

# PFAS and dl-POPs in Air by Expert Laboratory



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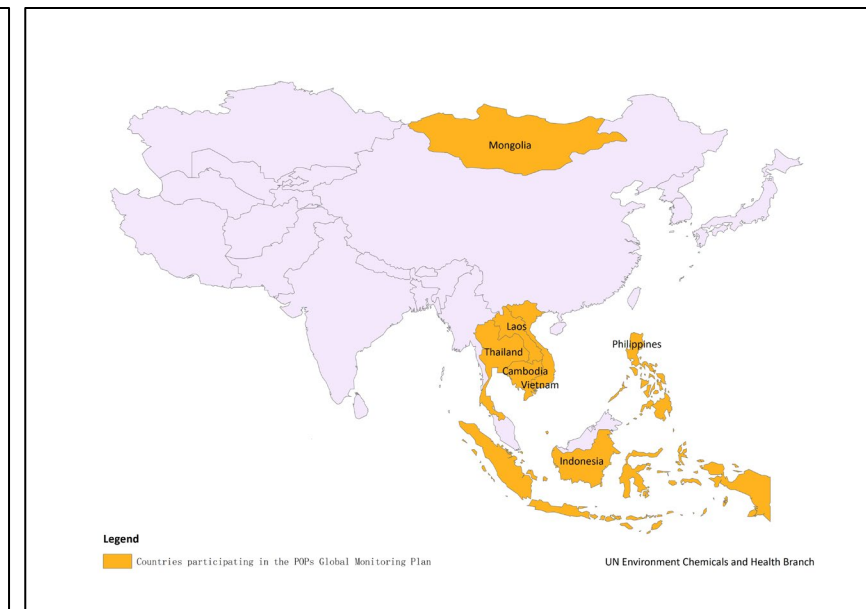
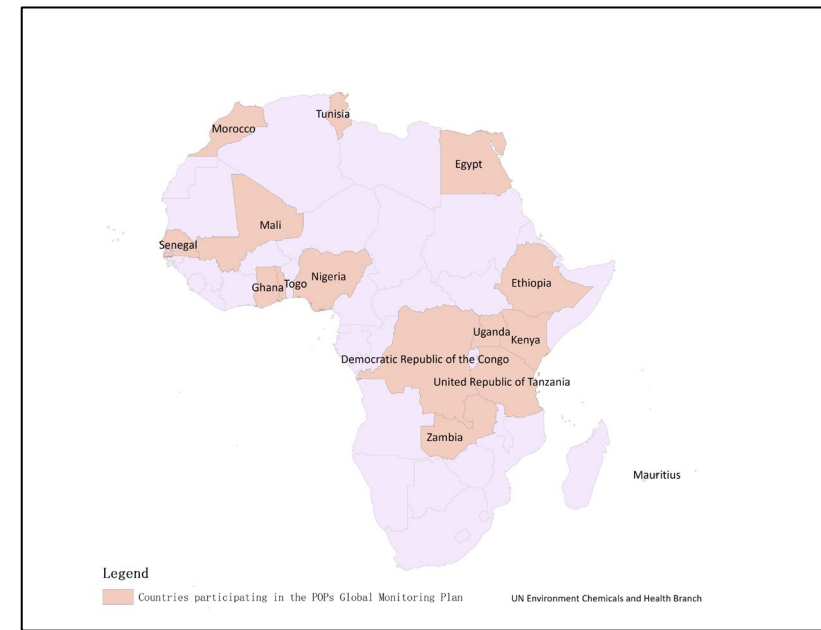
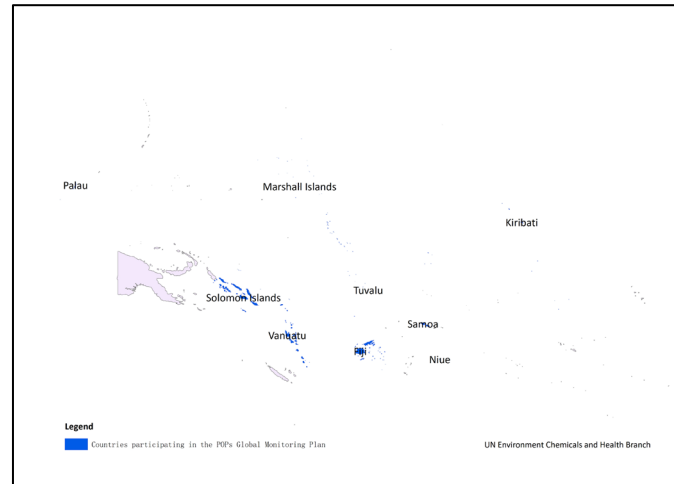
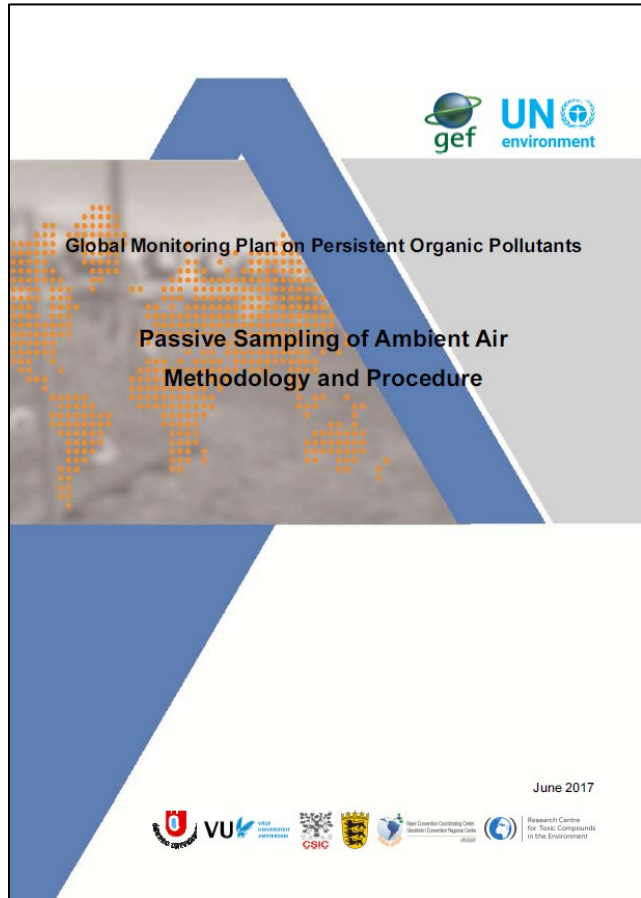
# Content

- Materials and Methods
- Results: Tables and graphics
  - Across all regions on regional basis
  - For each project Region on country basis
  - Comparison in relation to population density or income (WBC)
- Questions?

# Core matrix "air"

- dl-POPs in PAS PUFs
  - already included and analyzed in GMP1 (reference years 2010/2011)
  - from GMP1: 45 results available for comparison
  - From GMP2: 182 results available
- PFAS
  - From GMP1: not included, no data for comparison available
  - From GMP2: More than 350 PUFs received and analyzed
    - \* Some PUFs so deteriorated that no identification and quantification was possible
    - \* Multiple analyses with single PUFs for PFAS and PFOS precursors (only FOSA detectable) and combinations of PUFs from the same year; esp. to quantify the PFOS precursors
    - \* 9 samples from one country very exceptional, 8 excluded from assessments

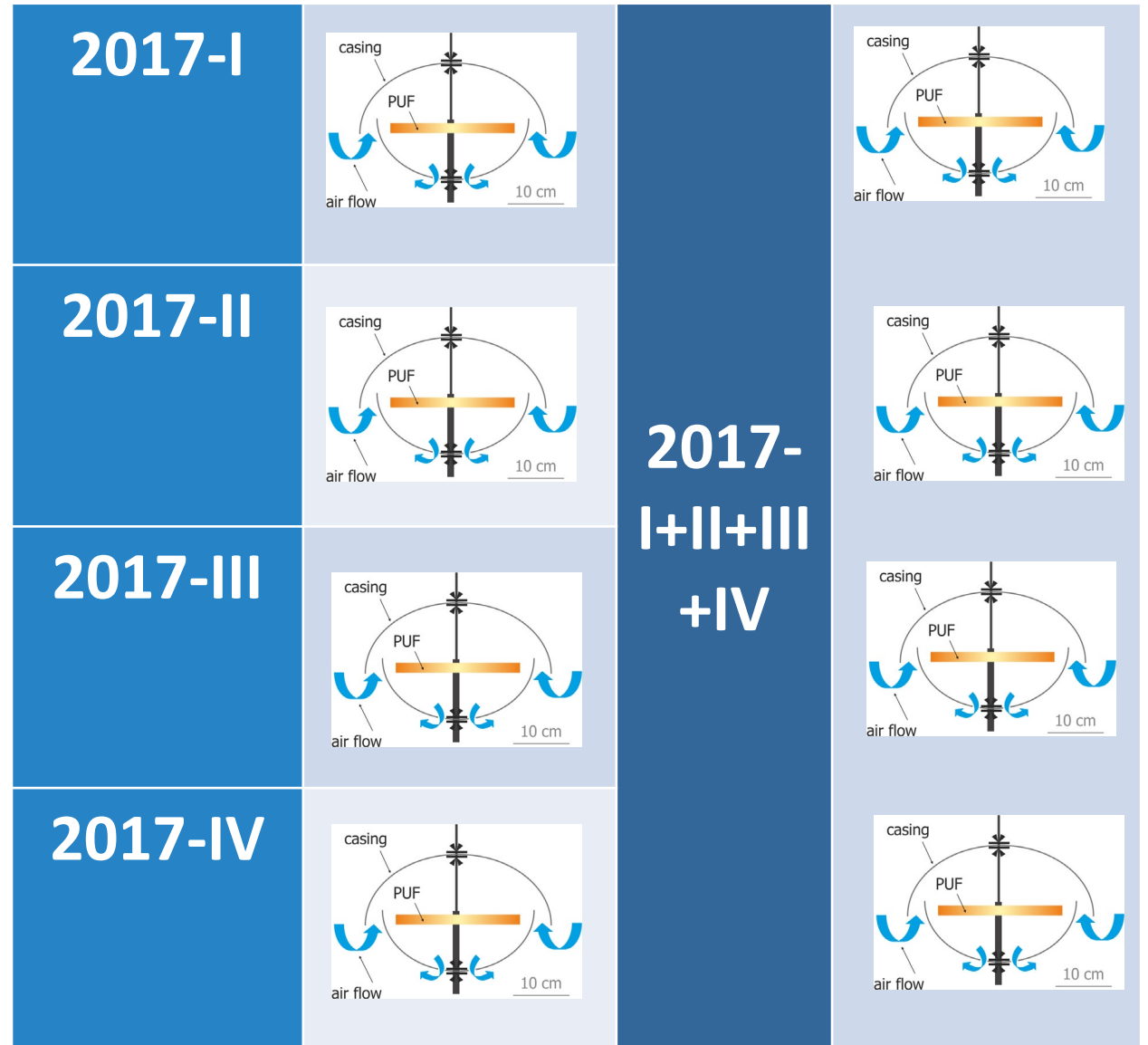
# UNEP guidance documents and participants



# Samples - Reporting

All samples/results are defined as

- ISO-3 code for country
- Sampling Year – YYYY
- Season (I, II, III or IV)
  
- Each season is defined as 90 days or 3 months
  
- Results are normalized to 1 PUF and 3 months exposure



# Definitions – World Bank indicators

Income according to World Bank classification (WBC)

WBC class	GNI per capita, Atlas method (current US\$)
High income	> 12,375
Upper middle income	3,996-12,375
Lower middle income	1,026-3,995
Low income	<= 1,025

Population density based on World Bank statistics

PD_Code	Range: Inhabitants <i>per</i> km <sup>2</sup>
A	<24.9999
B	>25-<99.99
C	>100-<499.9
D	>500-<999.99
E	>1,000-<10,000
F	>10,000

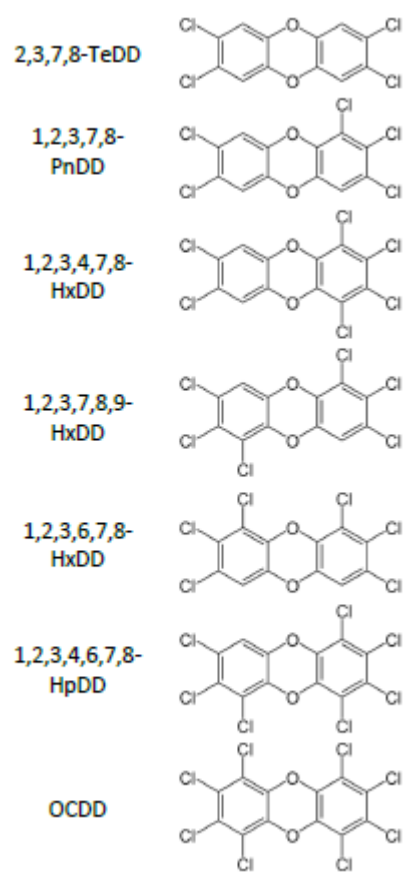
# PAS/PUF Results – dl-POPs

## A.1 GMP1 and GMP2 - All

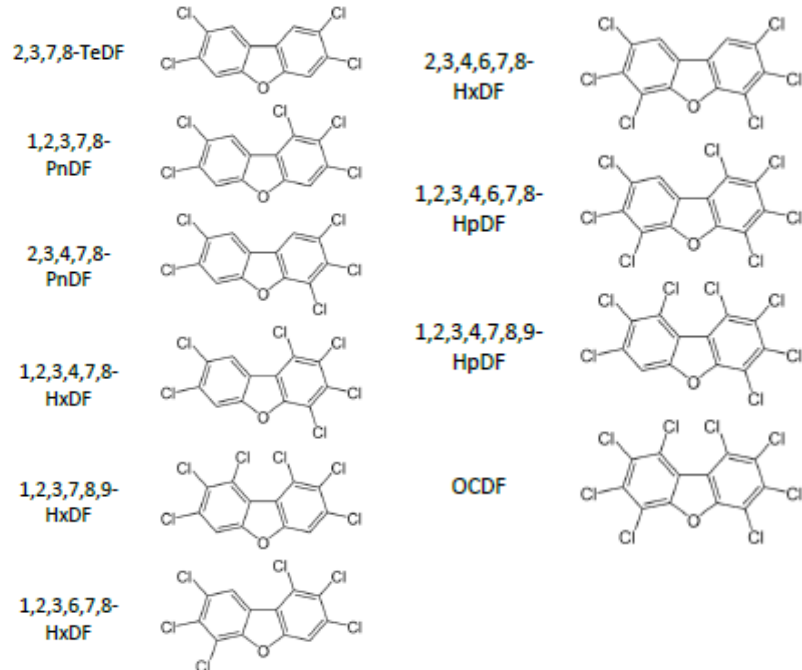
# Dioxin-like (dl) POPs with WHO<sub>2005</sub>-TEFs

