Dechlorination of PCBs During Anaerobic Sludge Digestion

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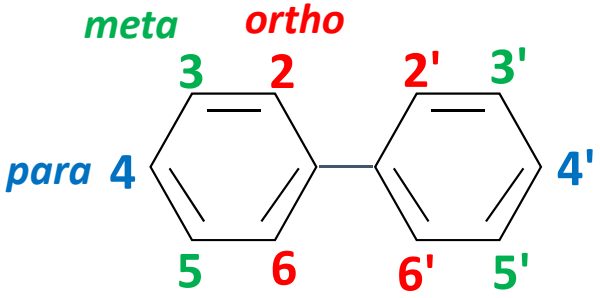
PCBs: PolyChlorinated Biphenyls



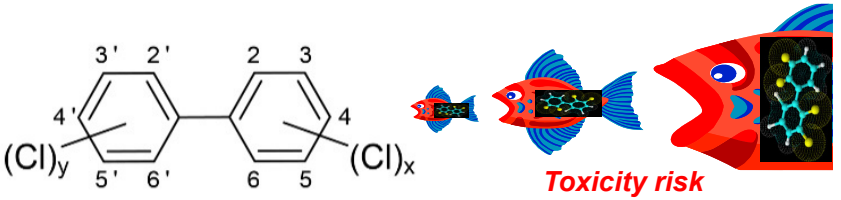
Structural formula of PCB

- ✓ Trade name for commercial mixtures of PCBs (80-110 PCB congeners)
- ✓ Aroclor mixtures are specified with a four-digit code

Aroclor { 1242, 1248, 1254, 1260 }

- ✓ Man-made, 209 congeners
- ✓ Non-flammable, resistant
  - transformers, capacitors, hydraulic fluid, adhesives, fire retardants, paints, coatings
- ✓ The number & location of chlorine atoms determine
  - properties
  - pathways and toxicity

Problems with PCBs



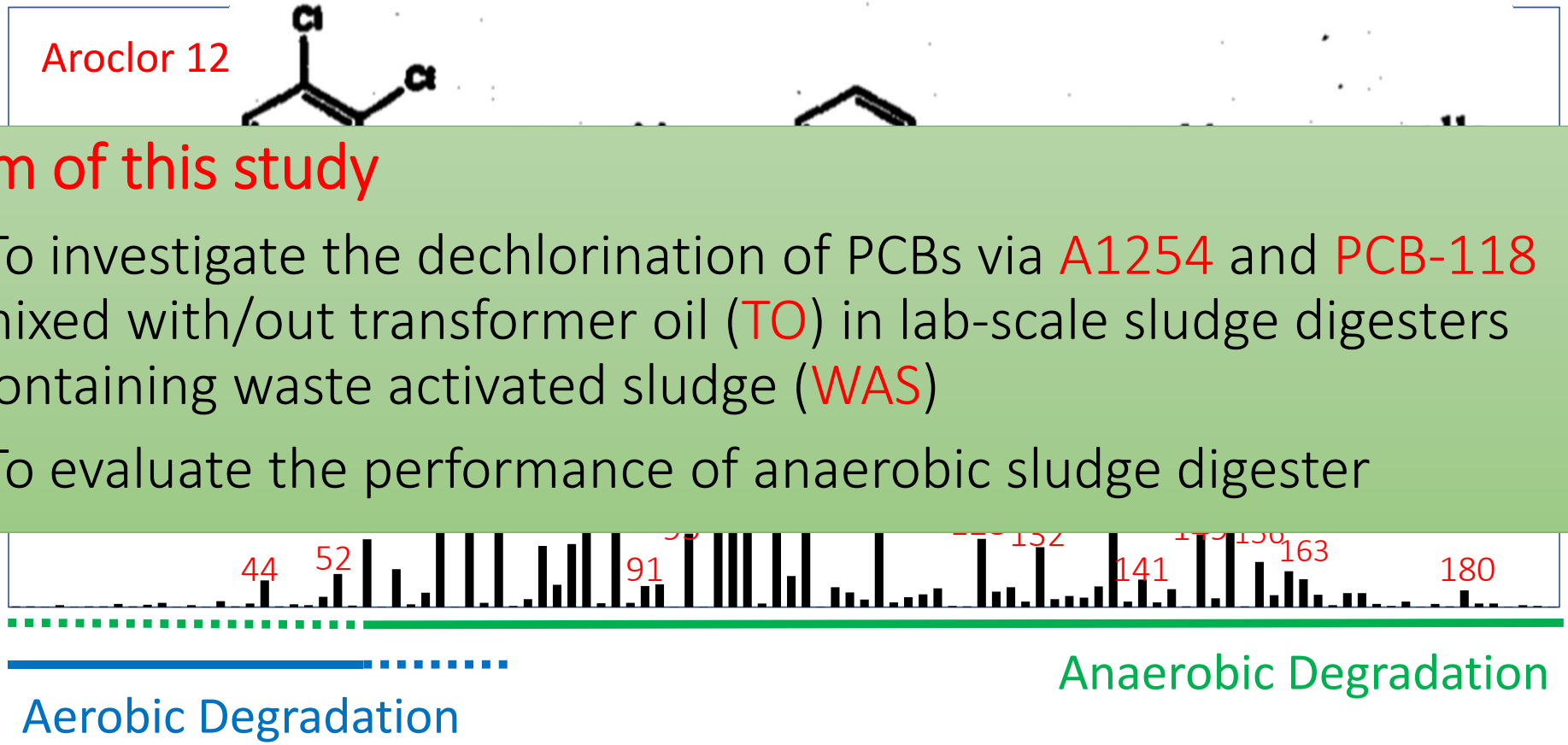
Sediment, streams, sewers, air: accidental spills or possibly illegal disposal; open burning /incomplete incineration; vaporization

rganic/toxic pollutant
e our water & food
ative/biomagnify in food chain
f being carcinogen

Continue to be a threat to human and ecosystem health which has led the European Union and many other countries to regulate the PCB concentrations in *air and water as well as sludge*.

