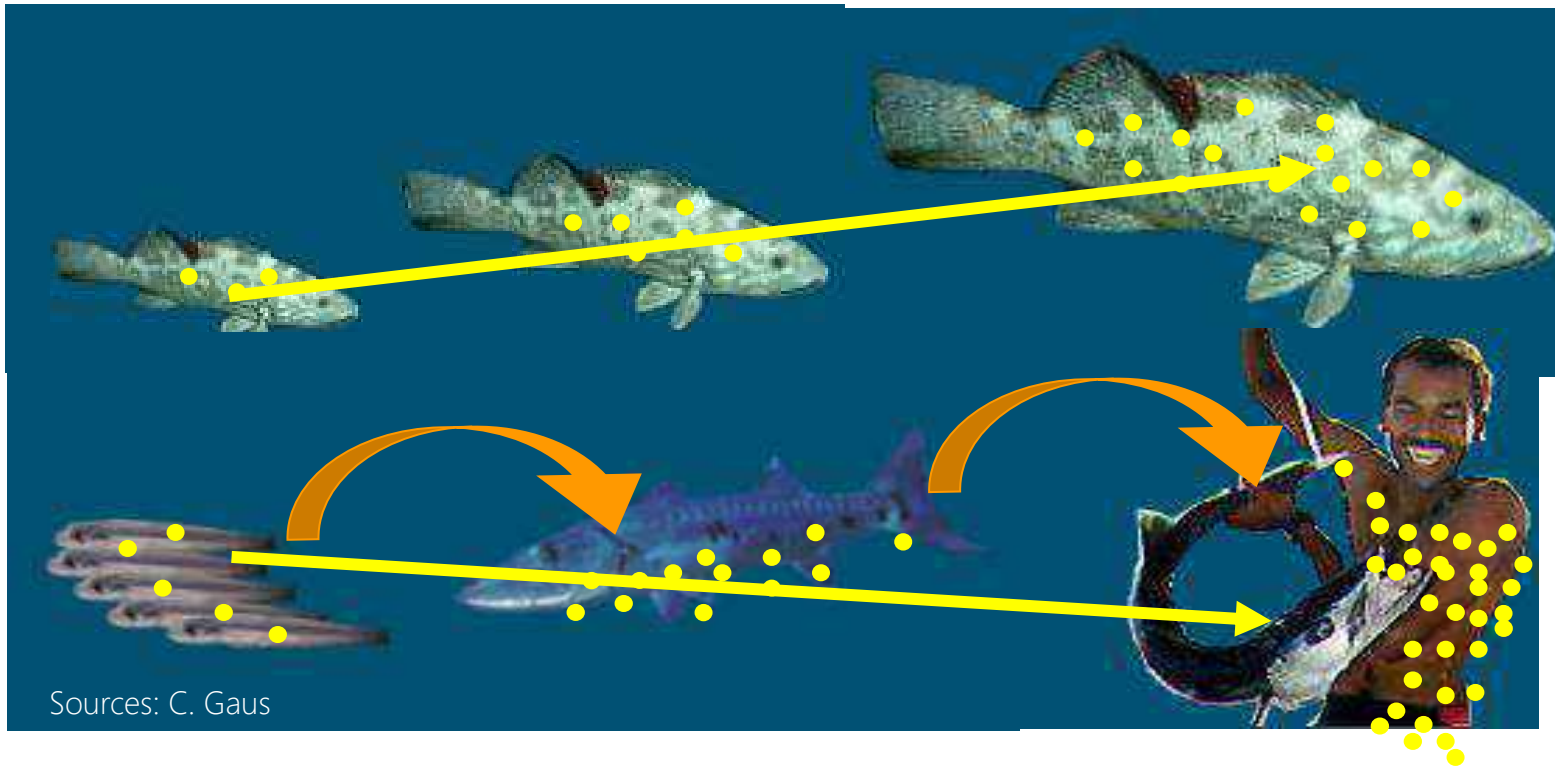
How is PCB exposure from food in Africa/Gambia?



### 3. Lifecycle of PCBs and human exposure via food

## Bioaccumulation and Biomagnification

Why higher PCB/POPs level in fish, meat & milk?



Bioaccumulation: increase with time

Biomagnification: increase with trophic level

- Enrichment factor with each food chain about 10 times (one order of magnitude)

### 3. Lifecycle of PCBs and human exposure via food

PCDD/Fs, PCBs (& other endocrine disruptors) are especially problematic during human development (lowest dose response conc.).

Top of the Foodchain:

Women accumulate POPs during their life and pass them to the baby during pregnancy and by breast milk

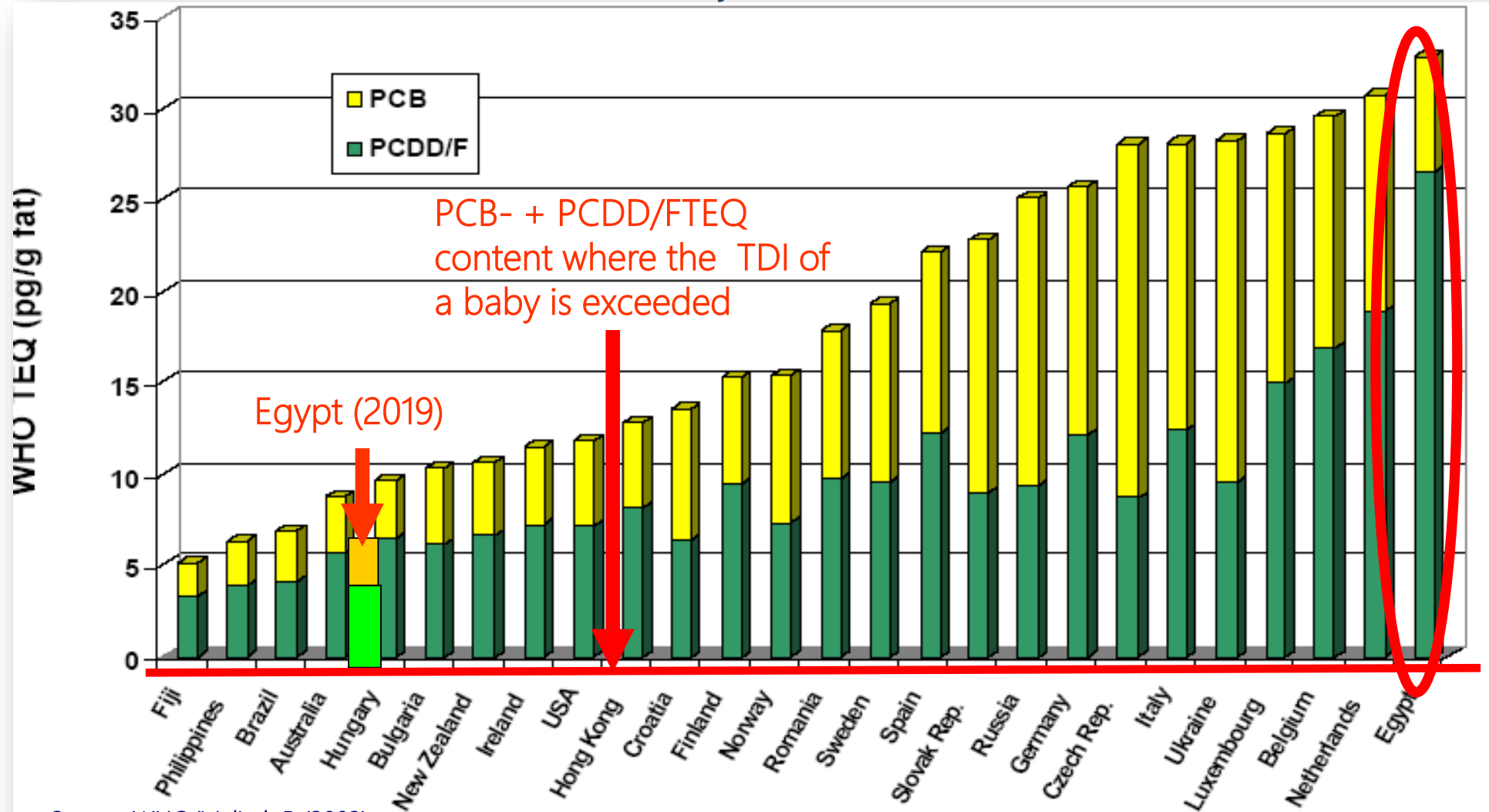
**Still best to breastfeed in the first 6 months! (WHO)**



### 3. Lifecycle of PCBs and human exposure via food

#### PCDD/F and PCB in WHO mothers milk survey

Still mothers milk is the best nutrition for the baby !