## PCDD/PCDF (as TEQ DF)

### PCDD

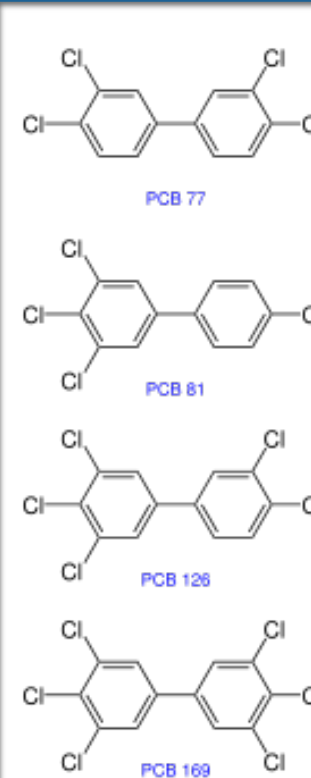


### PCDF

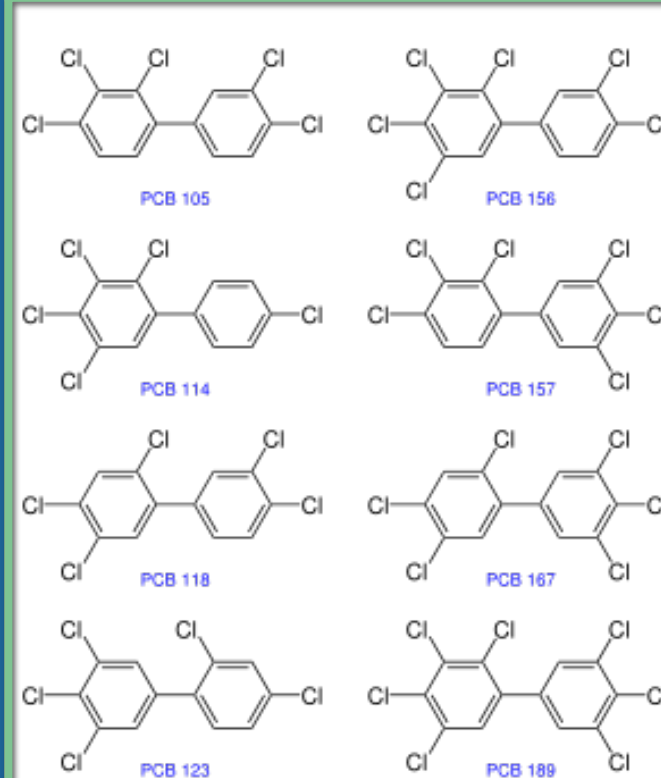


## Dioxin-like PCB (as TEQ PCB)

### Non-ortho (noPCB)



### mono-ortho PCB (moPCB)





# Overview number of samples dl-POPs - GMP1+GMP2

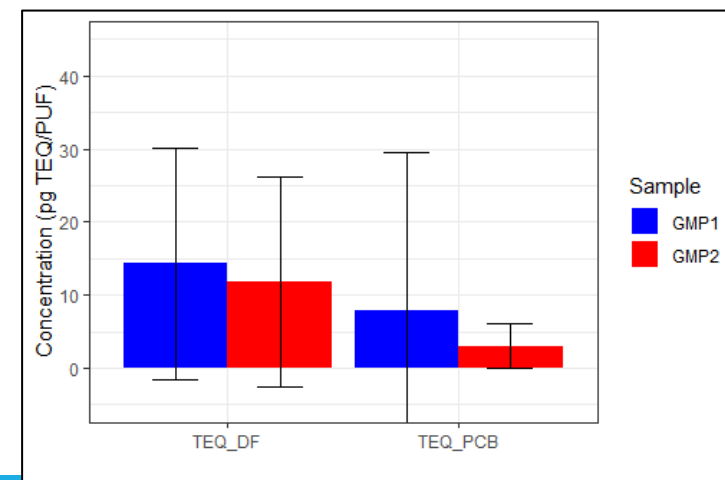
	Africa (N=94)	Asia (N=28)	GRULAC (N=79)	PAC (N=26)	Overall (N=227)
<b>Region</b>					
<b>Africa</b>	94 (100%)	0 (0%)	0 (0%)	0 (0%)	94 (41.4%)
<b>Asia</b>	0 (0%)	28 (100%)	0 (0%)	0 (0%)	28 (12.3%)
<b>GRULAC</b>	0 (0%)	0 (0%)	79 (100%)	0 (0%)	79 (34.8%)
<b>PAC</b>	0 (0%)	0 (0%)	0 (0%)	26 (100%)	26 (11.5%)
<b>GMP</b>					
<b>GMP1</b>	10 (10.6%)	0 (0%)	27 (34.2%)	8 (30.8%)	45 (19.8%)
<b>GMP2</b>	84 (89.4%)	28 (100%)	52 (65.8%)	18 (69.2%)	182 (80.2%)

Status:  
2020-10-01

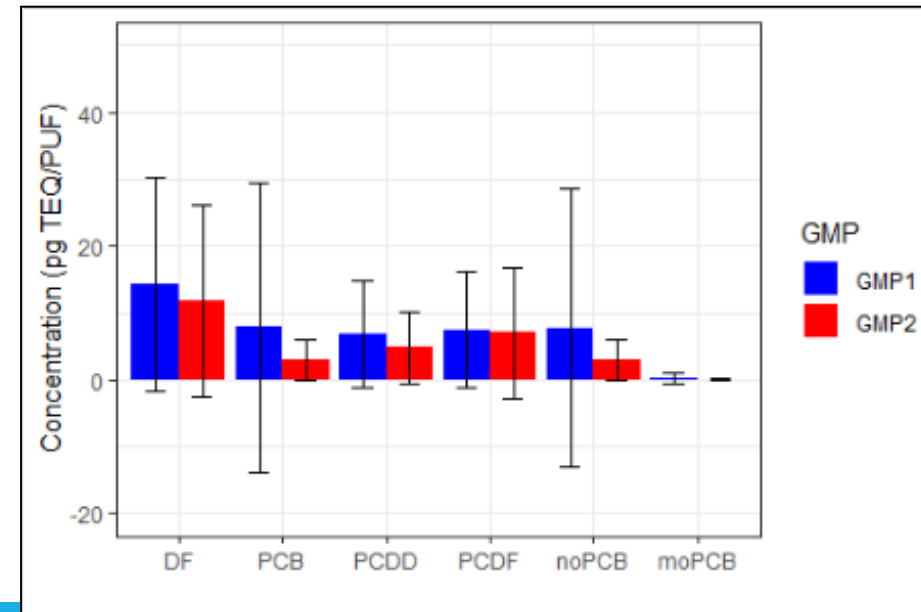
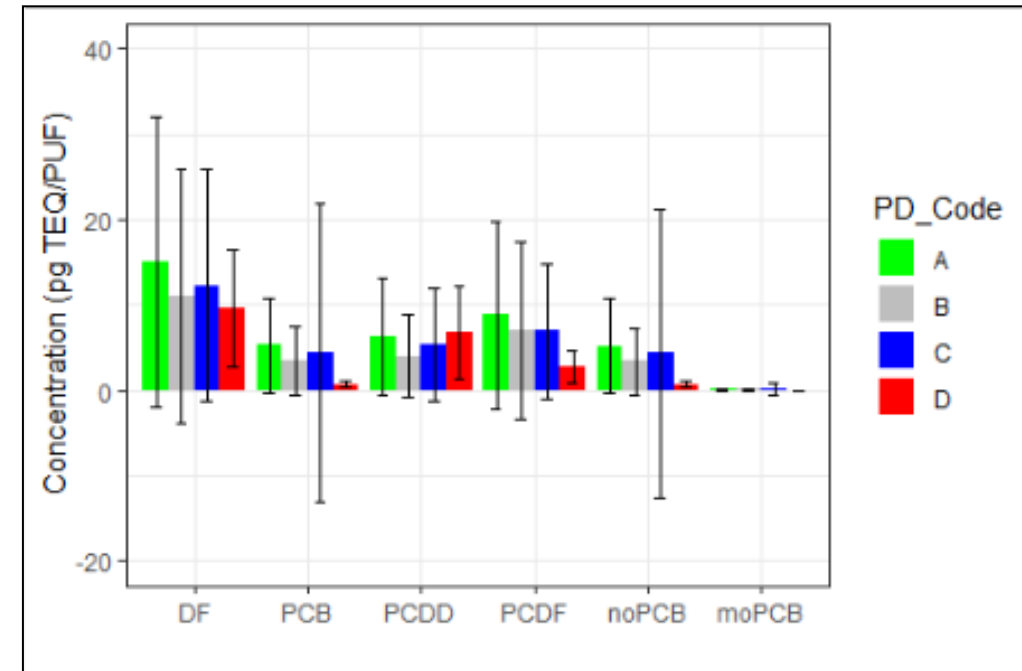
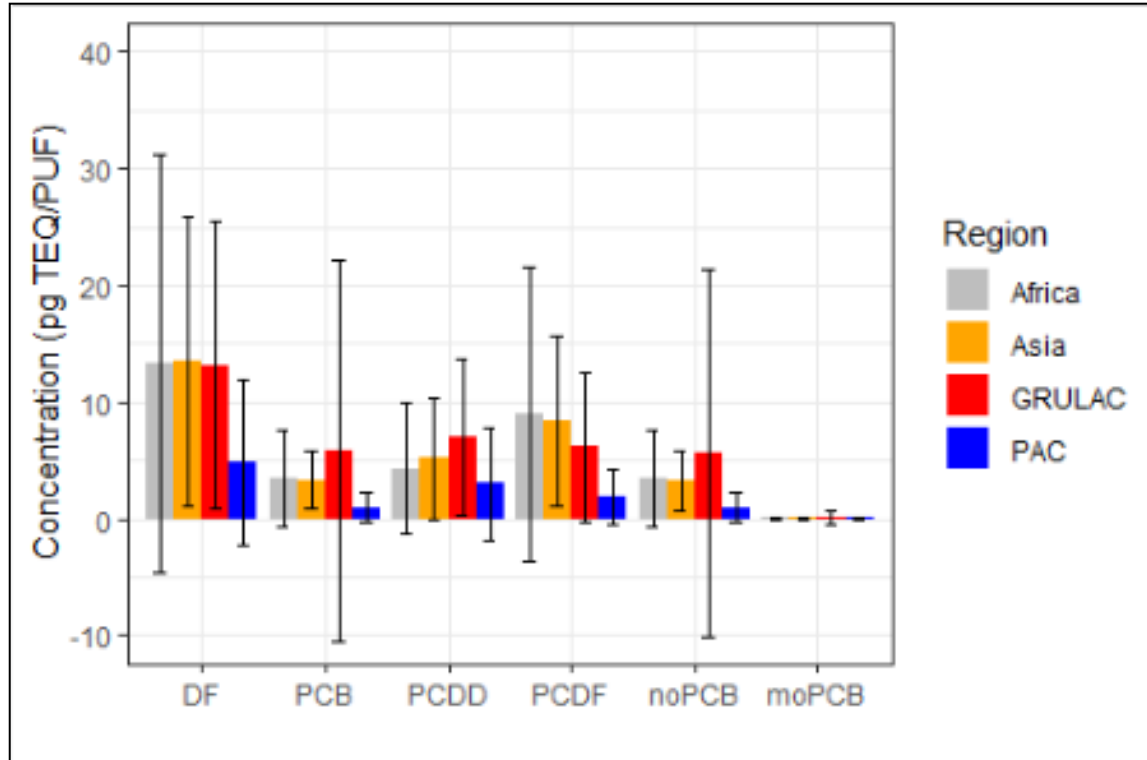
# Overview results dl-POPs – GMP1+GMP2