The dechlorination of PCBs is needed to reduce the exposure level of PCBs, thereby, reduce the potential carcinogenicity and bioaccumulation of PCBs

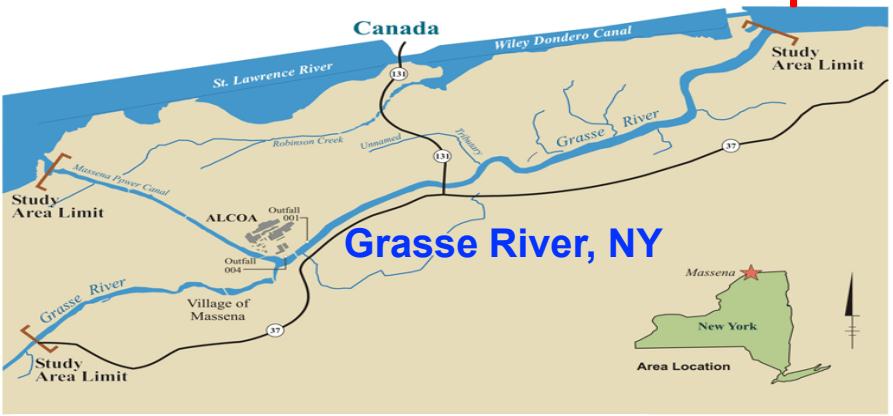
The Microbial Fate of PCBs

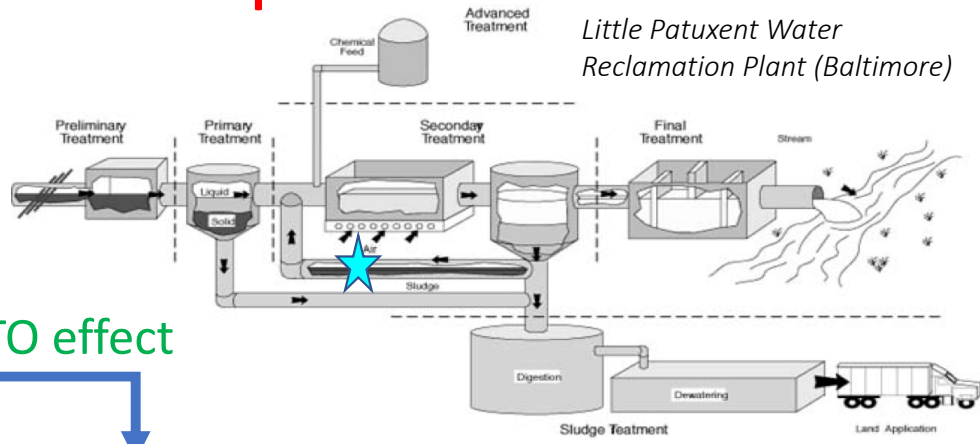


Aim of this study

- To investigate the dechlorination of PCBs via A1254 and PCB-118 mixed with/out transformer oil (TO) in lab-scale sludge digesters containing waste activated sludge (WAS)
- To evaluate the performance of anaerobic sludge digester

Experimental Set-up



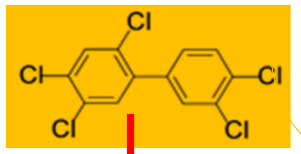


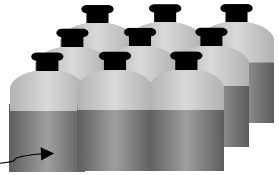
Little Patuxent Water Reclamation Plant (Baltimore)