Source: WHO/Malisch R (2003)

[https://www.who.int/health-topics/breastfeeding#tab=tab\\_1](https://www.who.int/health-topics/breastfeeding#tab=tab_1)

### 3. Lifecycle of PCBs and human exposure via food

Daily intake of PCDD/Fs and dl-PCBs via human milk Egypt (2001/2019) and Japan (1998)

WHO rec.	<u>Mother's milk</u> (pg TEQ/g fat)			<u>Intake baby*</u> (pg TEQ/kg bw/day)	
	PCDD/Fs	dl-PCBs	Total	PCDD/Fs	Total
Egypt (2001)	17.9	5.1	23.0	91.0	117
Egypt (2019)	5.6	3.4	9.0	28.5	45.7
<b>Fukuoka (Yusho)</b>	<b>15.0</b>	<b>18.0</b>	33.0	76.2	<b>168</b>

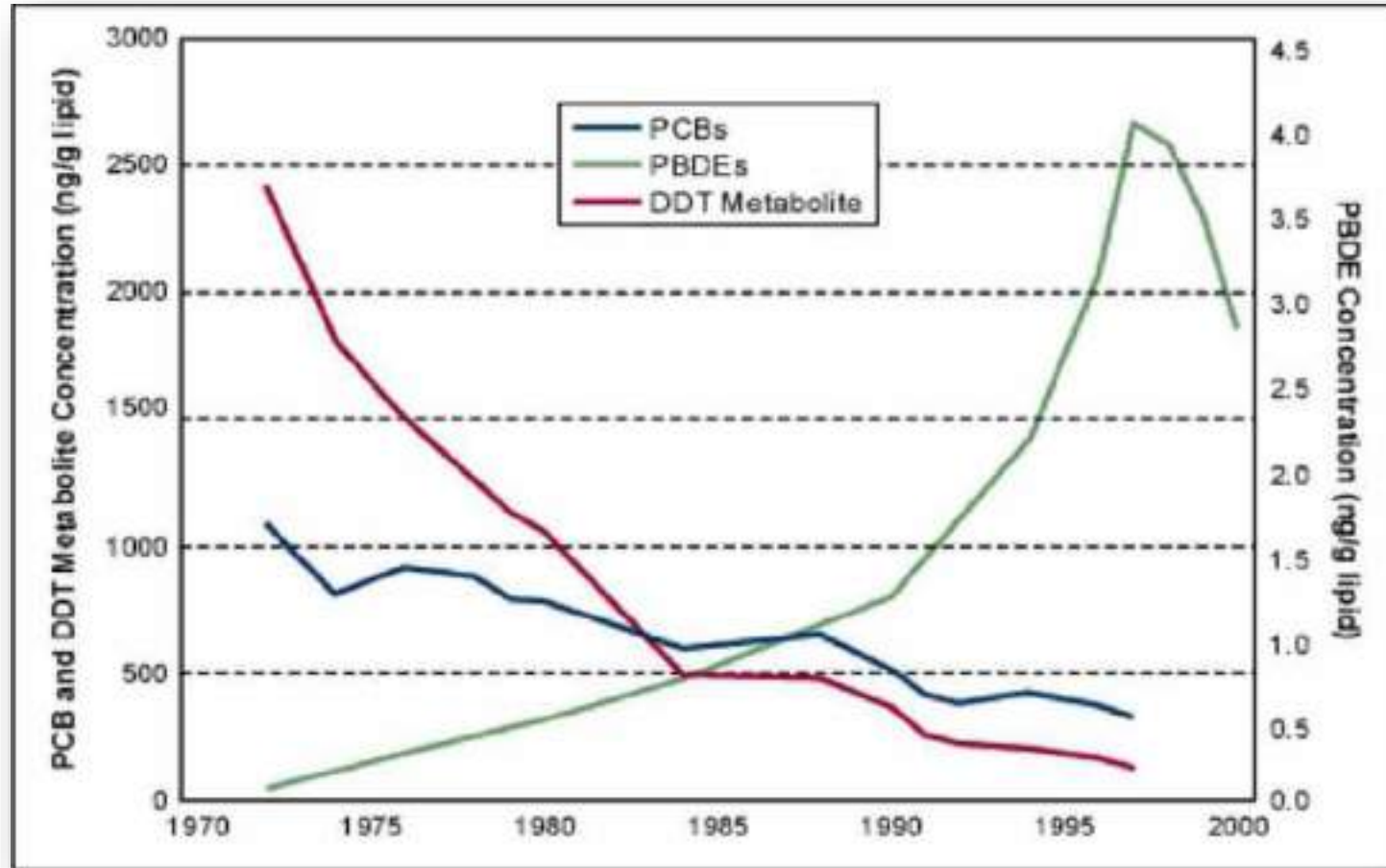
\*Calculated according to the exposure factors in USEPA handbook for 6 month baby

WHO tolerable daily intake: 1-4 pg TEQ/kg body weight/day.

EU tolerable daily intake: 2 pg TEQ/kg body weight/day (2005) and updated 2 pg TEQ/kg body weight/week (2018).

### 3. Lifecycle of PCBs and human exposure via food

#### Time trend of legacy & emerging POPs (Sweden)



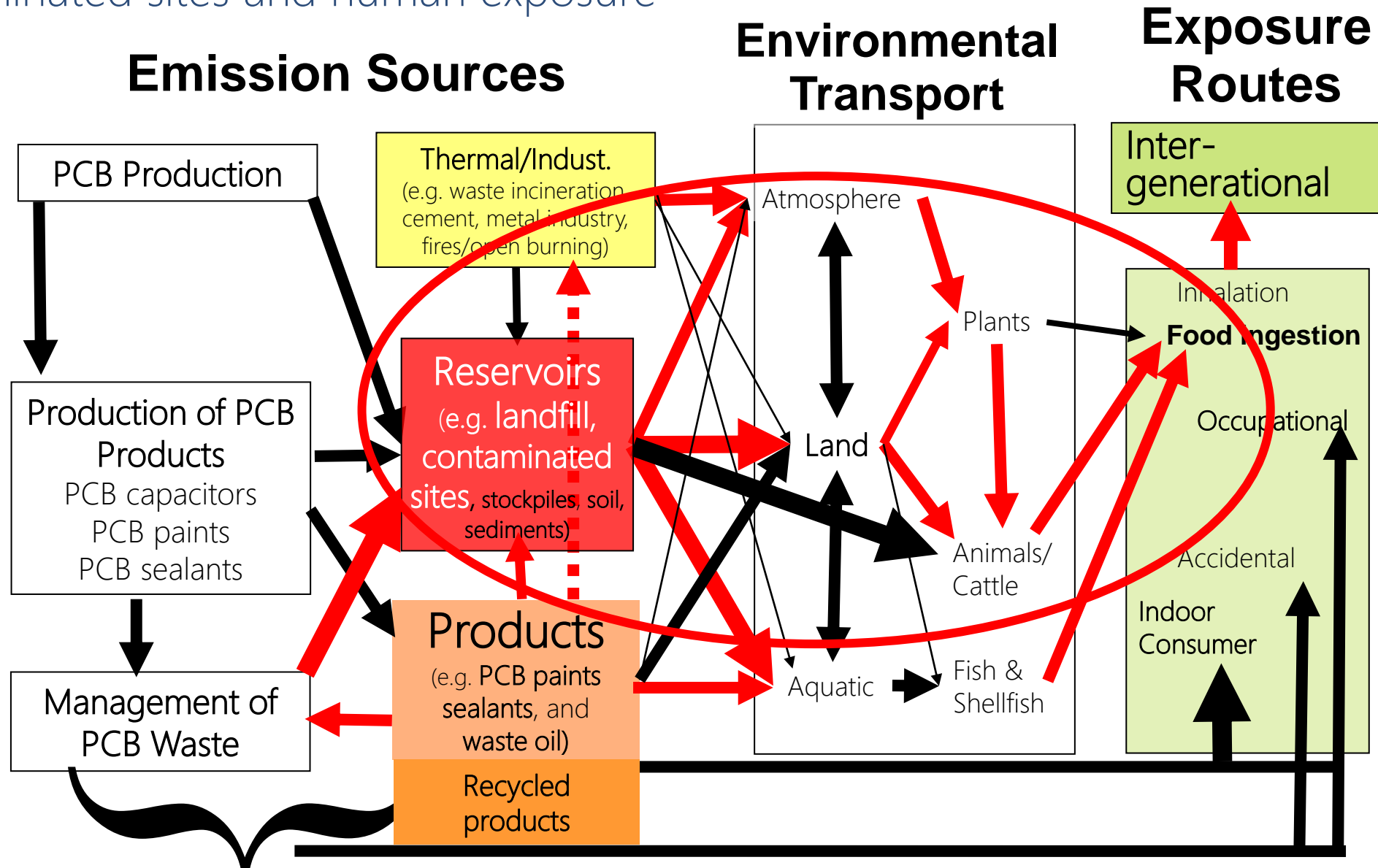
Source: Swedish Natural Research Defense Council

- PCBs in humans have slowly decrease in countries with PCB-control.
- PCB levels might increase in countries without PCB management !
- New industrial POPs increased in humans since the start of their use.