	Africa (N=94)	Asia (N=28)	GRULAC (N=79)	PAC (N=26)	Overall (N=227)
<b>TEQ_DF (pg TEQ/PUF)</b>					
Mean (SD)	13.3 (18.0)	13.5 (12.3)	13.1 (12.3)	4.90 (7.12)	12.3 (14.7)
Median [Min, Max]	3.62 [0.0552, 77.7]	9.80 [0.162, 40.3]	11.1 [0, 66.3]	1.00 [0.000495, 27.0]	6.80 [0, 77.7]
<b>TEQ_PCB (pg TEQ/PUF)</b>					
Mean (SD)	3.53 (4.12)	3.32 (2.51)	5.76 (16.3)	0.982 (1.22)	3.99 (10.1)
Median [Min, Max]	1.94 [0.000374, 20.9]	3.10 [0.00305, 8.57]	2.92 [0.00369, 142]	0.438 [0, 4.32]	2.25 [0, 142]

	GMP1 (N=45)	GMP2 (N=182)	Overall (N=227)
<b>TEQ_DF (pg TEQ/PUF)</b>			
Mean (SD)	14.3 (15.9)	11.8 (14.4)	12.3 (14.7)
Median [Min, Max]	9.70 [0, 66.3]	6.59 [0.000495, 77.7]	6.80 [0, 77.7]
<b>TEQ_PCB (pg TEQ/PUF)</b>			
Mean (SD)	7.91 (21.6)	3.02 (3.03)	3.99 (10.1)
Median [Min, Max]	2.11 [0, 142]	2.25 [0.000374, 16.4]	2.25 [0, 142]