2. TO effect

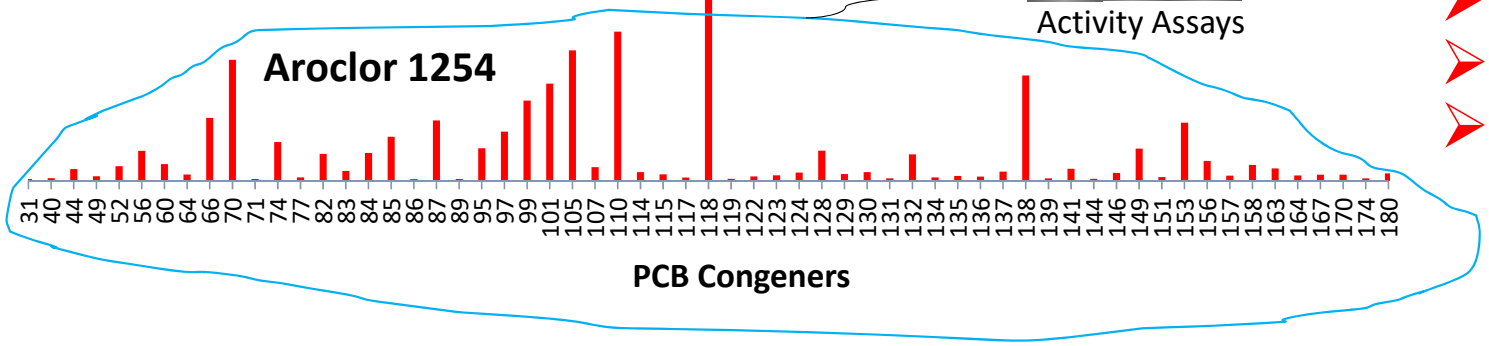
1. WAS used as carbon source

3. Grass river sediment: enrichment culture as a dechlorinating inoculum



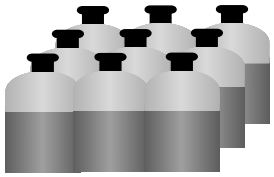


Activity Assays

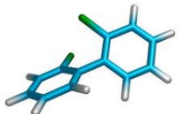


- Dechlorination rate
- Pathways