# 4. Point sources of PCBs, contaminated soil & human exposure

## PCB contaminated sites and human exposure

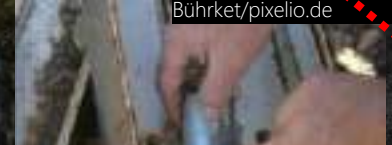


# 4. Point sources of PCBs, contaminated soil & human exposure

PCB deposition via air from open and leaking closed applications



Bild: Michael Bührket/pixelio.de



Bilder: Michael Müller Enviro-Consult; and Christine Herold

Point sources with direct exposure



Bild: Lunar Horse Media



Bild: Jochen Zellner /abfallbild.de



Bild: Thomas Max Müller/pixelio.de



Bild: Thomas Max Müller/pixelio.de

PCB Exposure  
beef/sheep/chicken



Bild: Petra Dirscherl/Pixelio

Exposure from grass/fodder



Bild: Susanne Schmich/Pixelio

Exposure via soil

## 4. Point sources of PCBs, contaminated soil & human exposure

### Problematic PCB (and PCDD/F) levels in soil for free range chicken and egg production

Chicken eggs a few 100 m from a **former PCB capacitor** factory were contaminated 6 times above regulatory limits (36.4 pg TEQ/kg fat) with high dioxin-like (dl)-PCB contribution (25 pg dl-PCB-TEQ/g fat).



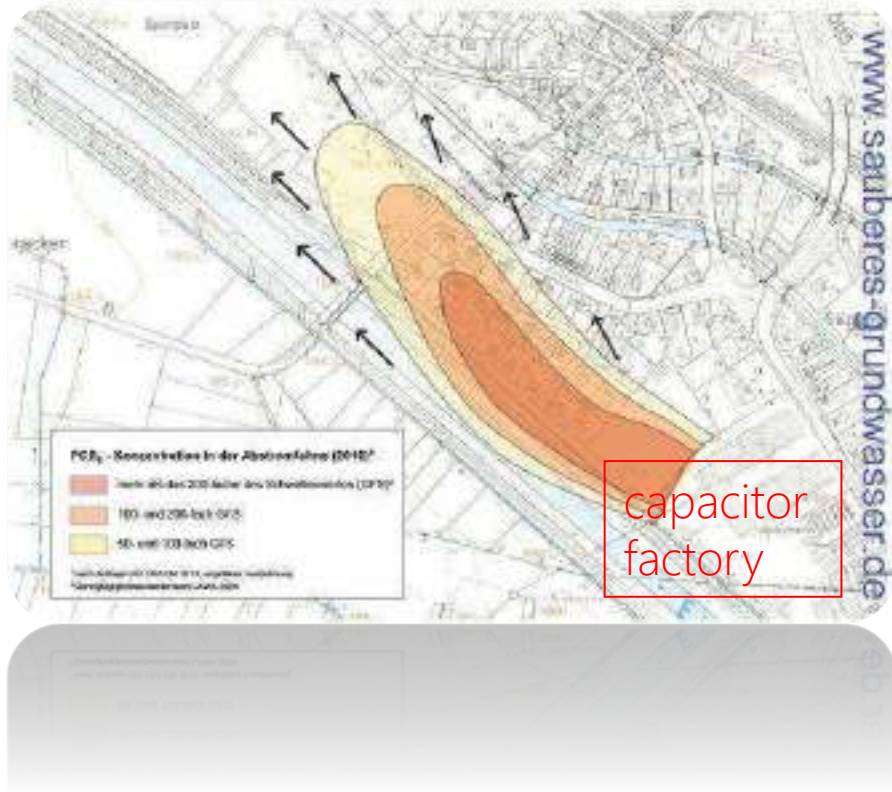
Chicken eggs several 100 m apart of a hazardous landfill were also above the regulatory limit for PCB-PCDD/F TEQ (cases in Germany).

**What are soil levels for contaminate eggs above health/legal limit?**

- Free range chicken consume ca. 12 to 30 g soil/day. Bio-accumulation and transfer of dl-PCBs (and PCDD/F) from soil to chicken/egg show that 2 ng PCB-TEQ/kg in soil is already sufficient to reach regulatory limits of EU in eggs (and meat) and that 1 such egg is above TDI.
- Therefore, important to understand for (former) PCB sources the impacted area with levels above 2 ng PCB-TEQ (similar for PCDD/Fs).

## 4. Point sources of PCBs, contaminated soil & human exposure

### Egg monitoring around a capacitor factory (Germany)



- The groundwater below the former production site in Köndringen, Germany and the associated landfill is contaminated with PCBs and a PCB plume impacts the ground water of the nearby town.
- Chicken eggs from private chicken keepers (A and B) close to a factory, a small town in South-West Germany which was used for the.

Also, fish from an adjacent creek were highly contaminated with PCBs. PCB in one portion eel was sufficient for a year TDI.

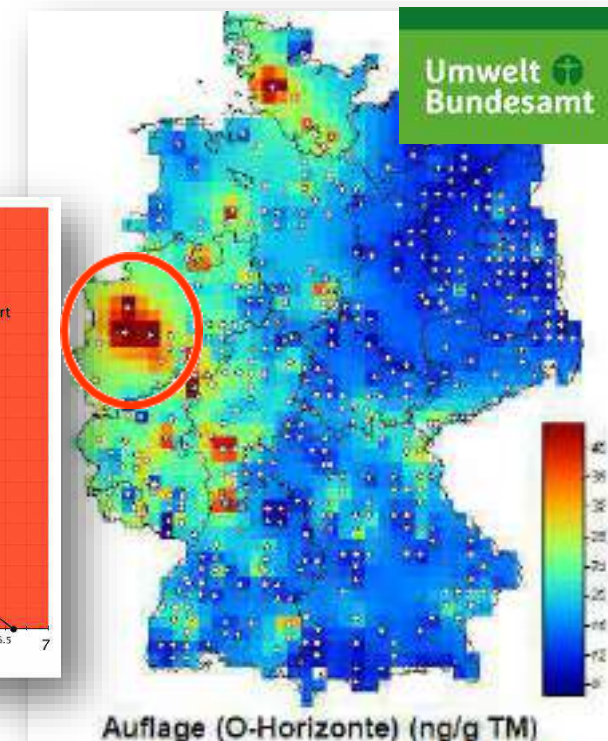
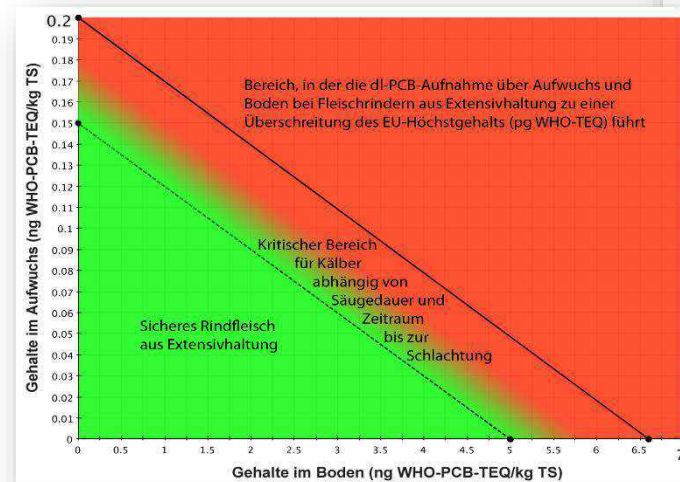
## 4. Point sources of PCBs, contaminated soil & human exposure

### What is the reach of individual PCB point sources?

A key question is the reach of individual point sources (considering the 2.5 ng PCB-TEQ/kg soil; and ca. 0.15 ng PCB-TEQ in grass). This is in particular relevant to decide if livestock breeding is impacted /possible.

For a few sources the reach of the PCB-contamination has been assessed e.g.:

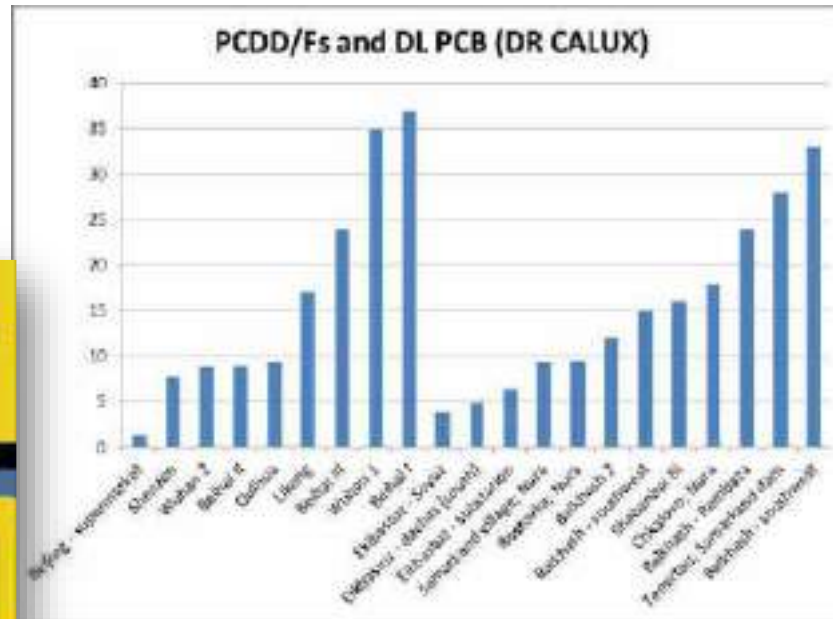
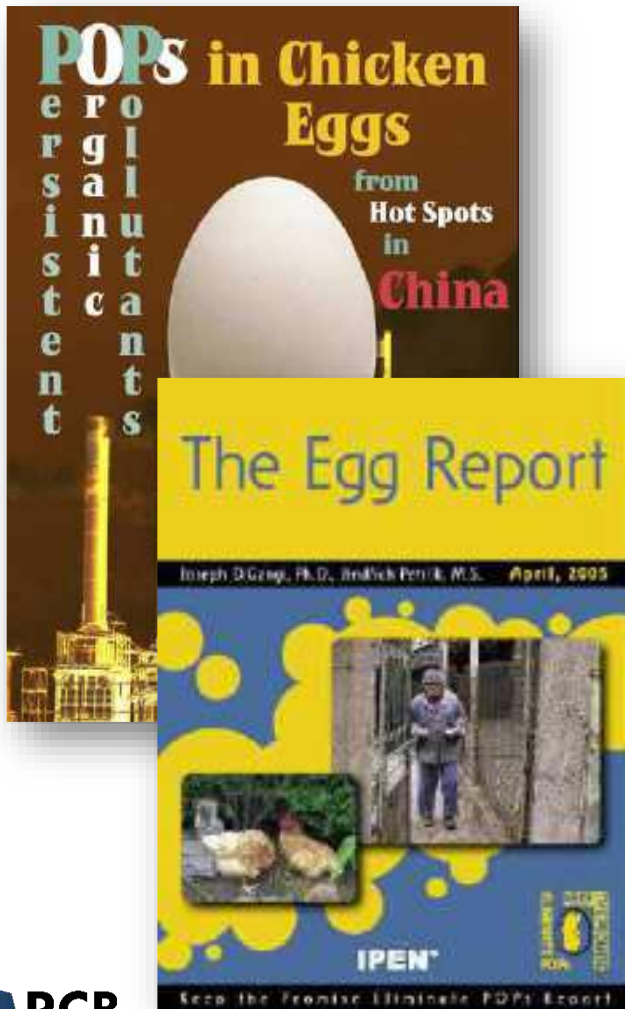
- Steel production Taranto/Italy: PCB/Dioxin-contamination led to the ban on grazing within 20 km from the industrial area (Esposito et al. 2014).
- Emissions of the PCB production in Slovakia led to elevated PCB levels in humans up to 50 km in prevailing wind direction (Wimmerova et al. 2015 Environ Sci Pollut Res Int. 22(19):14405-14415).
- The release from Toronto/Canada had a measurable PCB-impact of 20 - 30 km in surrounding (Cziszar 2012; 2013)



What is the impacted area and reach of large PCB contaminated sites from PCB equipment storage in Africa and the impacted food/cattle?

## 4. Point sources of PCBs, contaminated soil & human exposure

### Contamination of chickens around emission sources



- Studies in industrial and developing countries (e.g. IPEN global egg studies) show that soils around industrial emission sources (metal industries, incinerators, PCB use/processing) can be polluted that PCDD/F+PCB TEQ levels in eggs/meat can be above regulatory limit.
- 50% of small private chicken herds in Netherlands were above EU limit!
- In rural area chicken are normally below limit if no point source on farm.

## 4. Point sources of PCBs, contaminated soil & human exposure

### PCB/Dioxin contamination of meat/milk around steel plant in EU

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

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



- Around primary steel plant in Italy PCB & PCDD/F contamination of meat & milk (sheep/goat).
- (Diletti et al, Giua et al; Organohal Cpds 71; 2009)
- Industrial PCB pattern in soils & sheep from transformers and oil release and mismanagement.



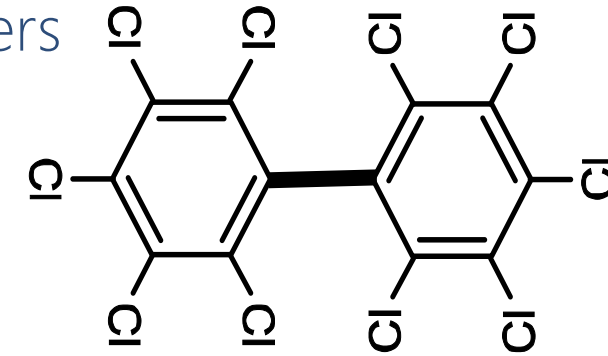
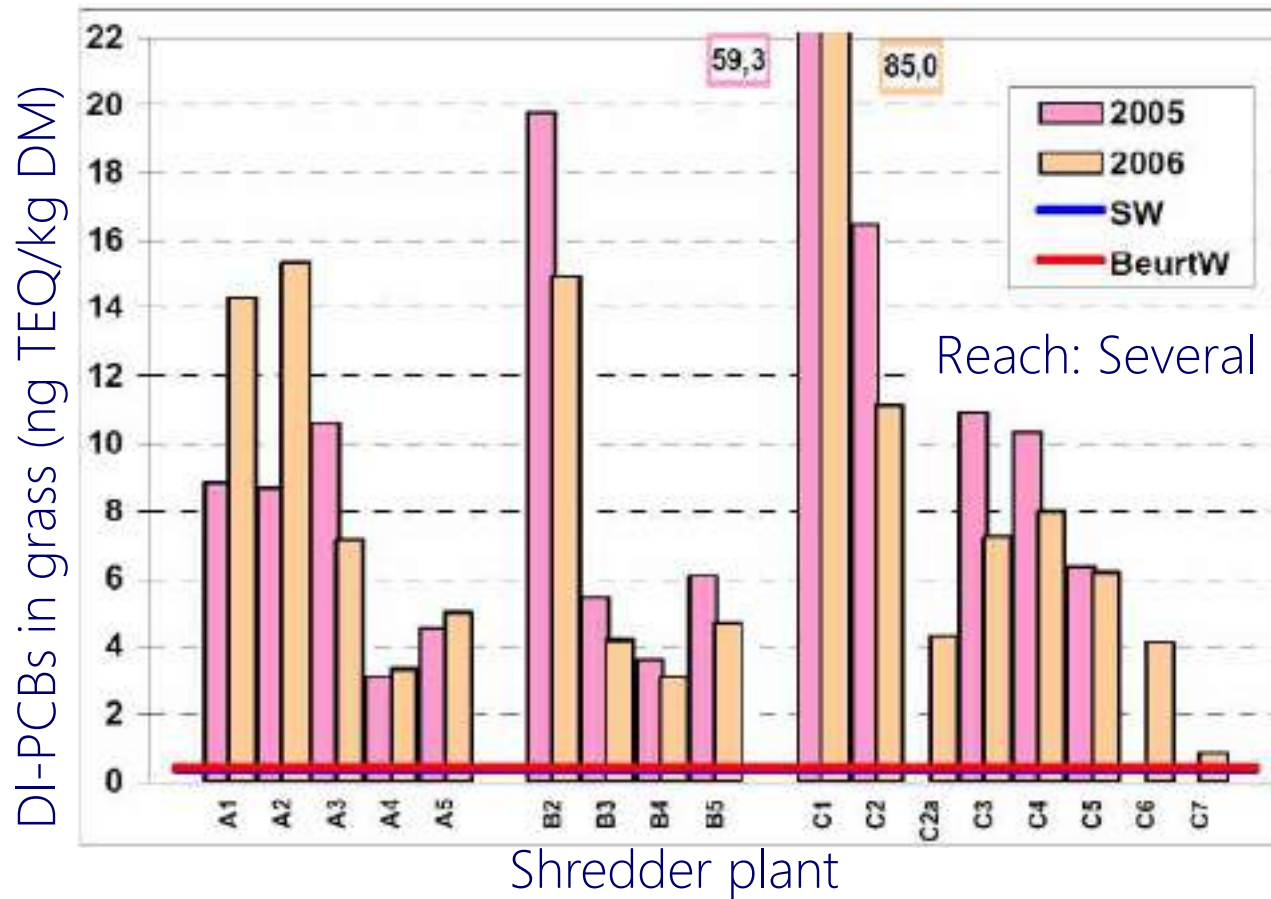
**1600 sheeps and goats needed to be slaughtered**