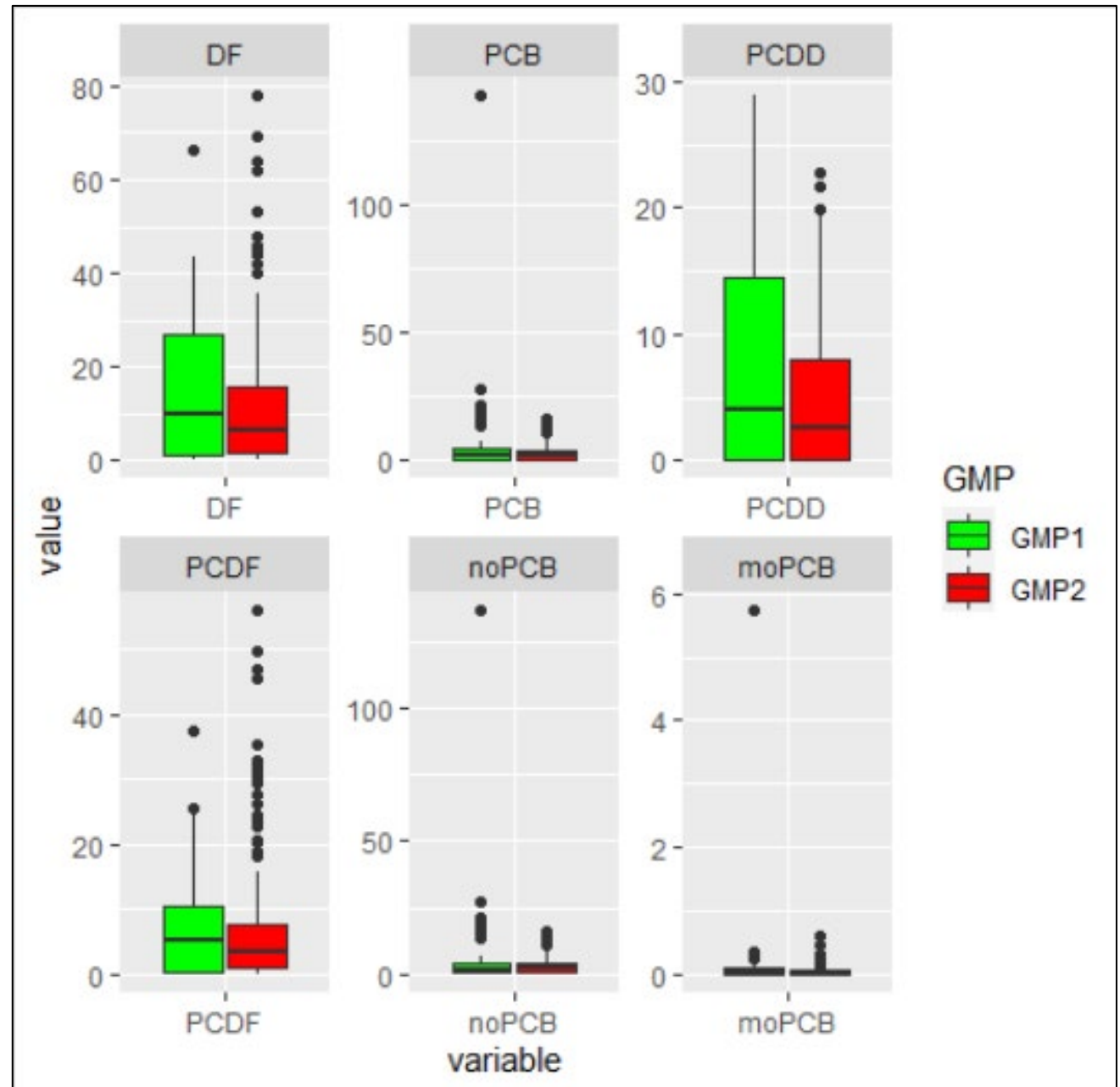


# GMP1 and GMP2 means

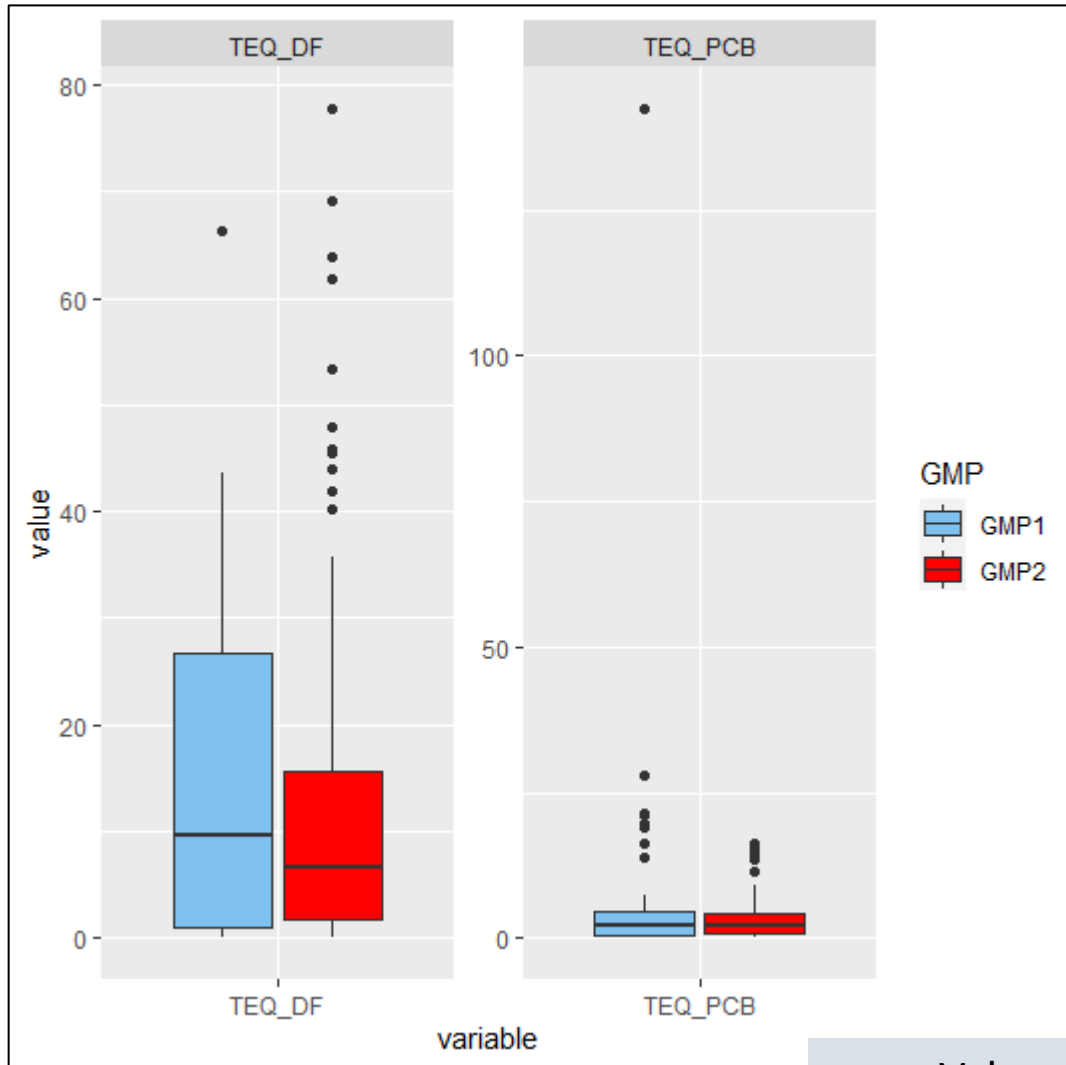


# dl-POPs GMP1 (2010/2011) vs. GMP2 (2006-2019)

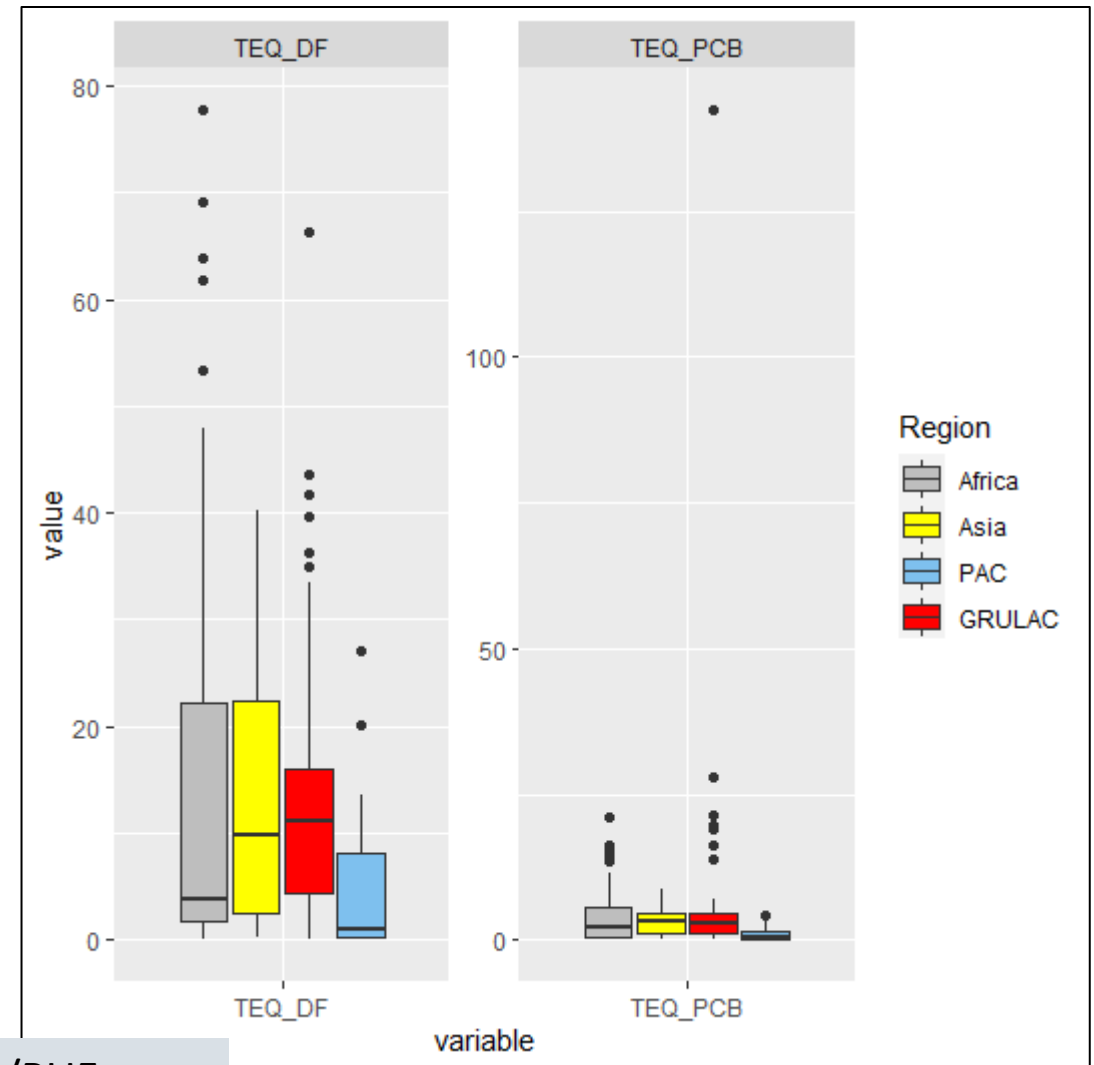
Values in pg WHO<sub>2005</sub>-TEQ/PUF



# GMP1 vs. GMP2

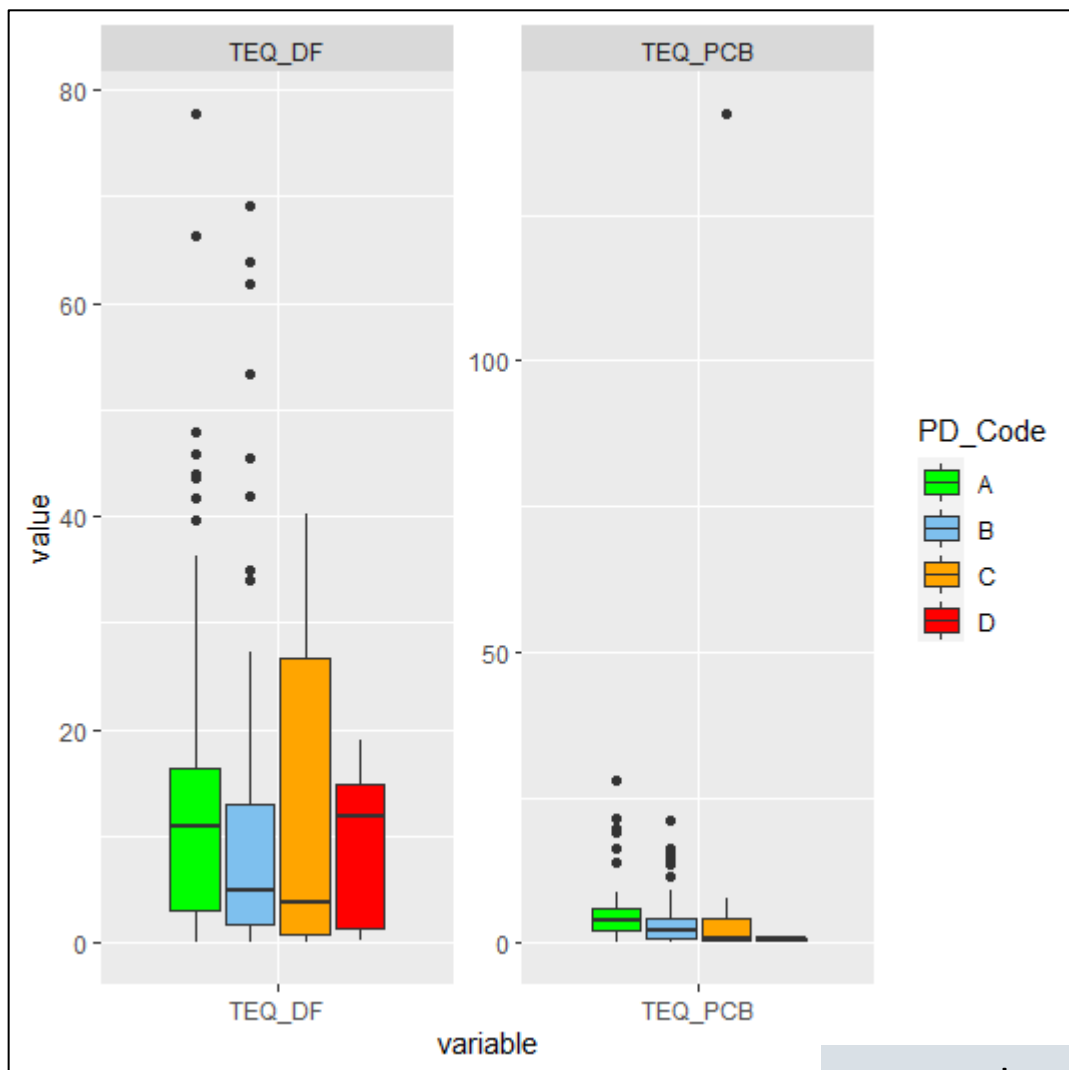


# Regions

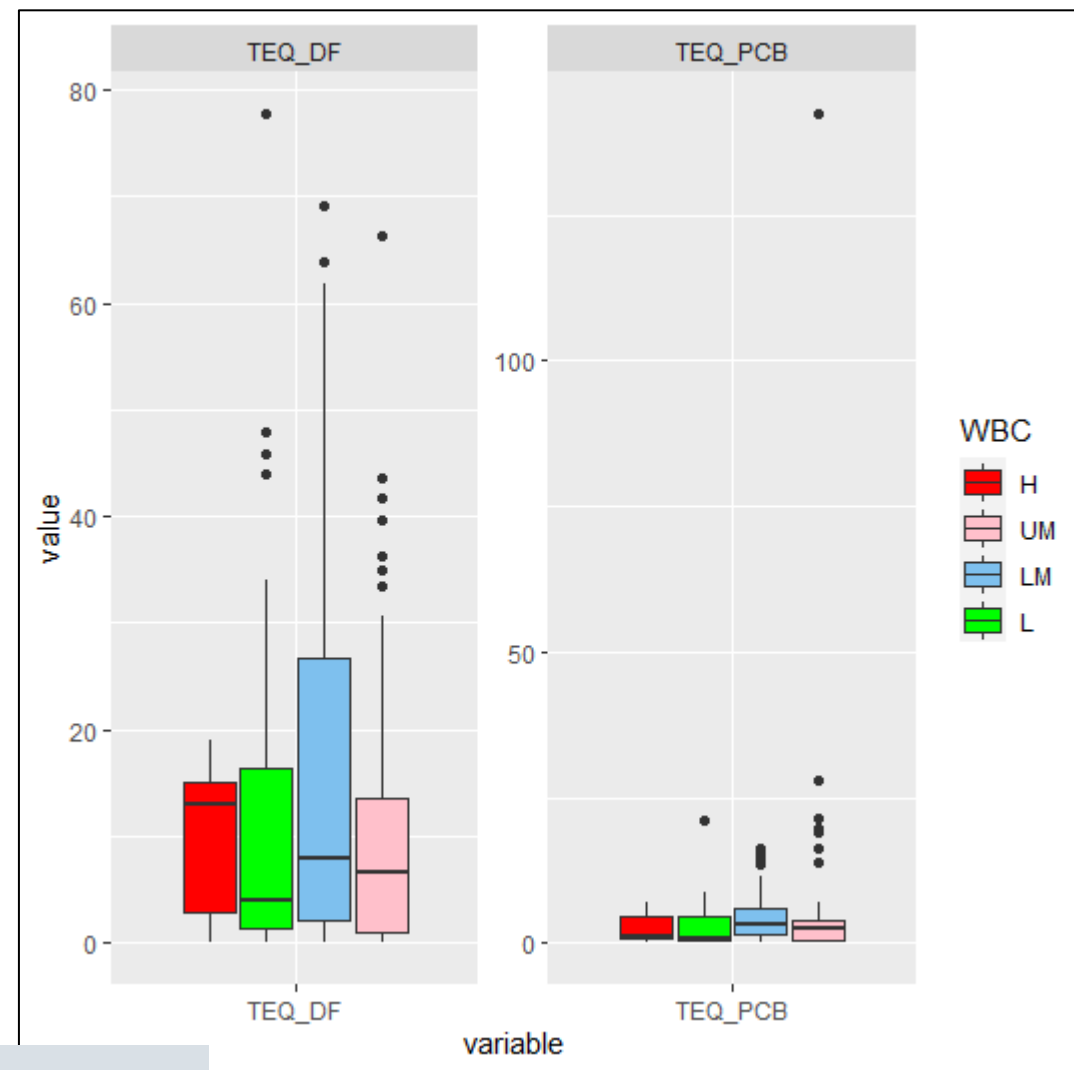


Values in pg TEQ/PUF

# Population density

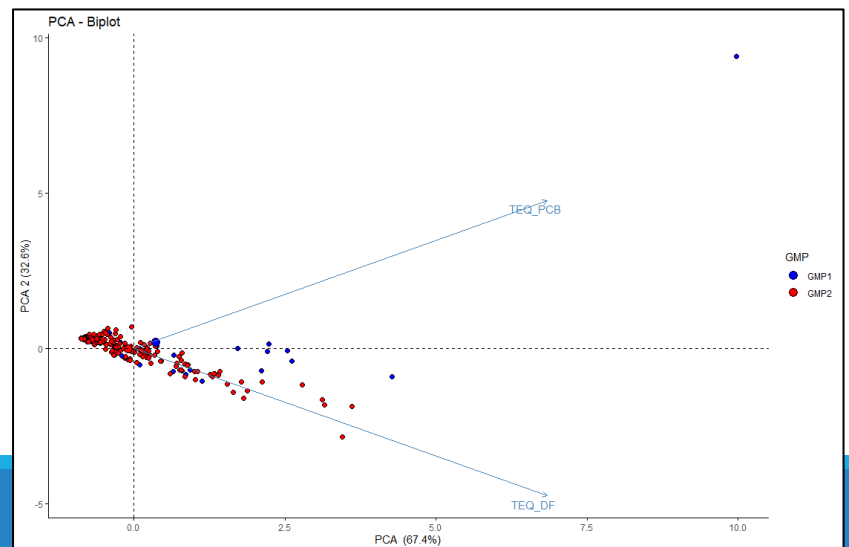
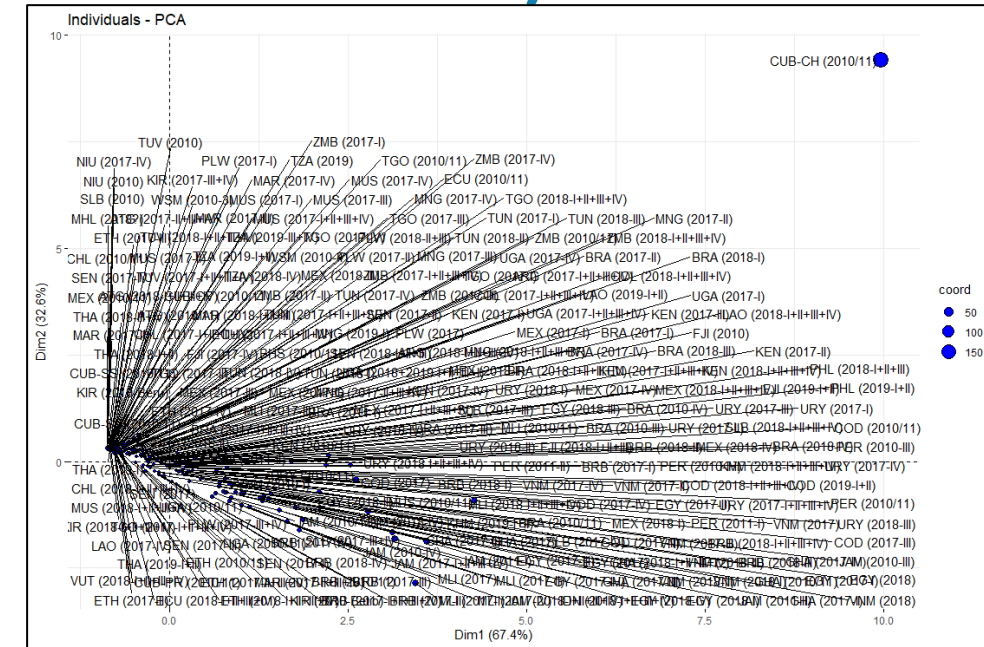
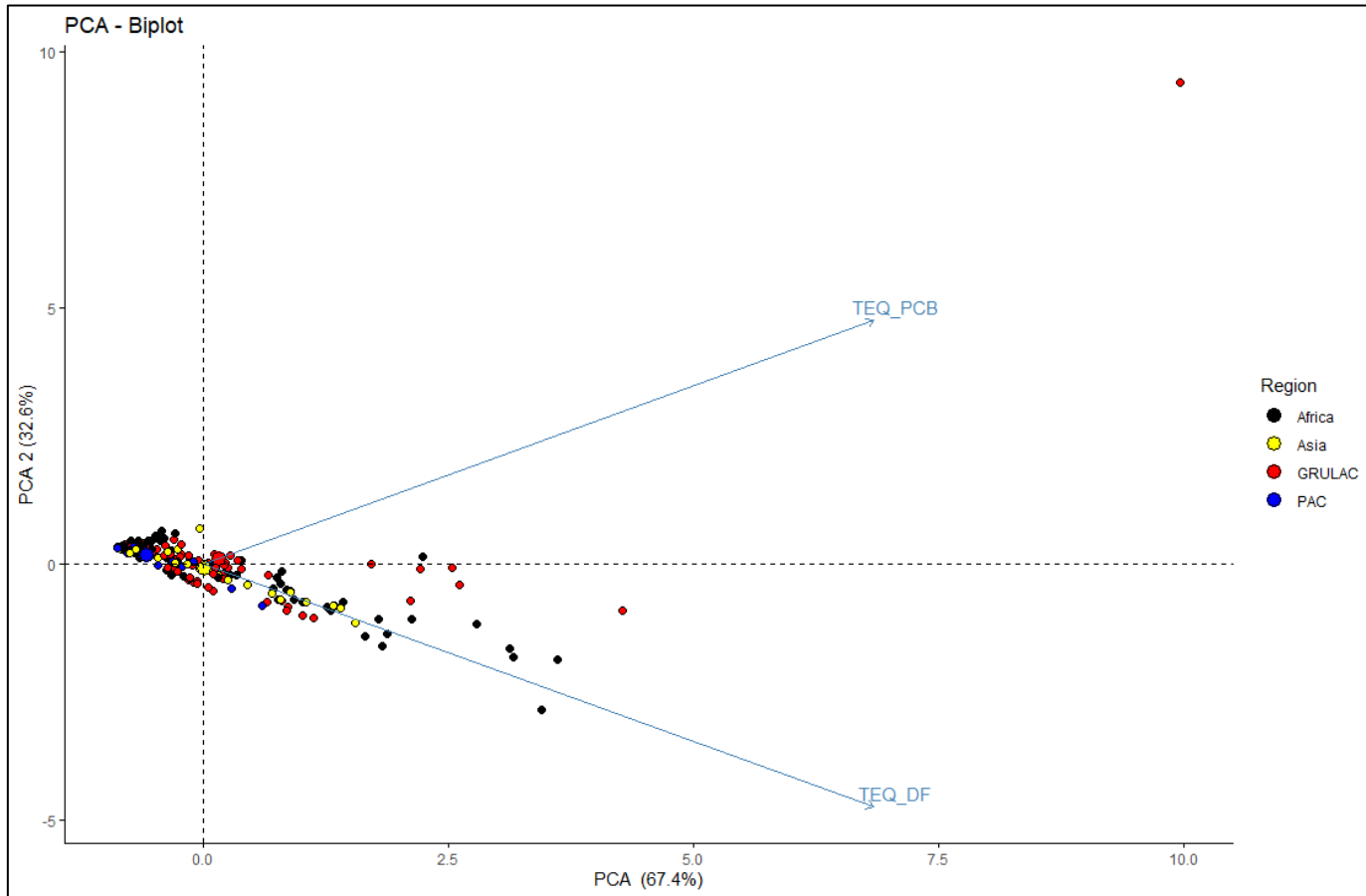