- Community analysis
- Digester performance

High Throughput PCB Reducing Microbial Analysis/Monitoring

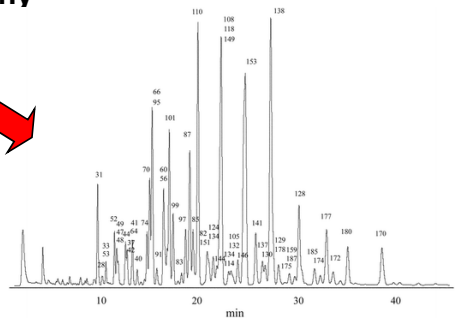


Activity Assays

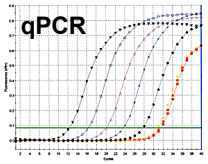


PCB Extraction

Gas Chromatography



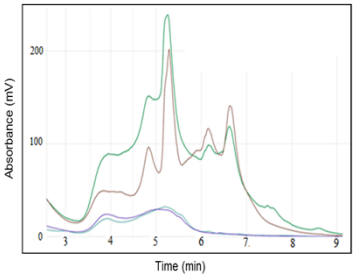
DNA Extraction



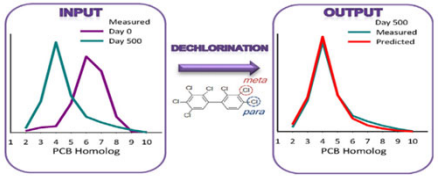
Species Enumeration

PCR

dHPLC

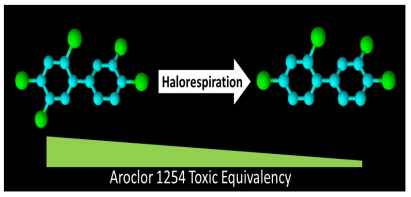


Species Diversity

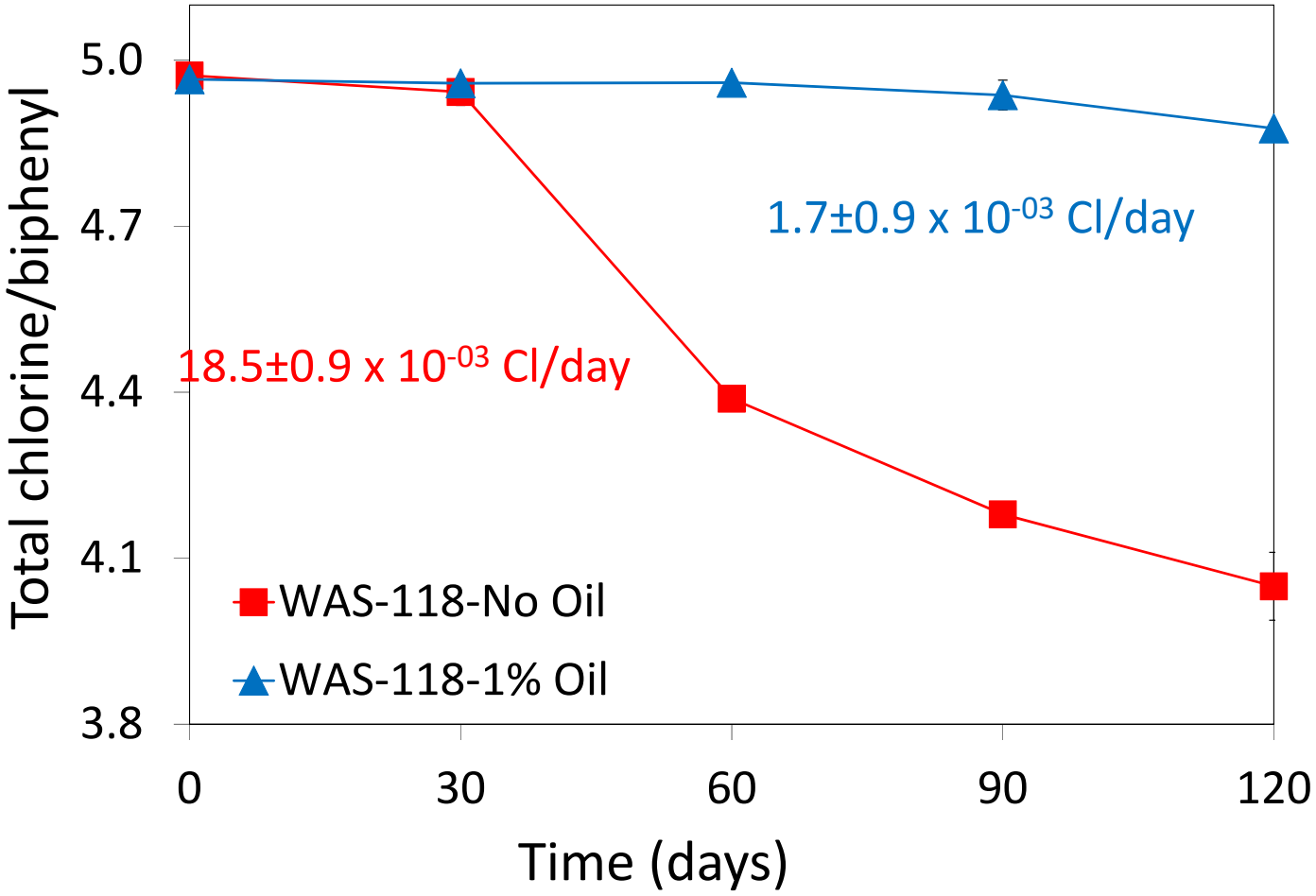


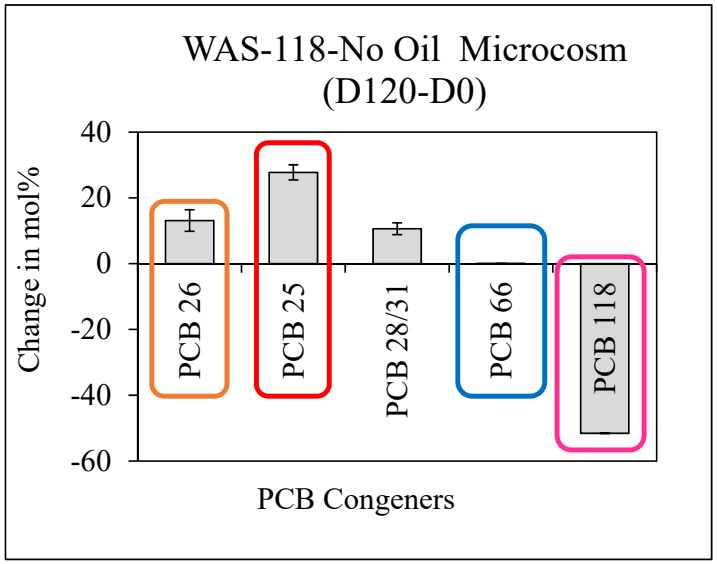
Dechlorination pathway determination

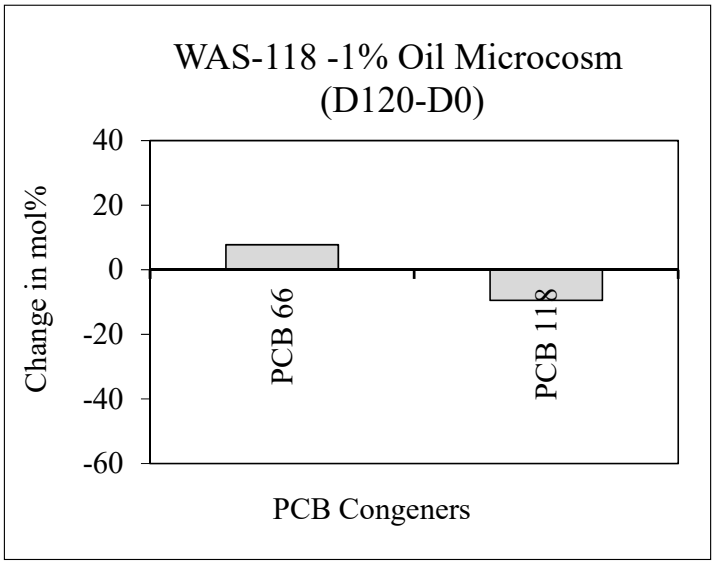