**2012: 20 km restriction zone for cattles.**

**Higher cancer rates in area**

## 4. Point sources of PCBs, contaminated soil & human exposure

### PCBs Challenges in Material Cycles: Metal Scrap recycling - Shredders



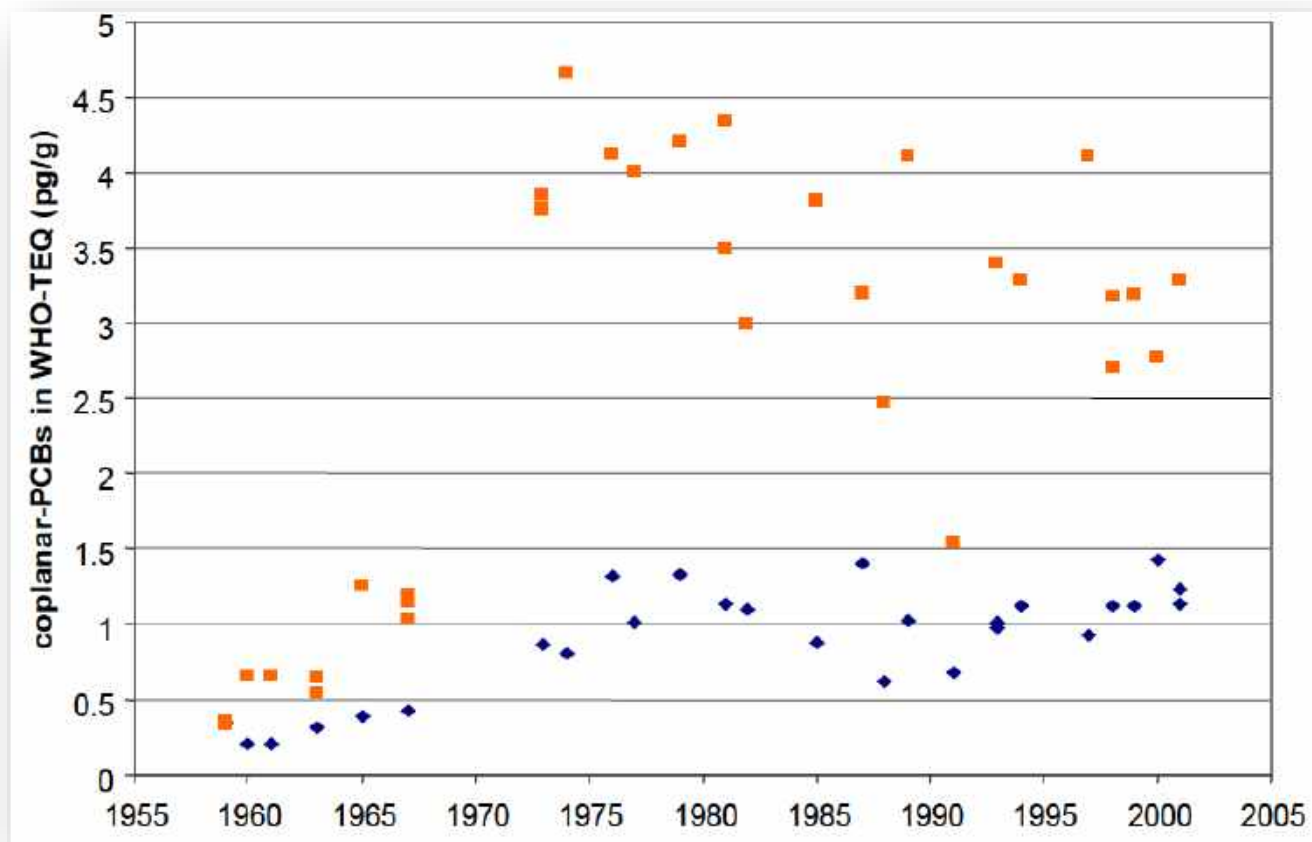
Even today in industrial countries the releases from shredders contaminate the surrounding with PCBs that grass is contaminated above EU regulatory limit and danger for cattle and related exposure.



## 4. Point sources of PCBs, contaminated soil & human exposure

### Time trend of PCB-contamination in German soils

The time trend in a German agricultural soil (@Bonn), which have been measured since early 1960s with sewage sludge amendment (■) in comparison with an agricultural soil treated with mineral fertilizer (◆).



Open applications main PCB releases for Germany in 1966 to 1973

## 4. Point sources of PCBs, contaminated soil & human exposure

PCB contamination sources as large pollution & exposure threat –  
Case study metal scrap recycling

Steel plant Choindez/Courrendlin



PCB release from electric arc furnace treating PCB in scrap.



Bild: Michael Bührket/pixelio.de

Metals from PCB equipment ((own) transformers, capacitors).



Bild: Michael Müller

PCB paints on metal scrap (electricity poles, pipes, steel constructions, silos)

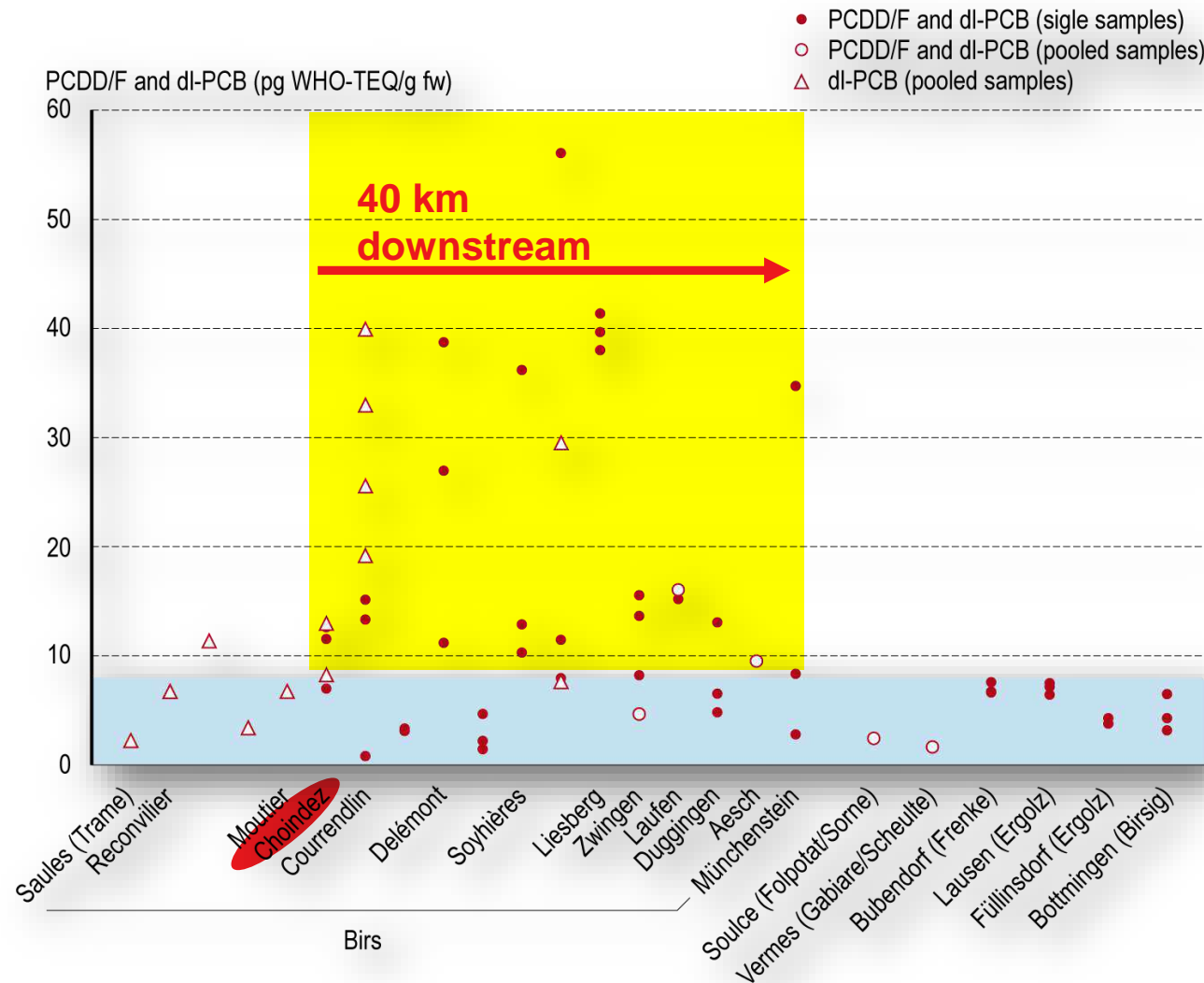


Jakob Ehrhardt - pixelio.de

Contamination of a Swiss river.