# Income



Values in pg TEQ/PUF

# Samples GMP1 and GMP2 (distribution)



# PAS/PUF Results – dl-POPs

## A.2 GMP 2 - Across All Projects



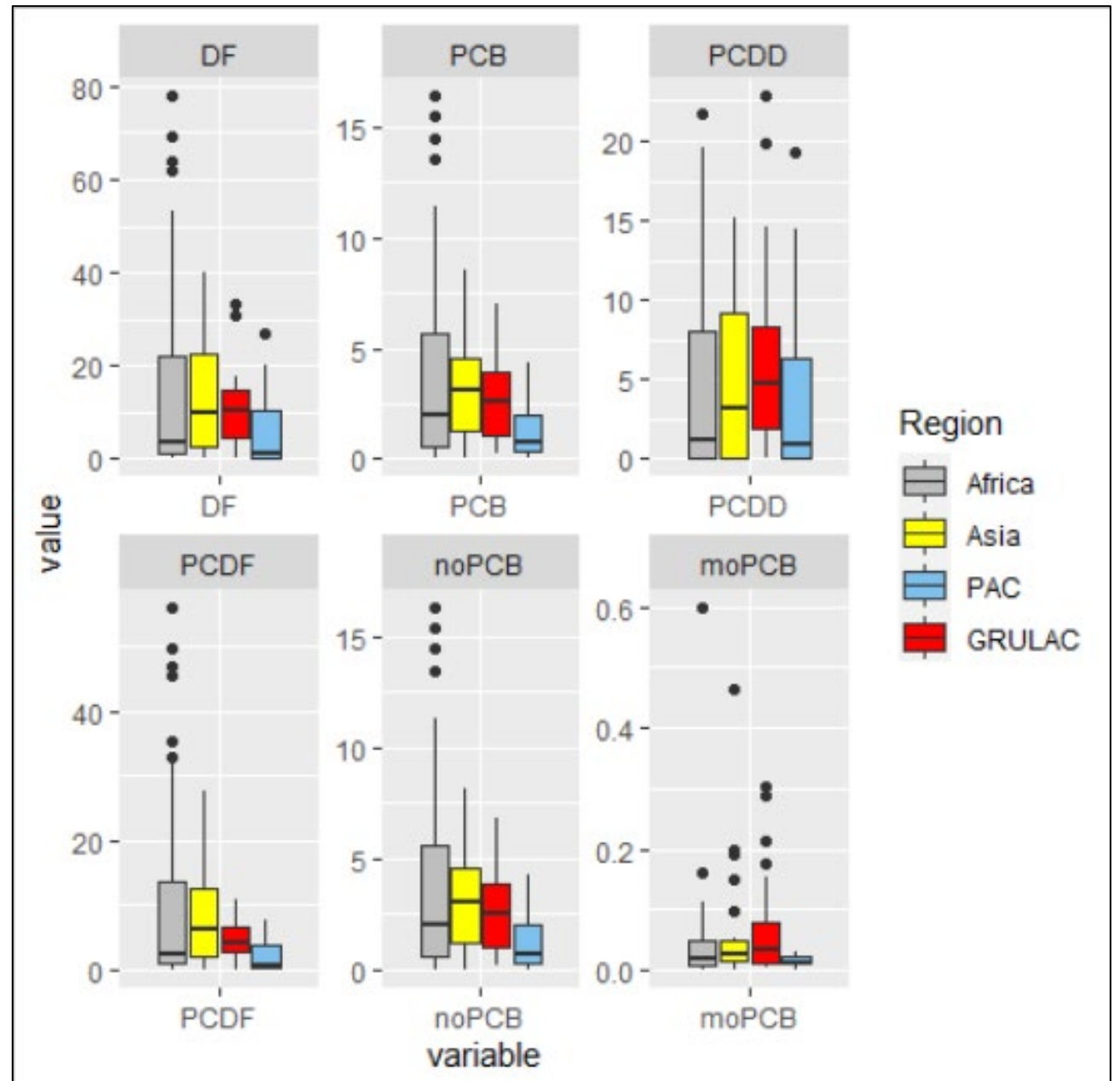
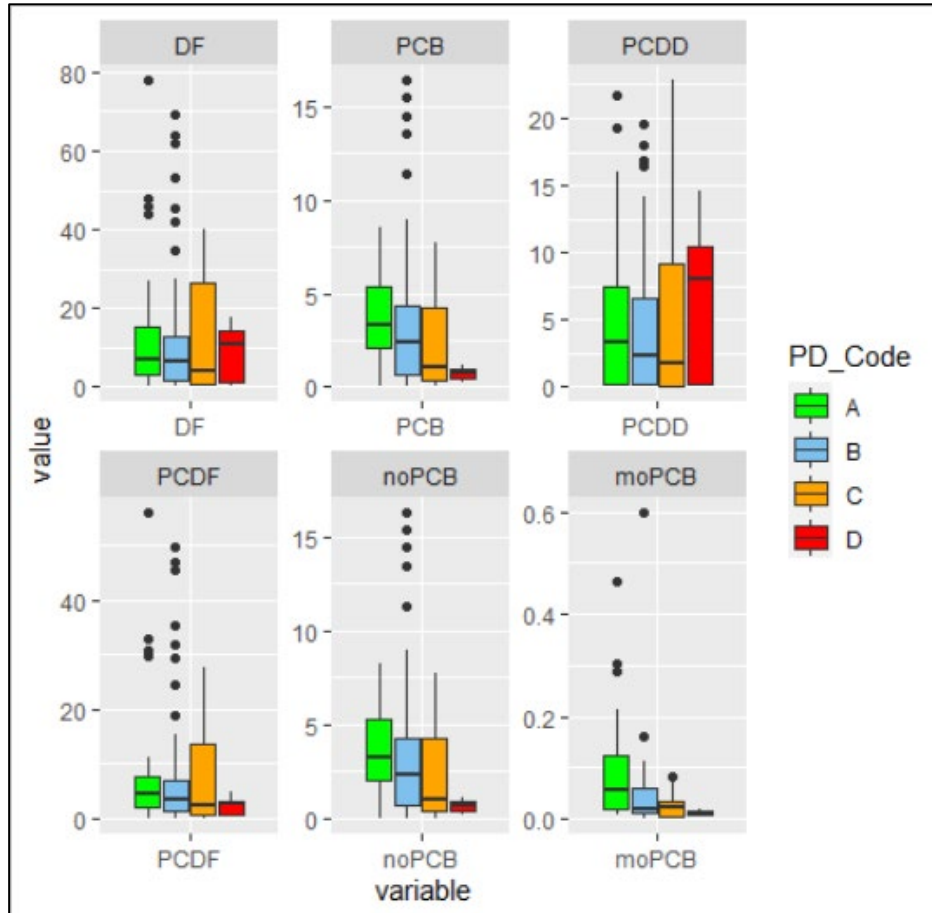
# Number/classification PAS/PUFs GMP2 for dl-POPs

	Africa (N=83)	Asia (N=28)	GRULAC (N=52)	PAC (N=19)	Overall (N=182)
<b>Region</b>					
<b>Africa</b>	83 (100%)	0 (0%)	0 (0%)	0 (0%)	83 (45.6%)
<b>Asia</b>	0 (0%)	28 (100%)	0 (0%)	0 (0%)	28 (15.4%)
<b>GRULAC</b>	0 (0%)	0 (0%)	52 (100%)	0 (0%)	52 (28.6%)
<b>PAC</b>	0 (0%)	0 (0%)	0 (0%)	19 (100%)	19 (10.4%)
<b>YYYY</b>					
<b>Y2017</b>	58 (69.9%)	9 (32.1%)	26 (50.0%)	11 (57.9%)	104 (57.1%)
<b>Y2018</b>	21 (25.3%)	12 (42.9%)	26 (50.0%)	7 (36.8%)	66 (36.3%)
<b>Y2019</b>	4 (4.8%)	7 (25.0%)	0 (0%)	1 (5.3%)	12 (6.6%)
<b>Sample</b>					
<b>a</b>	27 (32.5%)	11 (39.3%)	20 (38.5%)	12 (63.2%)	70 (38.5%)
<b>q</b>	56 (67.5%)	17 (60.7%)	32 (61.5%)	7 (36.8%)	112 (61.5%)

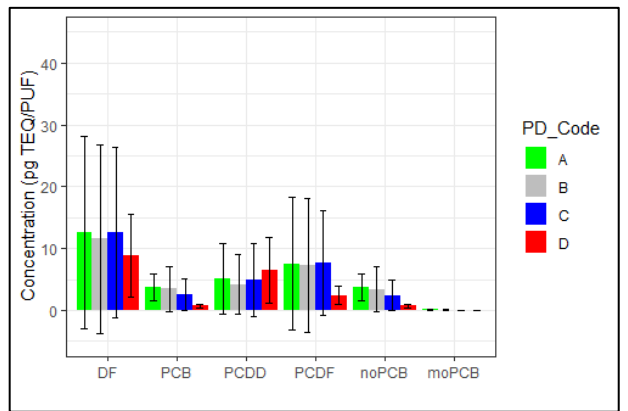
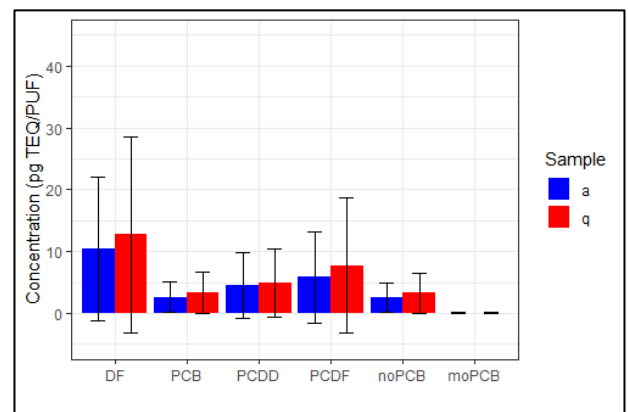
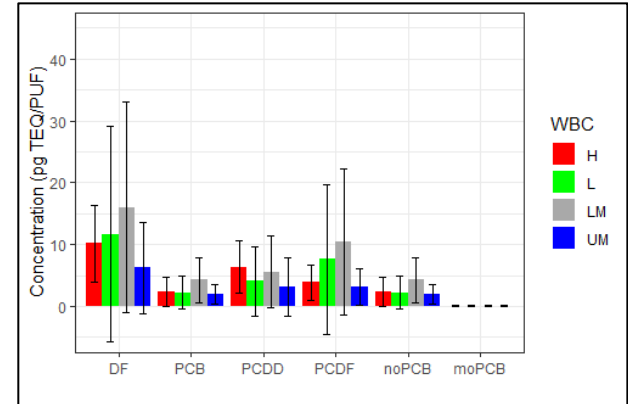
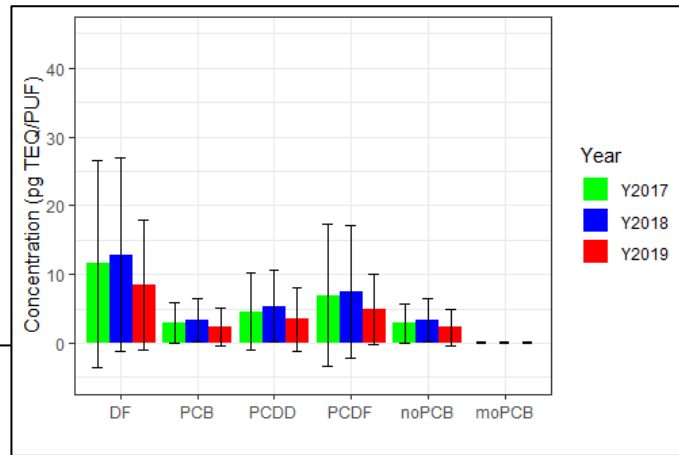
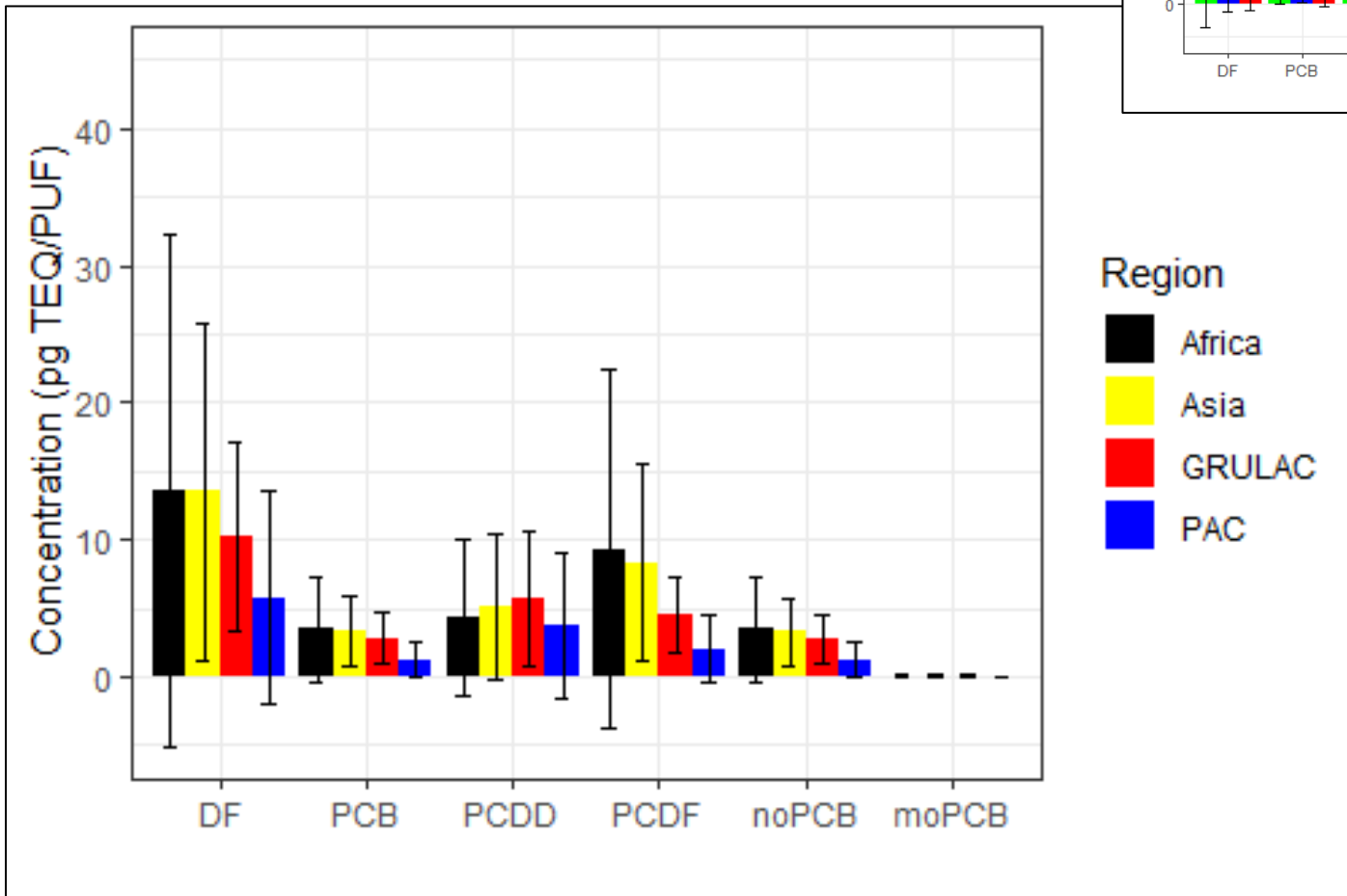
# Summary results PAS/PUFs GMP2 for dl-POPs