Dechlorination Activity

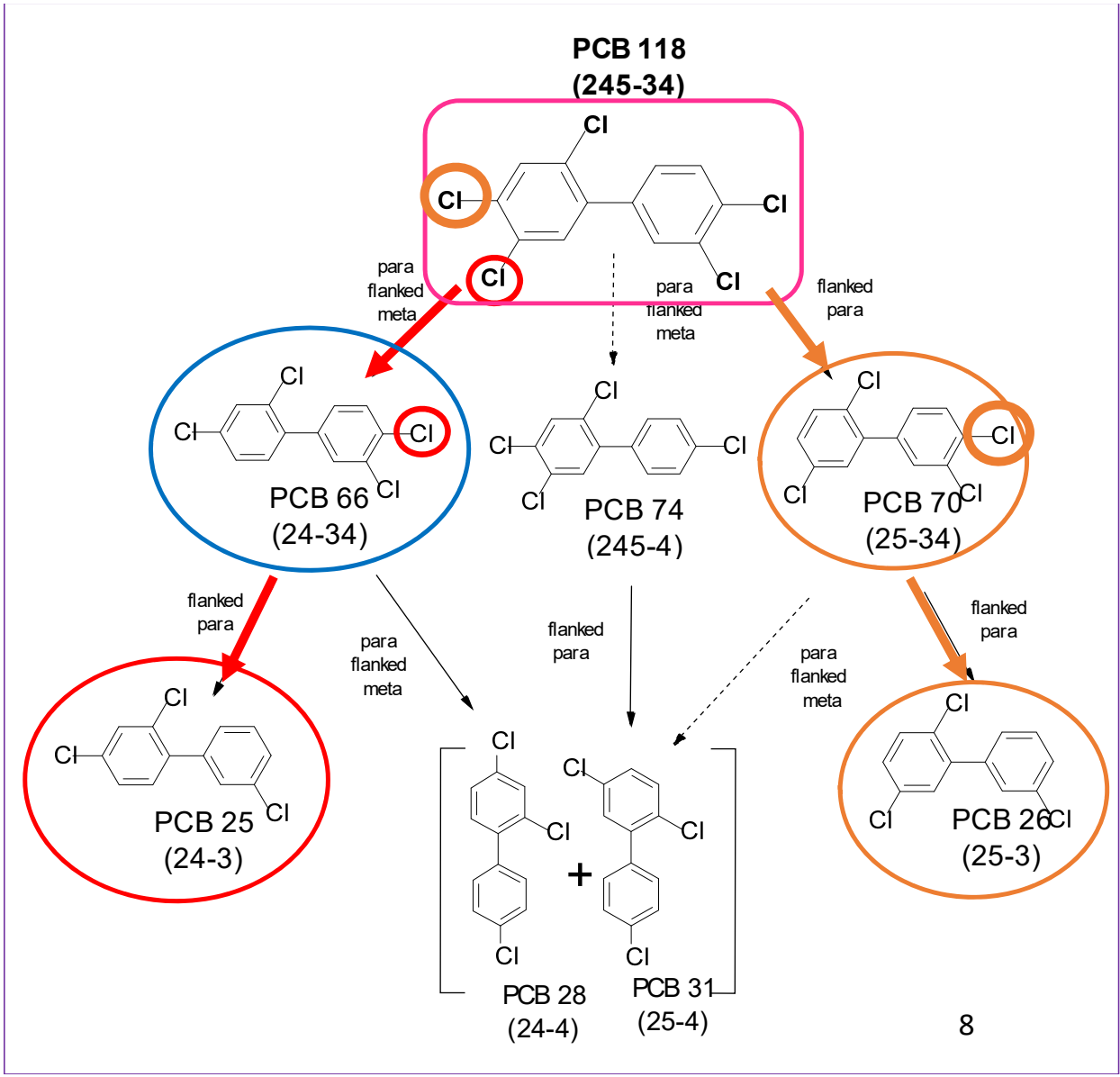


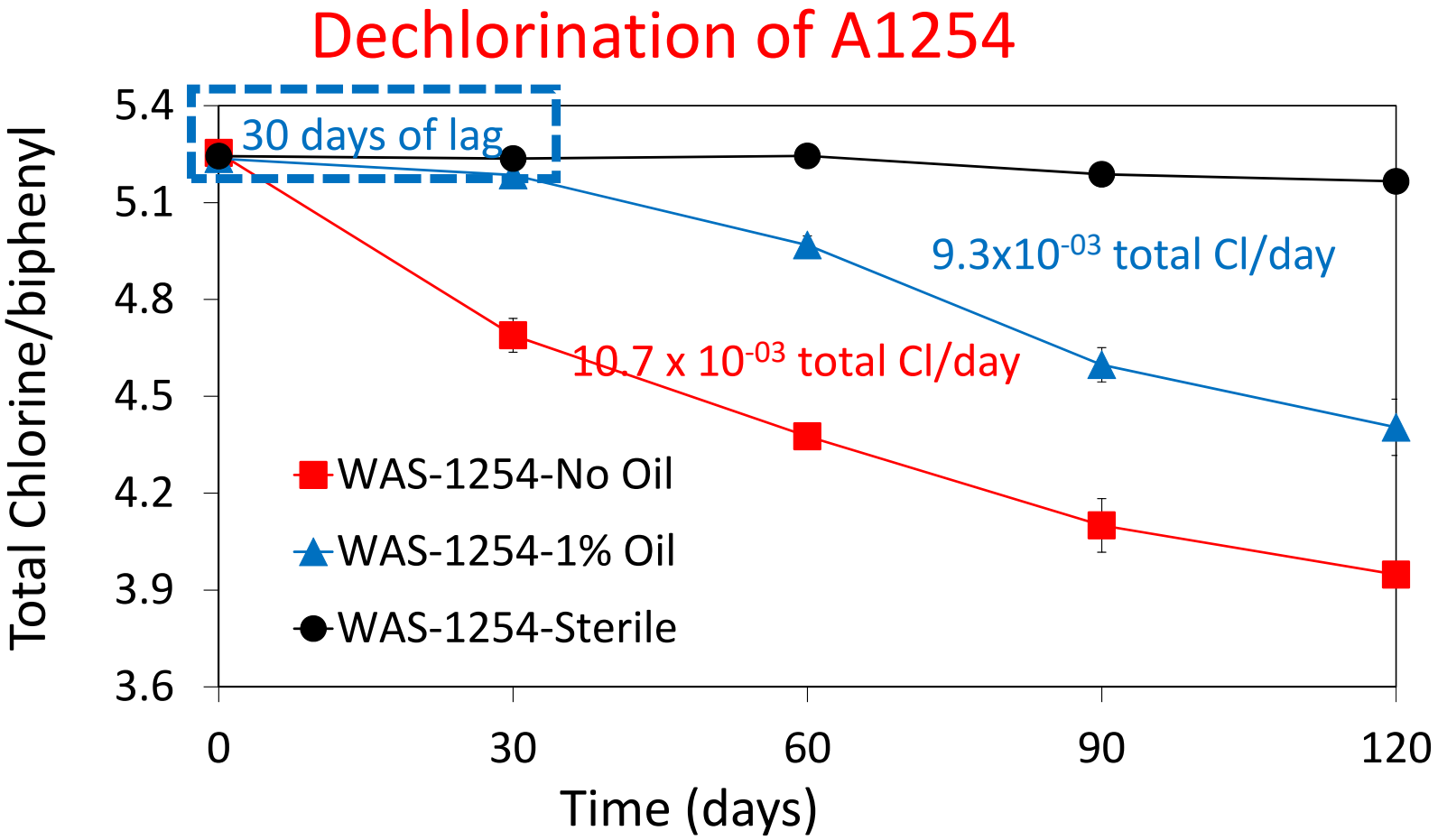
Dechlorination of PCB-118



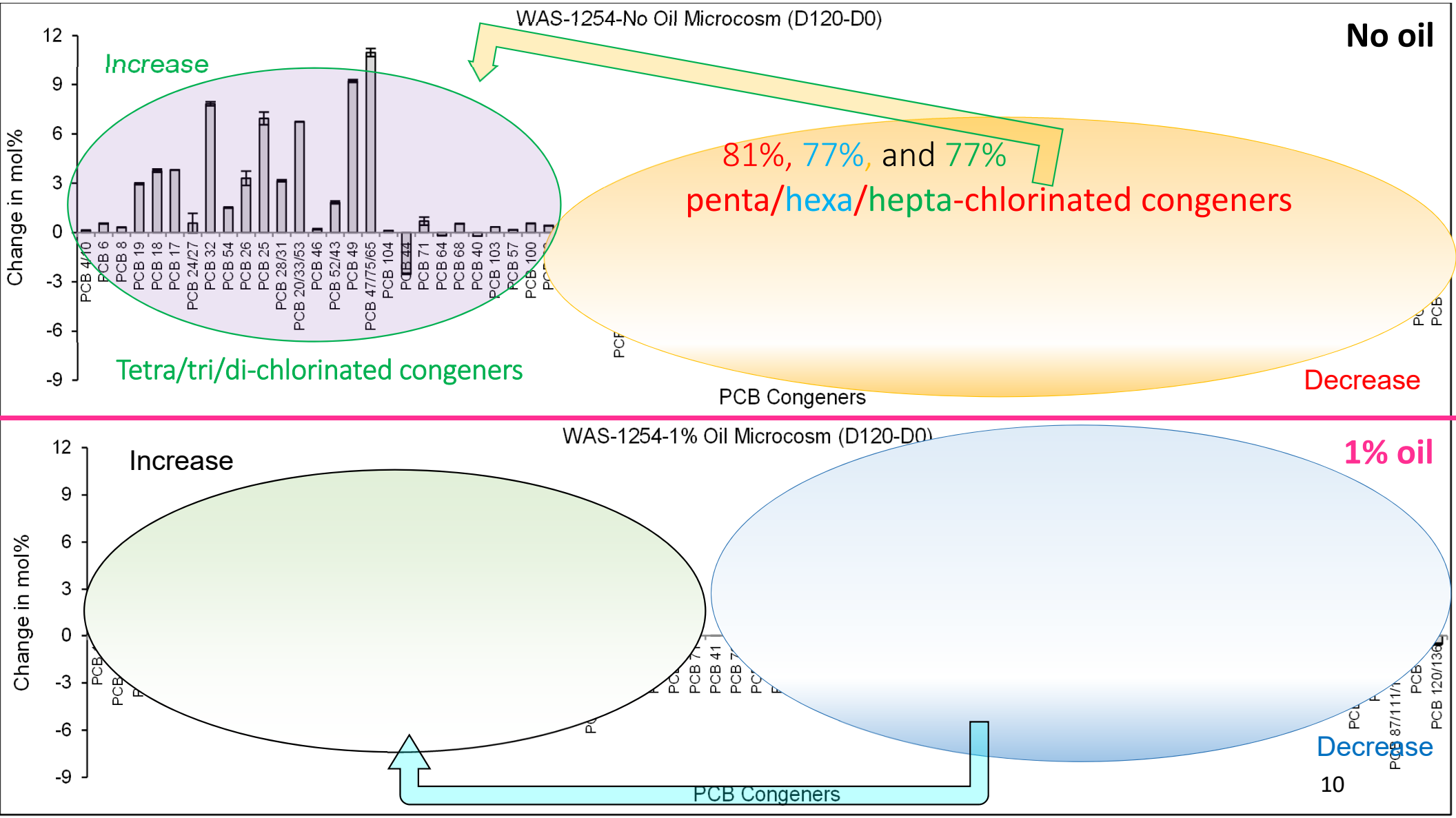

WAS-118-No Oil Microcosm
(D120-D0)
Change in mol%
40
20
0
-20
-40
-60
PCB 26
PCB 25
PCB 28/31
PCB 66
PCB 118
PCB Congeners