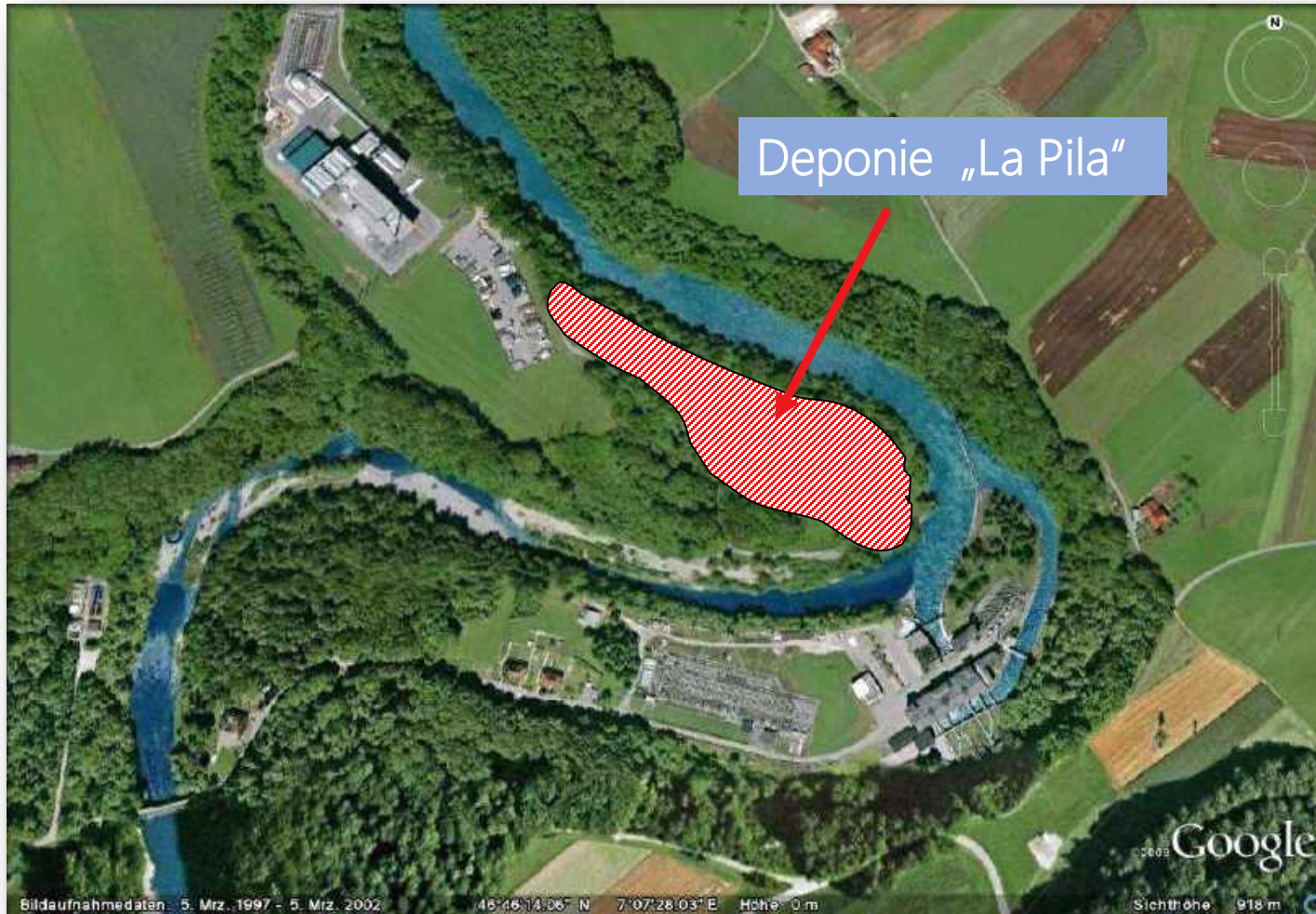
## 4. Point sources of PCBs, contaminated soil & human exposure

PCB contamination point sources: Metal smelter dl-PCBs and PCDD/Fs in fish from river Birsi



## 4. Point sources of PCBs, contaminated soil & human exposure

### Landfill as PCB point source for the river Saane

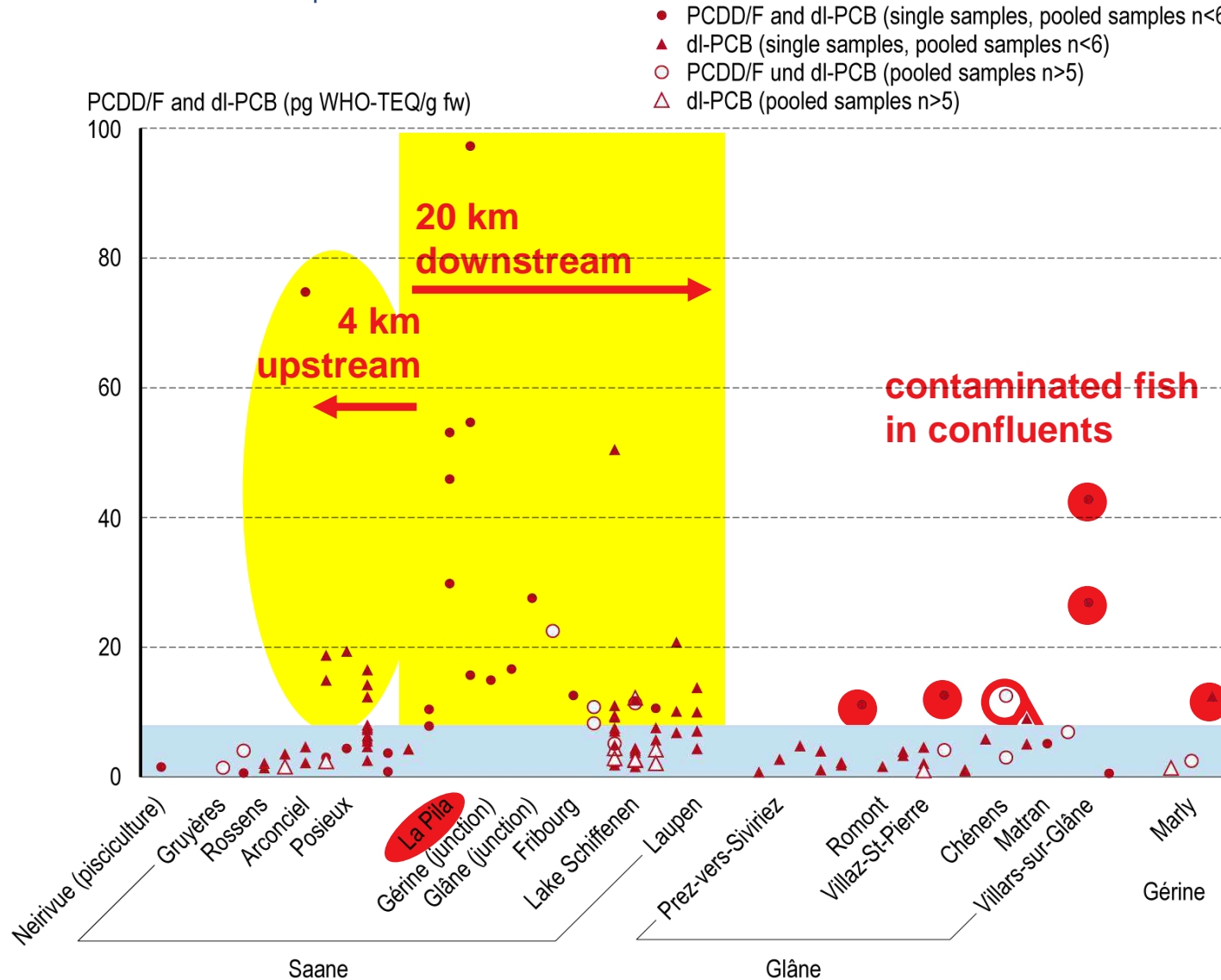


- PCB inventory of the landfill: > 20 tonnes deposited 1960/70s
- Source: Landfill of a capacitor factory
- Continuous emission with peak emission during flooding.