	Africa (N=83)	Asia (N=28)	GRULAC (N=52)	PAC (N=19)	Overall (N=182)
<b>DF (pg TEQ/PUF)</b>					
Mean (SD)	13.6 (18.7)	13.5 (12.3)	10.2 (6.92)	5.75 (7.76)	11.8 (14.4)
Median [Min, Max]	3.77 [0.0552, 77.7]	9.80 [0.162, 40.3]	10.2 [0.141, 33.5]	1.49 [0.000495, 27.0]	6.59 [0.000495, 77.7]
<b>PCB (pg TEQ/PUF)</b>					
Mean (SD)	3.47 (3.82)	3.32 (2.51)	2.79 (1.87)	1.22 (1.26)	3.02 (3.03)
Median [Min, Max]	2.03 [0.000374, 16.4]	3.10 [0.00305, 8.57]	2.60 [0.253, 7.01]	0.675 [0.00234, 4.32]	2.25 [0.000374, 16.4]

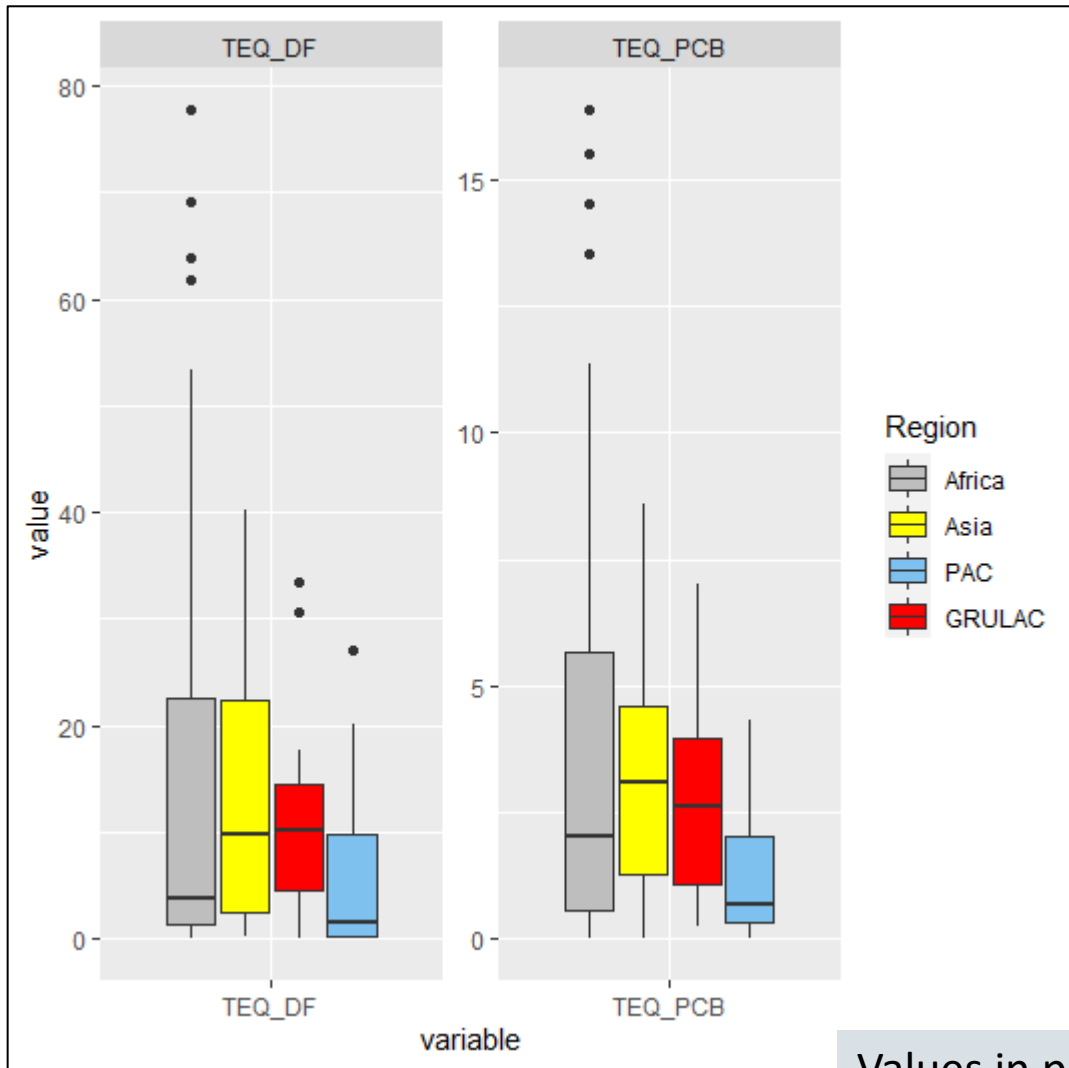
# dl-POPs – 6 partial TEQs (pg WHO<sub>2005</sub>-TEQ/PUF)



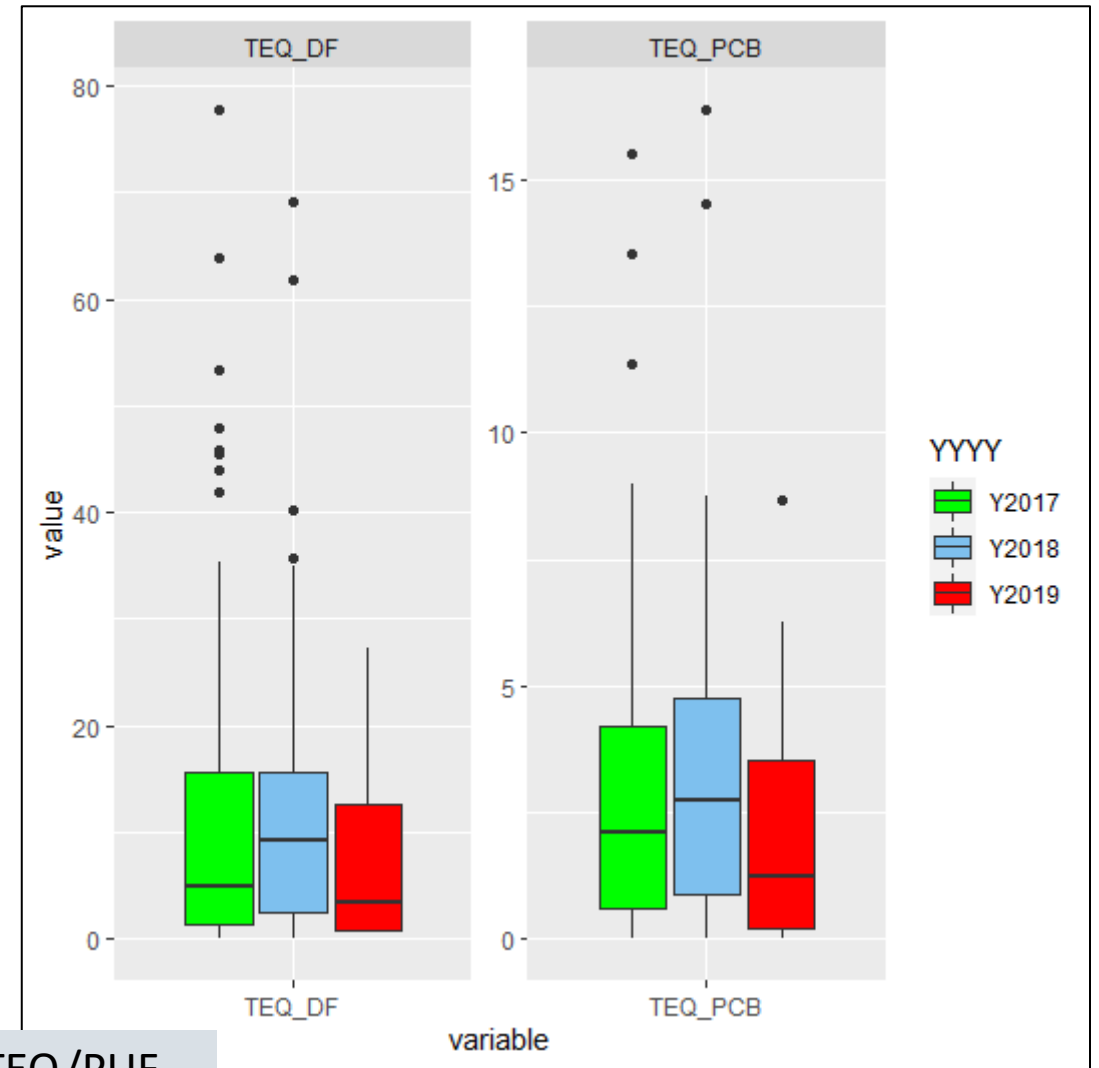
# Mean values, GMP2 dl-POPs (pg WHO<sub>2005</sub>-TEQ/PUF)