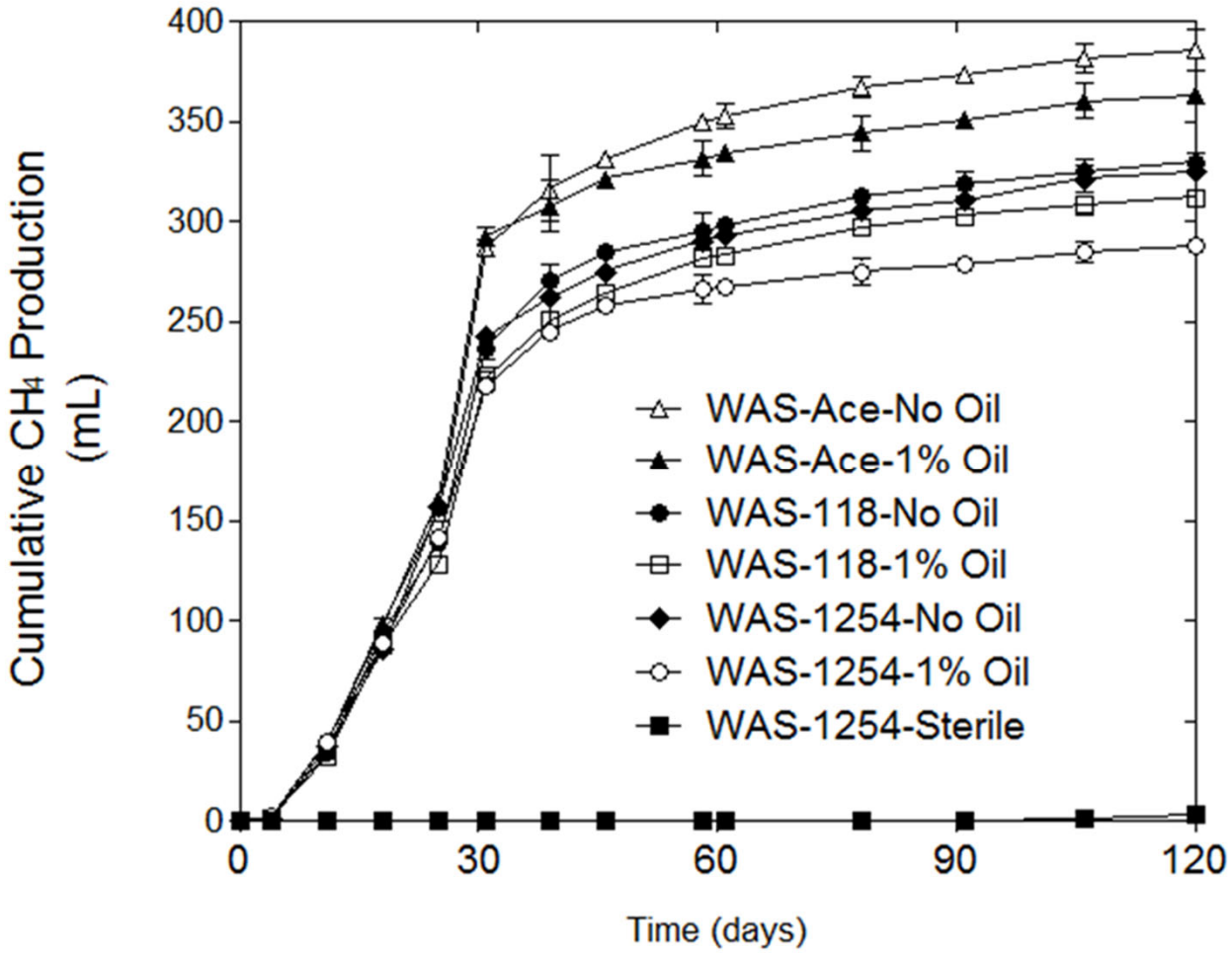

WAS-118 -1% Oil Microcosm
(D120-D0)
Change in mol%
40
20
0
-20
-40
-60
PCB 66
PCB 118
PCB Congeners


PCB 118
(245-34)
para flanked meta
para flanked meta
flanked para
PCB 66
(24-34)
PCB 74
(245-4)
PCB 70
(25-34)
flanked para
para flanked meta
flanked para
para flanked meta
flanked para
PCB 25
(24-3)
PCB 28
(24-4)
PCB 31
(25-4)
PCB 26
(25-3)
8



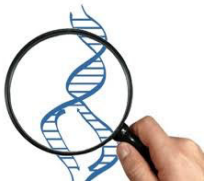
✓The overall dechlorination extent of Aroclor 1254 decreased from 25% to 16% by the addition of 1% TO into the microcosms


WAS-1254-No Oil Microcosm (D120-D0)
No oil
Increase
81%, 77%, and 77%
penta/hexa/hepta-chlorinated congeners
Tetra/tri/di-chlorinated congeners
Decrease
Change in mol%
PCB Congeners
WAS-1254-1% Oil Microcosm (D120-D0)
1% oil
Increase
Decrease
Change in mol%
PCB Congeners



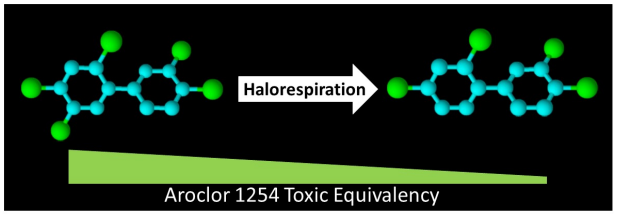
Gas production rates:
883-1116 mL CH_4/g of VS destroyed
consistent with typical results of 750-1120 mL/g of VS destroyed

Variation of the cumulative CH_4 productions throughout the 120 days of incubation



Phylogenetic tree showing the relationships between the 16S rRNA gene sequences of phylotypes (P1-P10) identified in PCB dechlorinating WAS microcosms inoculated with Grasse River sediments (shown in bold) and selected reference sequences of the domain Bacteria.

Conclusions



- ✓PCB-118 and A1254 *dechlorination occurred* even in the presence of Transformer Oil in sludge digester, albeit at lower rate with TO
- ✓Transformer Oil did *not affect the dechlorination pathway*
- ✓The *toxicity of dioxin-like congeners reduced* by 90% and 68% without or with TO
- ✓Hence, results indicate that *Anaerobic Digesters* in WWTPs can be considered as a *potential step* for toxicity reduction of PCB contaminated sludge and/or for dechlorination of PCB contaminated transformer oils

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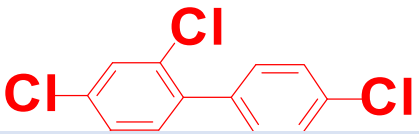
Why A1254 & PCB-118 in TO?



- ✓ One of the toxic congeners.
- ✓ One of the PoPs.
- ✓ The largest reservoirs of PCBs
- ✓ About 125 million transformers containing PCBs in use as of 1999.
- ✓ 61% of PCBs in electrical transformers still in use, 12% in electrical capacitors and 27% in storage waiting for disposal (Jones, 2003)

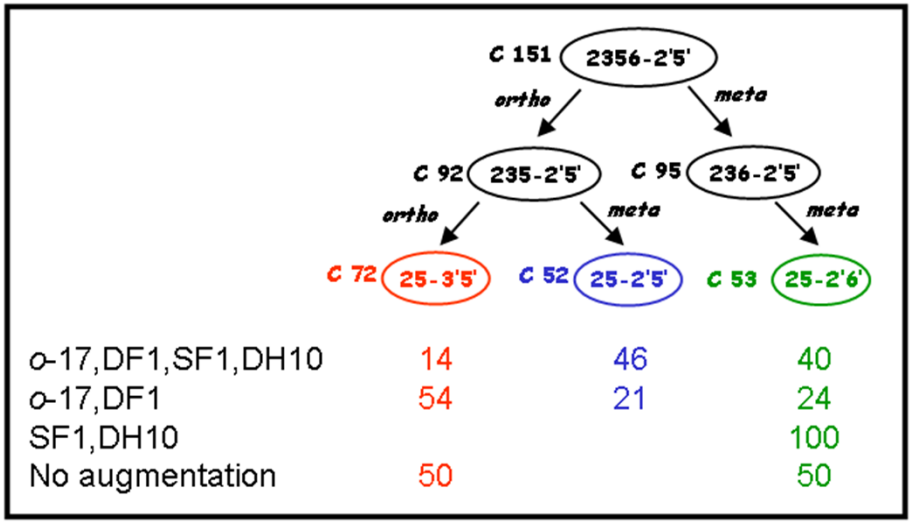
- ✓ The 2nd most produced/sold Aroclor mixture (sales records of Monsanto U.S., the leading manufacturer globally)
- ✓ Widely found in sludge, sediment, and soil around the globe.
- ✓ The most toxic PCB mixture with 8-16 times more toxic than A1248 and 3-6 times more toxic than A1242 and A1260, *due to its large % of congeners with the dioxin-like properties.*