<https://www.fr.ch/daec/pila>

## 4. Point sources of PCBs, contaminated soil & human exposure

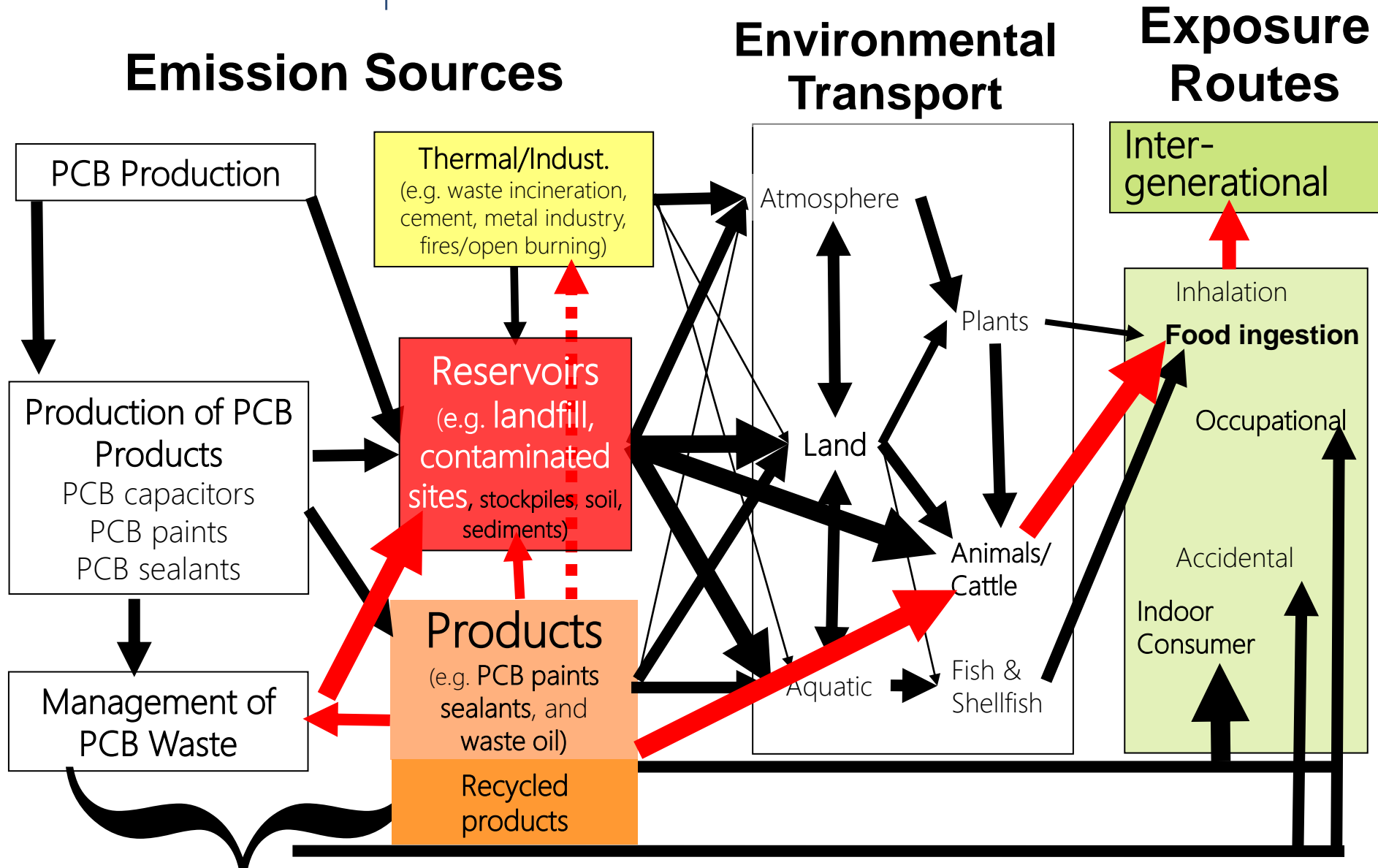
### PCB contamination from point sources: Landfill dl-PCBs and PCDD/Fs in fish from river Saane



- 20% of the analyzed samples (n=120)
- above the Maximum Level (ML)
- Near La Pila all samples above ML
- Some pooled sample >70 individuals
- 95% of the WHO-TEQ from dl-PCB

# 5. PCB waste oil management and short-cuts to food & human exposure

## "Life-Cycle" of PCBs and human exposure – SHORTCUTS



# 5. PCB waste oil management and short-cuts to food & human exposure

## Challenge in PCBs Management of Waste oils

Waste oils is a large material and recycling flow including e.g. used transformer oils, lubricant oils, hydraulic oils, cutting oils.

It has been discovered and documented e.g. in Sri Lanka that PCB oils from transformers going out of the grid are frequently reused by small companies to fill or refill other transformers.

Furthermore the waste oil is used in Sri Lanka for the production of grease and for underbody corrosion protection of cars.

In Ghana and Nigeria PCB containing waste oils were reported to be partly reused in creams or pomade.

This demonstrates that PCB oils in developing countries are recycled into open uses with associated releases and human exposure.

A large challenge to control PCB containing oils in developing countries due to recycling value of waste oils and the cost if they are disposed.



## 5. PCB waste oil management and short-cuts to food & human exposure

### PCB challenges in material cycles: Waste oils challenges in industrial countries - Food crisis

#### PCB/Dioxin crises Belgium (1999)

Ca. 25 liter PCB oil were disposed in the wrong collection box for food fat/oil and mixed with 107 t fat for animal feed.

Chicken eggs, meat from chicken, pork and beef were found in Belgium several hundred times above today's EU food limits.

446 poultry farms, 746 pig and 393 cattle farms impacted.

20,000 t poultry, 6,000 t pigs, 400 t cattle, million eggs (were destroyed/combusted).

1 billion US\$ direct costs for Belgium food production.

**Material Cycle Management of oils/fat:** In the EU it is since then **prohibited** that industrial waste oils and waste food fats are managed within the **same** company!

Ref: Fiedler et al. (2000) Study on behalf of the EU Commission, Sep.2000.



## 5. PCB waste oil management and short-cuts to food & human exposure

### PCB challenges in material cycles: Waste oils challenges in industrial countries - Food crisis

#### Irish pork-crisis (2008):

Waste oil containing PCBs were used to dry animal feed in Ireland which was used then as commercial feed for pork and beef.

Concentrations of PCDD/F and PCBs, discovered in pork meat at levels that were between 80 and 200 times EU food limits.

On 6 December 2008, the Food Safety Authority of Ireland ordered the recall and destruction of all Irish pork products dating back to 1. September.

The Financial damage was approximately 120 million EURO

Ref. :

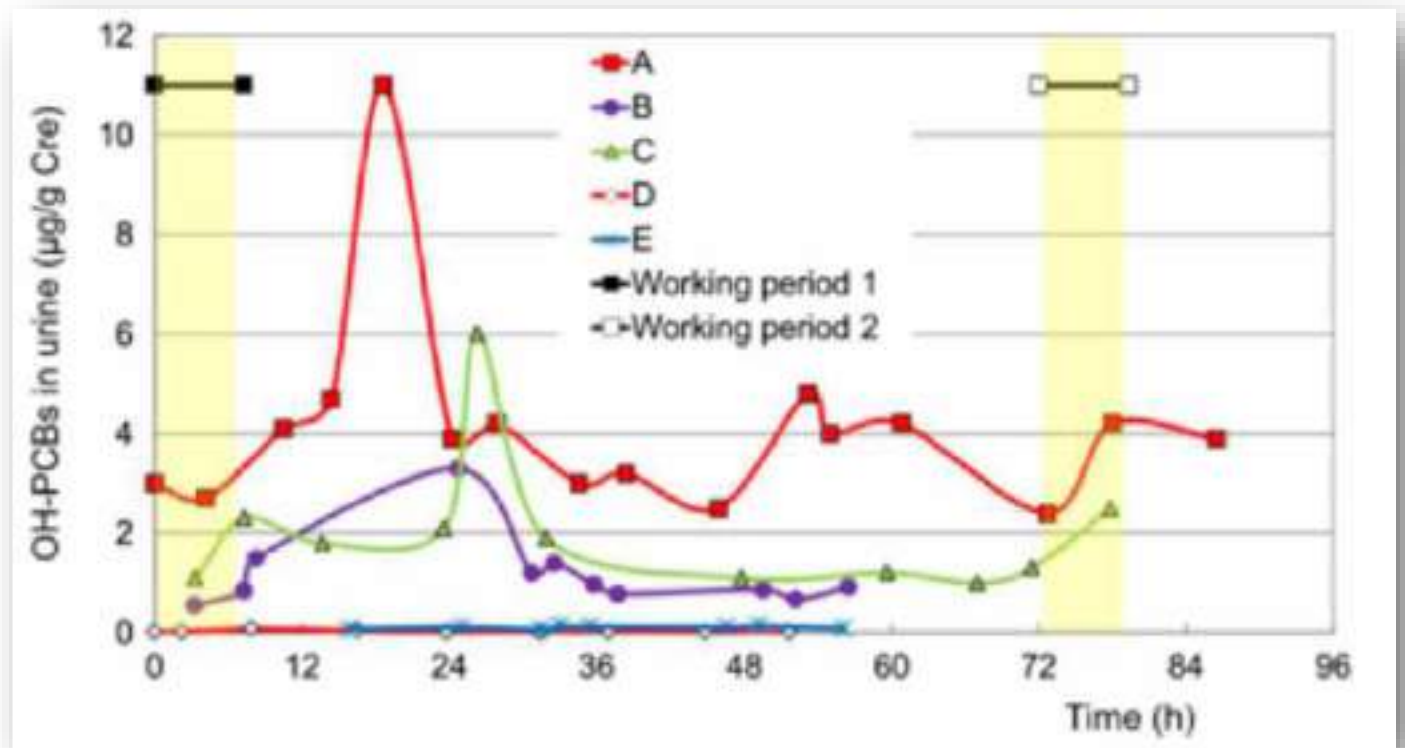
- 1) Marnane (2012) J. Environ. Monit., 14, 2551–2556.
- 2) [http://en.wikipedia.org/wiki/2008\\_Irish\\_pork\\_crisis](http://en.wikipedia.org/wiki/2008_Irish_pork_crisis)

## 6. PCB equipment/oil management and workers exposure

### Exposure to PCBs during management of PCB equipment (case study Japan)

PCB metabolites (OH-PCBs) increase in PCB-equipment transport workers depending on the behavior of workers with protection (PPE).