# Regions



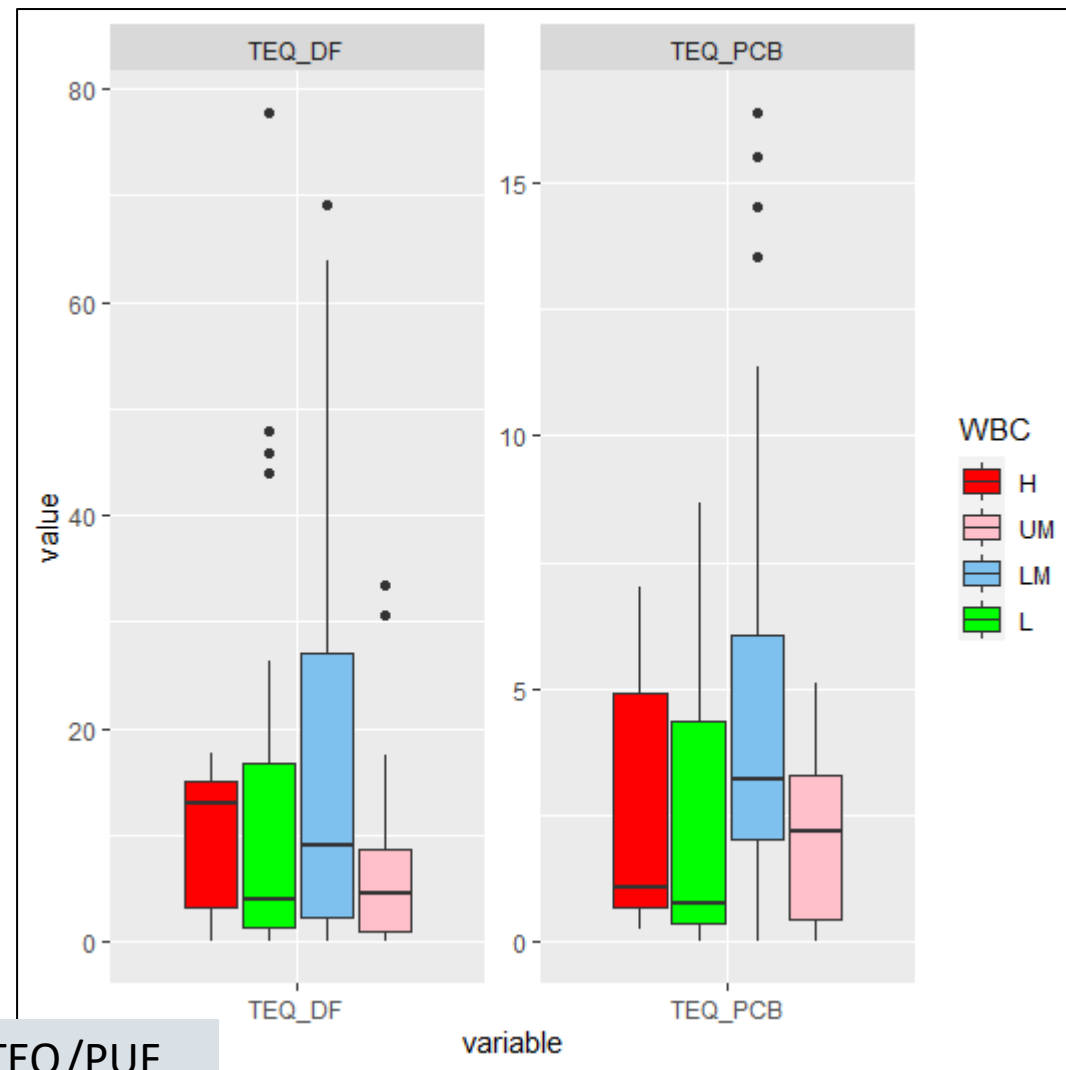
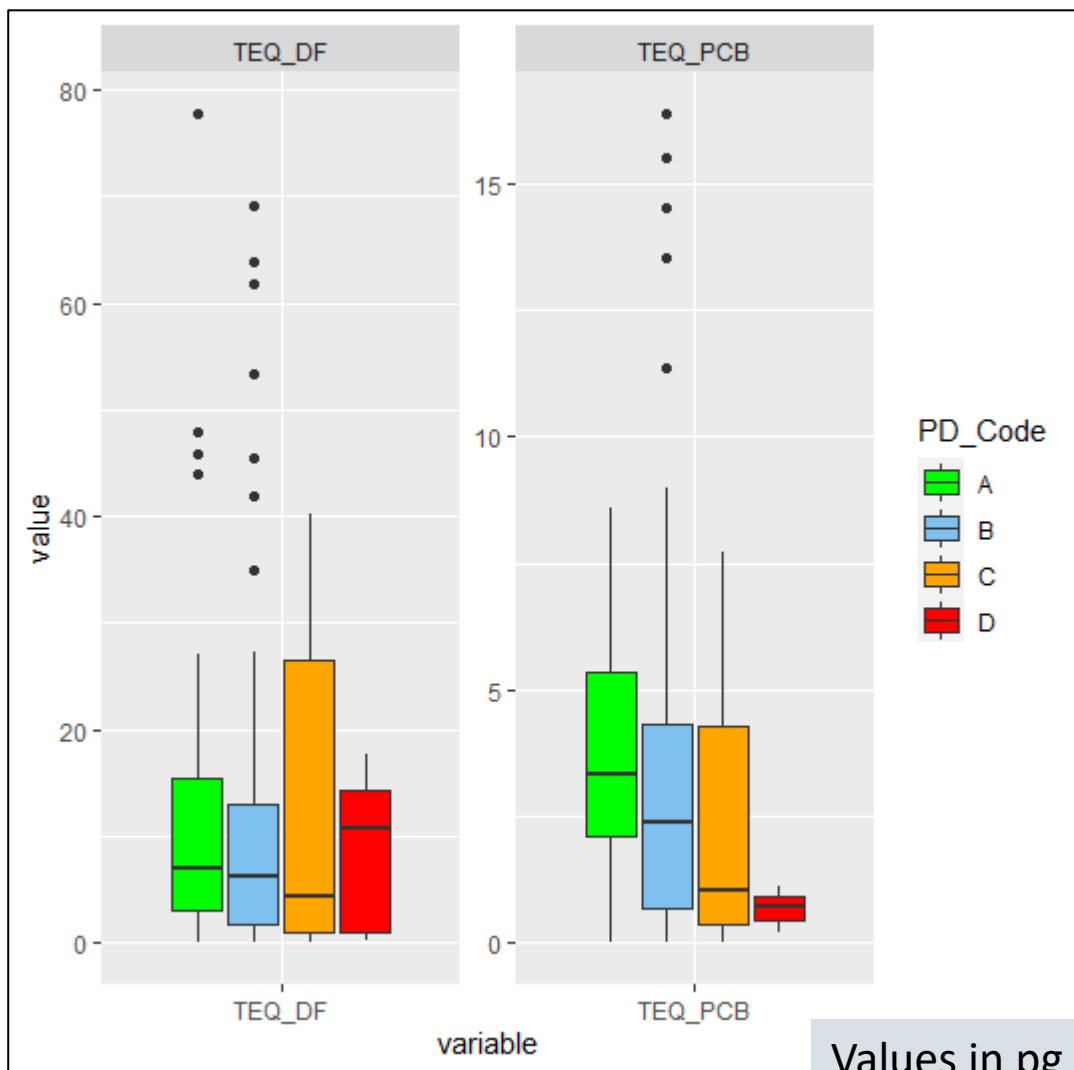
# Sampling year



Values in pg WHO<sub>2005</sub>-TEQ/PUF

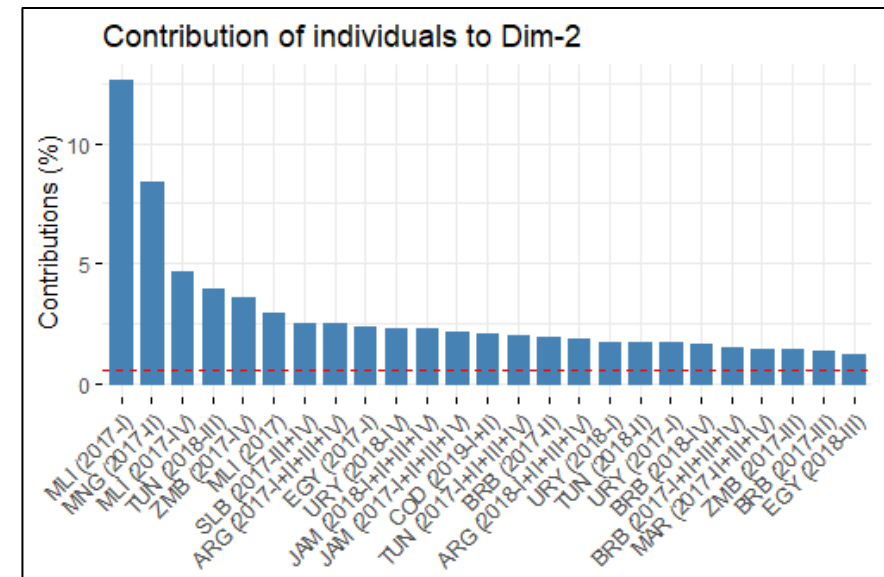
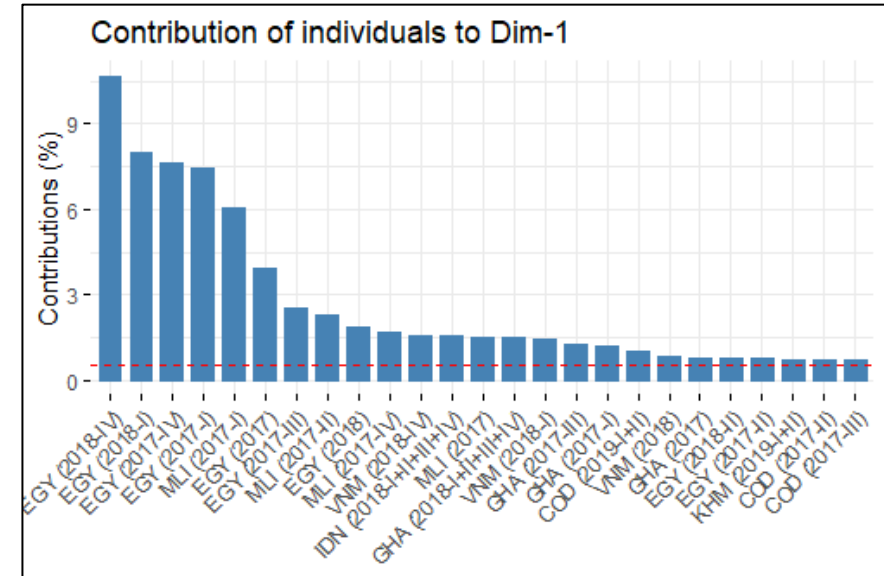
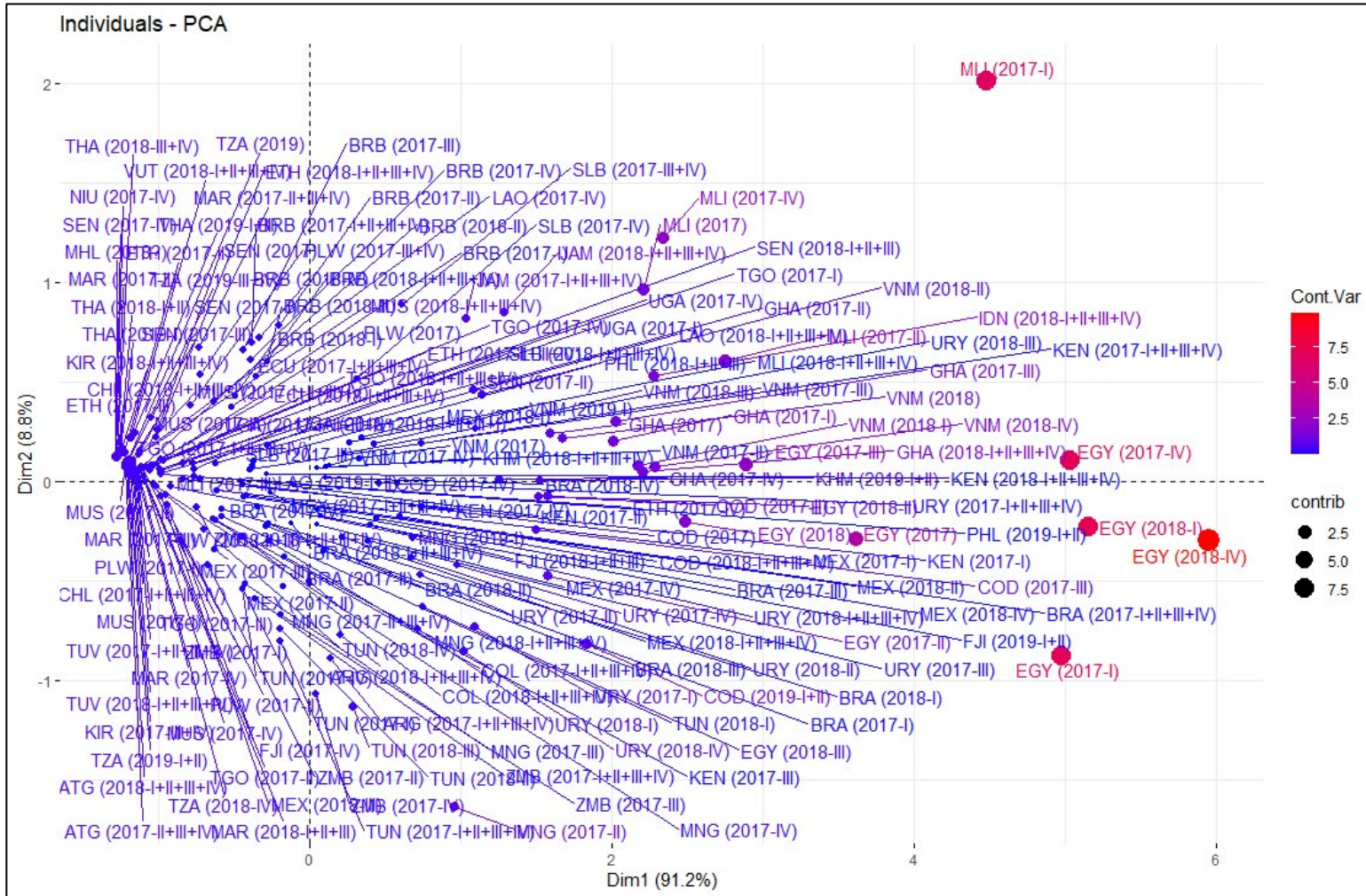
# Population density