Congener IUPAC no.	TEF
Coplanar	
#126 (345-34)	0.1
#169 (345-345)	0.03
#77 (34-34)	0.0001
Mono-ortho coplanar	
#118 (245-34)	0.00003
#105 (234-34)	0.00003
#123 (345-24)	0.00003
#114 (2345-4)	0.00003
#156 (2345-34)	0.00003
#157 (234-345)	0.00003
#167 (245-345)	0.00003
#189 (2345-345)	0.0003

Dechlorination pathway	Average ± Standard deviation (mole‰)
	GR
PCB 35 (34-3) --> PCB 11 (3-3)	13.81±13.86
PCB 40 (23-23) --> PCB 16 (23-2)	8.57±3.61
PCB 42 (23-24) --> PCB 17 (24-2)	32.34±9.53
PCB 43 (235-2) --> PCB 18 (25-2)	18.92±9.77
PCB 44 (23-25) --> PCB 18 (25-2)	29.19±7.74
PCB 46 (23-26) --> PCB 19 (26-2)	17.27±11.95
PCB 59 (236-3) --> PCB 27 (26-3)	16.05±14.51
PCB 60 (234-4) --> PCB 28 (24-4)	10.23±5.15
PCB 64 (236-4) --> PCB 32 (26-4)	13.57±11.79
PCB 66 (24-34) --> PCB 25 (24-3)	8.88±8.16
PCB 66 (24-34) --> PCB 28 (24-4)	42.84±10.8
PCB 67 (245-3) --> PCB 25 (24-3)	10.44±8
PCB 67 (245-3) --> PCB 26 (25-3)	8.12±8.13
PCB 70 (25-34) --> PCB 26 (25-3)	10.04±9.18
PCB 70 (25-34) --> PCB 31 (25-4)	29.12±10.1
PCB 71 (26-34) --> PCB 27 (26-3)	15.05±12.2
PCB 71 (26-34) --> PCB 32 (26-4)	13.43±12.56
PCB 74 (245-4) --> PCB 28 (24-4)	15.96±11.75
PCB 77 (34-34) --> PCB 35 (34-3)	14.47±14.25
PCB 77 (34-34) --> PCB 37 (34-4)	18.22±17.51
PCB 84 (236-23) --> PCB 45 (236-2)	13.28±13.11
PCB 84 (236-23) --> PCB 46 (23-26)	20.8±13.09
PCB 85 (234-24) --> PCB 47 (24-24)	18.29±3.28
PCB 87 (234-25) --> PCB 44 (23-25)	7.46±7.51
PCB 87 (234-25) --> PCB 49 (24-25)	35.04±11.23
PCB 91 (236-24) --> PCB 51 (24-26)	22.89±2.97
PCB 94 (235-26) --> PCB 53 (25-26)	15.46±12
PCB 95 (236-25) --> PCB 53 (25-26)	92.99±6.42
PCB 97 (245-23) --> PCB 42 (23-24)	16.42±4.9
PCB 99 (245-24) --> PCB 47 (24-24)	65.22±6.63
PCB 99 (245-24) --> PCB 49 (24-25)	26.67±15.68
PCB 101 (245-25) --> PCB 49 (24-25)	42.91±23.07
PCB 101 (245-25) --> PCB 52 (25-25)	19.34±13.85
PCB 105 (234-34) --> PCB 66 (24-34)	10.86±4.41
PCB 110 (236-34) --> PCB 59 (236-3)	26.18±23.57
PCB 110 (236-34) --> PCB 64 (236-4)	19.33±17.85
PCB 110 (236-34) --> PCB 71 (26-34)	17.01±16.51
PCB 118 (245-34) --> PCB 66 (24-34)	30.57±16.47
PCB 118 (245-34) --> PCB 67 (245-3)	21.02±16.5
PCB 118 (245-34) --> PCB 70 (25-34)	24.68±15.5
PCB 118 (245-34) --> PCB 74 (245-4)	28.31±18.03
PCB 123 (345-24) --> PCB 66 (24-34)	10.01±6.36
PCB 138 (234-245) --> PCB 99 (245-24)	53.87±3.52
PCB 153 (245-245) --> PCB 101 (245-25)	11.69±7.45
PCB 153 (245-245) --> PCB 99 (245-24)	16.97±8.84
PCB 158 (2346-34) --> PCB 119 (246-34)	7.43±2.43

Selective Activity of Different Phylotypes

Dechlorination of PCB-151



o-17,DF1,SF1,DH10	14	46	40
o-17,DF1	54	21	24
SF1,DH10			100
No augmentation	50		50

Selective activities

Designation	Dechlorination Activities	Culture Status
o-17	Flanked *ortho/meta*	Co-culture
DF-1	Double flanked *meta/para*	Isolate
DEH-10	Double flanked *meta/para* *para* flanked *meta*	Microcosm
SF-1	Double flanked *meta* *ortho* flanked *meta*	Microcosm

Fagervold et al., 2011

Scale-up of PCB Dechlorinators

Distribution of Biocatalysts On-site

SediMite as a delivery system

sowers@umbc.edu

- ✓Develop scale-up protocol for PCB biocatalysts
- ✓Harvest and transport under nitrogen