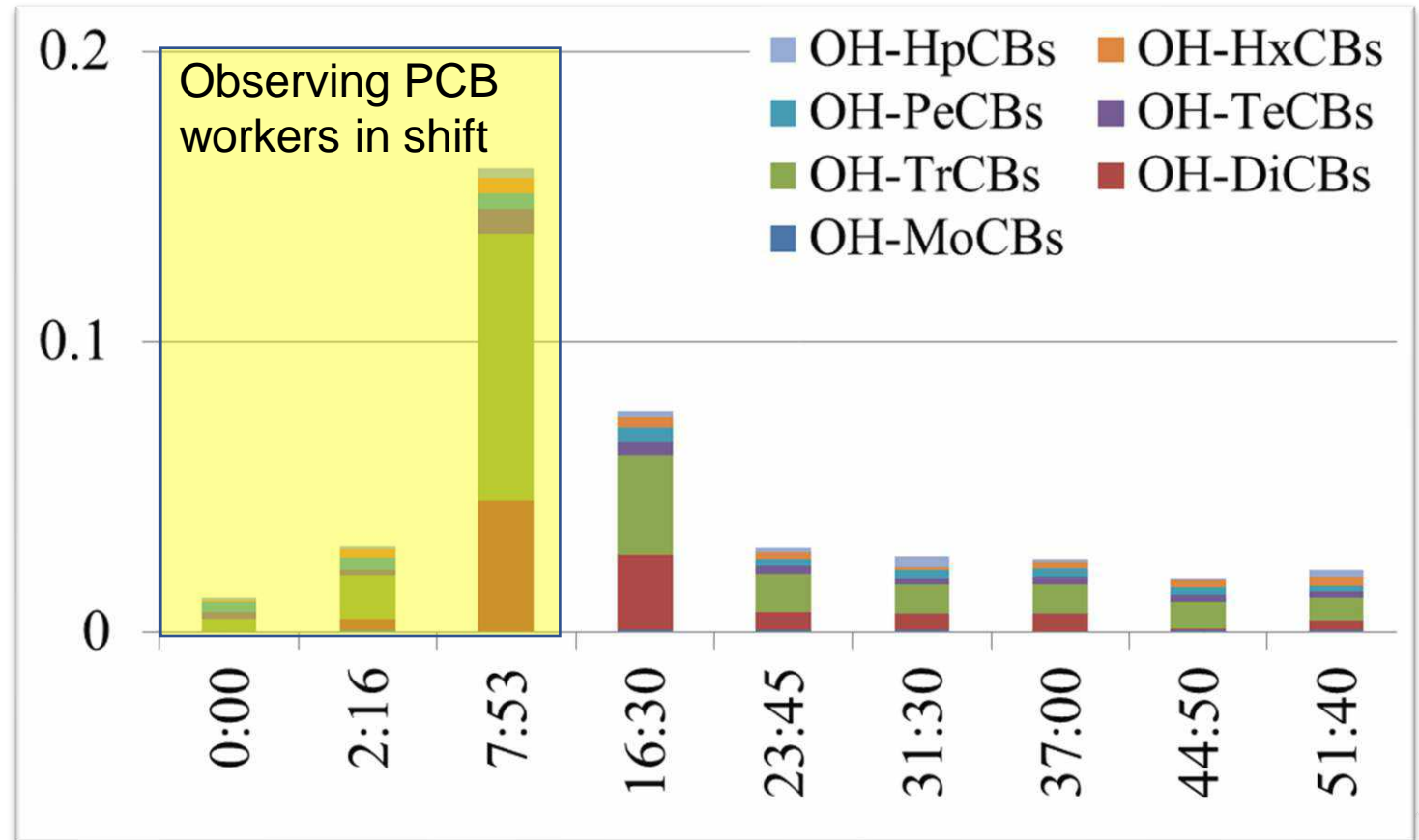
Good education, protection and survey needed for PCB management!



## 6. PCB equipment/oil management and workers exposure

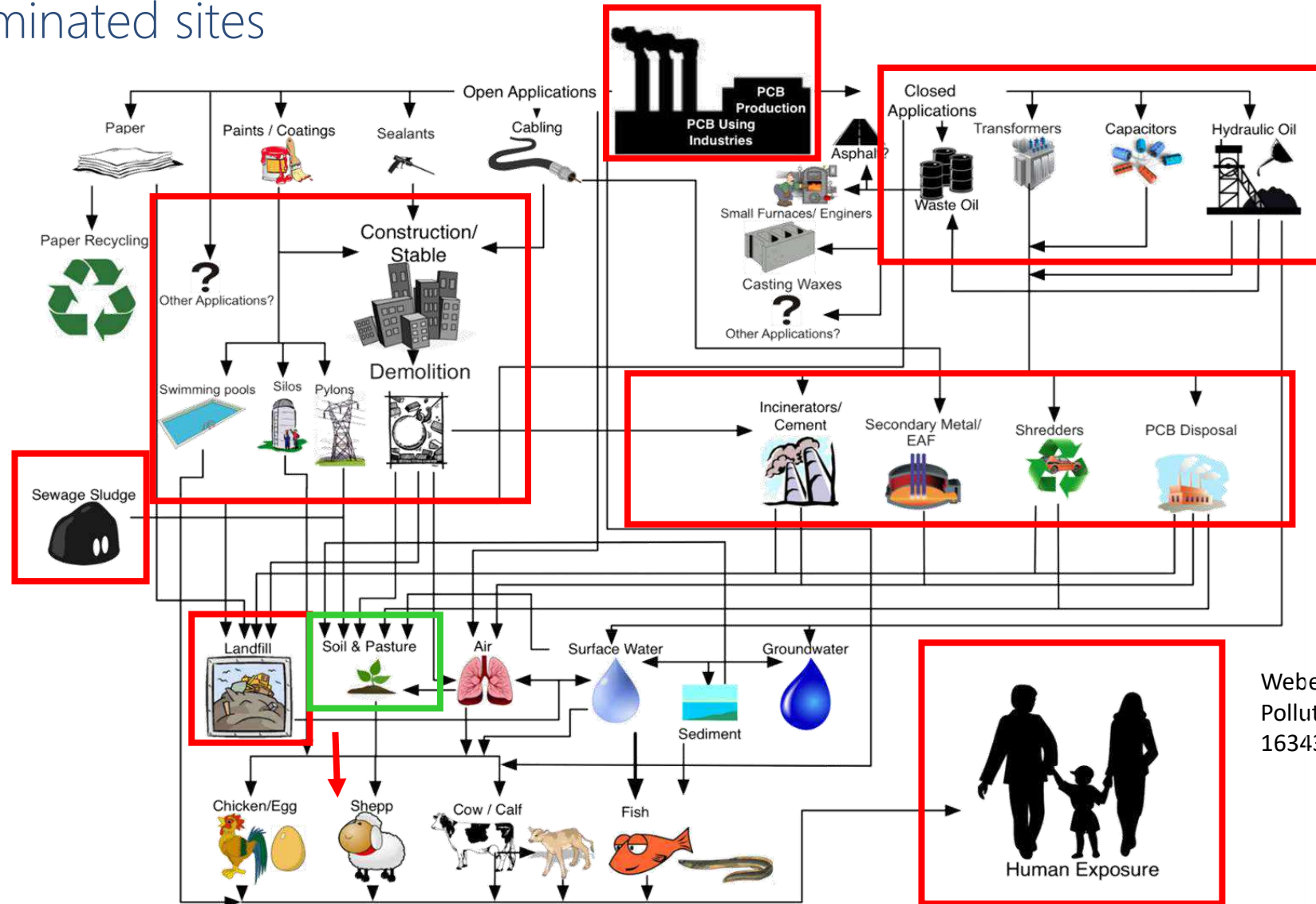
### Exposure to PCBs during management of PCB equipment (case study Japan)

PCB metabolites (OH-PCBs) even slightly increases in researchers monitoring the transport workers (without touching any equipment).



# 6. PCB equipment/oil management and workers exposure

The life cycle of PCBs in production, use, waste treatment and disposal/recycling resulted in contaminated sites



Weber et al. (2018) Environ Sci Pollut Res Int. 25(17), 16325-16343;

## More Information

- <http://chm.pops.int/Implementation/PCBs/DocumentsPublications/tabid/665>
- Basel Convention: [www.basel.int](http://www.basel.int)
- Rotterdam Convention: [www.pic.int](http://www.pic.int)
- Stockholm Convention: <http://chm.pops.int/>
- Montreal Protocol/Vienna Convention: <http://ozone.unep.org>
- SAICM: <http://www.saicm.org/>
- POPs phase out & alternatives: <http://poppub.bcrc.cn/>
- OECD/IOMC: <http://www.oecd.org/chemicalsafety/>
- Science: [www.ipcp.ch](http://www.ipcp.ch); <http://greensciencepolicy.org/>
- NGO: [www.ban.org](http://www.ban.org); [www.ipen.org](http://www.ipen.org); [www.ihpa.info](http://www.ihpa.info); [www.chemsec.org](http://www.chemsec.org)
- Better-world-links: <http://www.betterworldlinks.org/>





**Thank you for your attention !**

<https://www.pcb.unitar.org/>