# Income

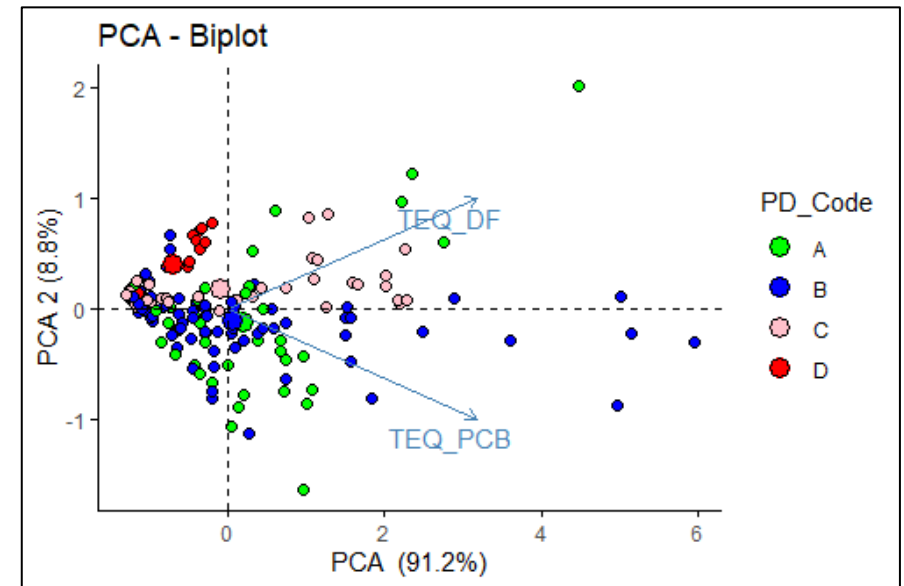
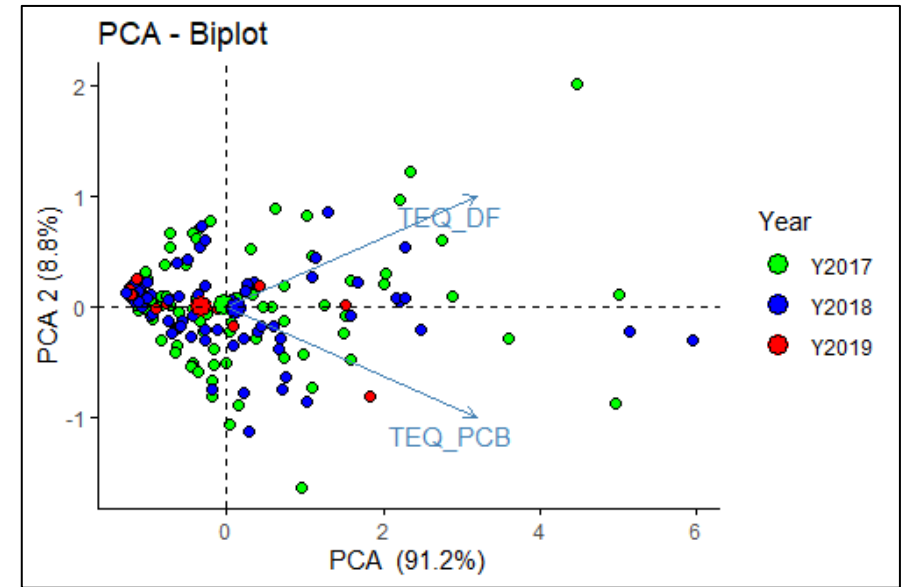
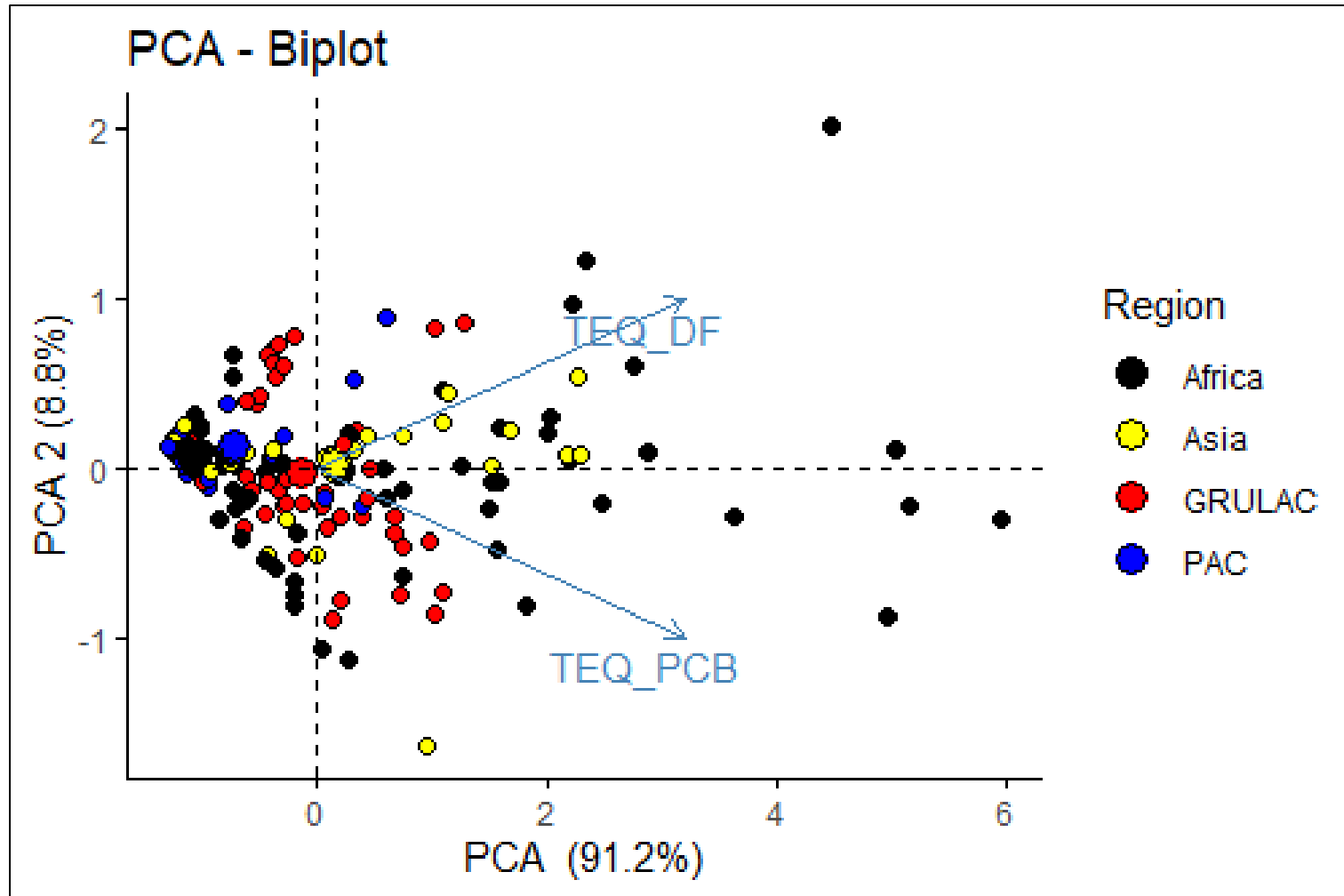


Values in pg WHO<sub>2005</sub>-TEQ/PUF

# PCA, variance GMP2 dl-POPs

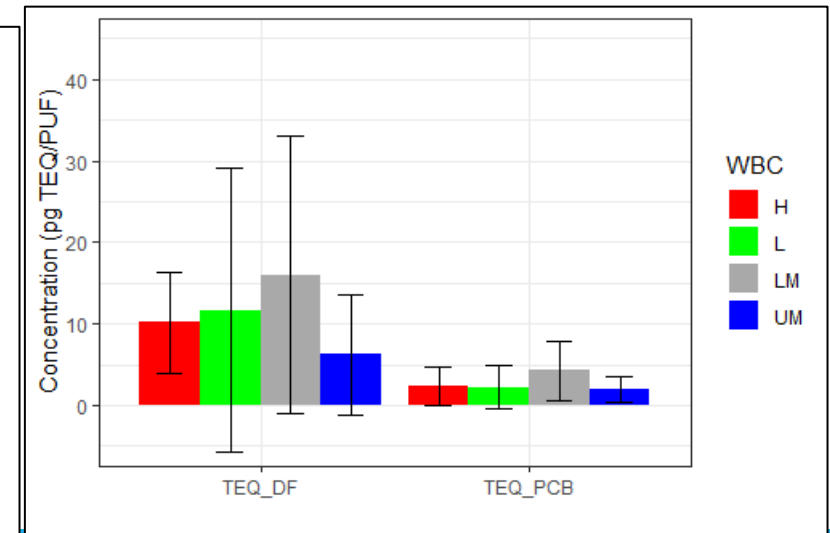
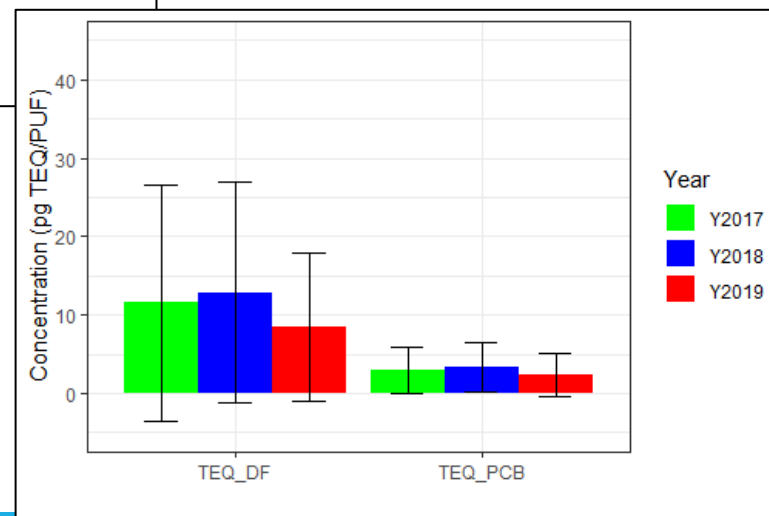
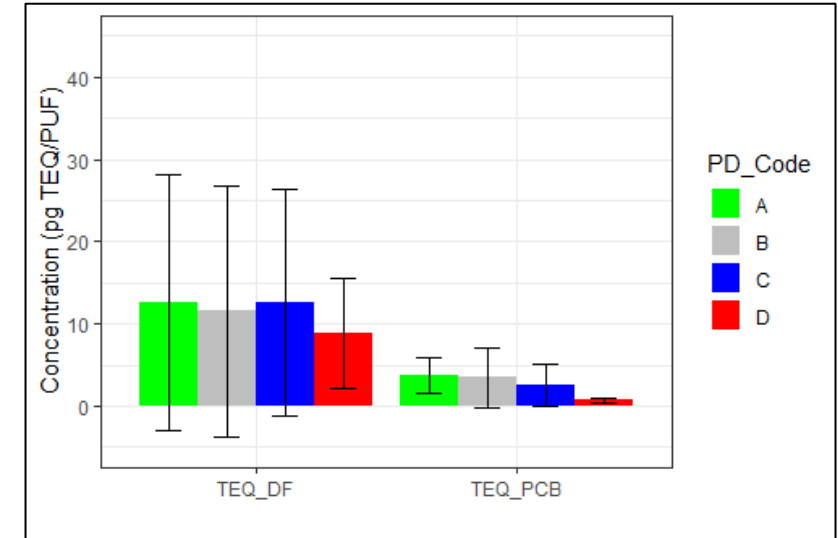
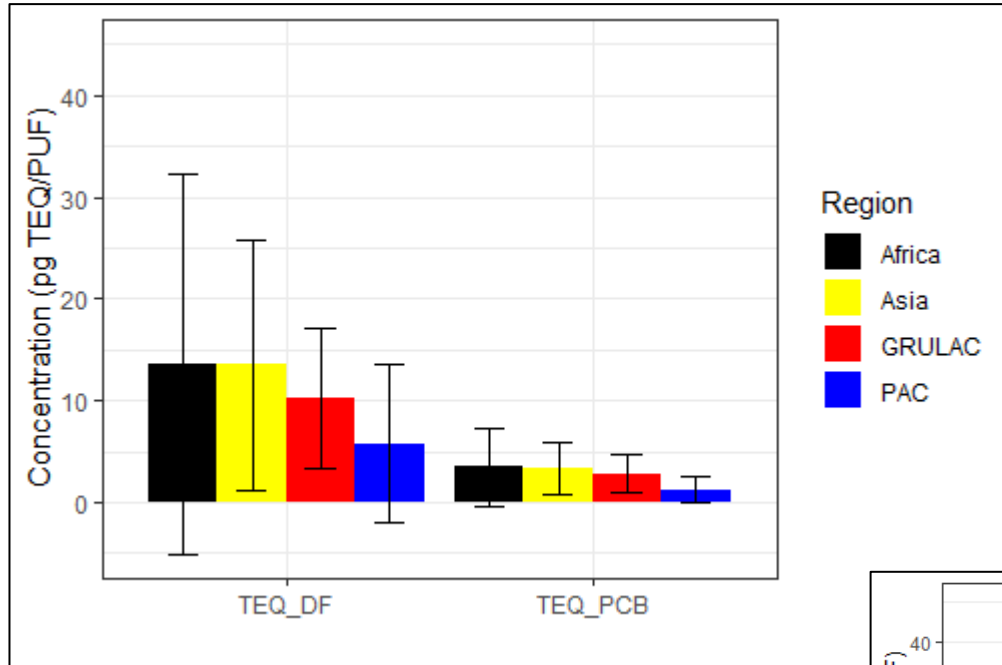


# PCA dl-POPs GMP2





# Mean values and SD (standard deviation) - GMP2



# dl-POPs Results

## A.3 Asia Region

Country name	ISO-3	Project Region	WBC 2017	WBC 2018	PD 2017	PD 2018
Cambodia	KHM	Asia	LM	LM	B	B
Indonesia	IDN	Asia	LM	LM	C	C
Lao PDR	LAO	Asia	LM	LM	B	B
Mongolia	MNG	Asia	LM	LM	A	A
Philippines	PHL	Asia	LM	LM	C	C
Thailand	THA	Asia	UM	UM	C	C
Vietnam	VNM	Asia	LM	LM	C	C

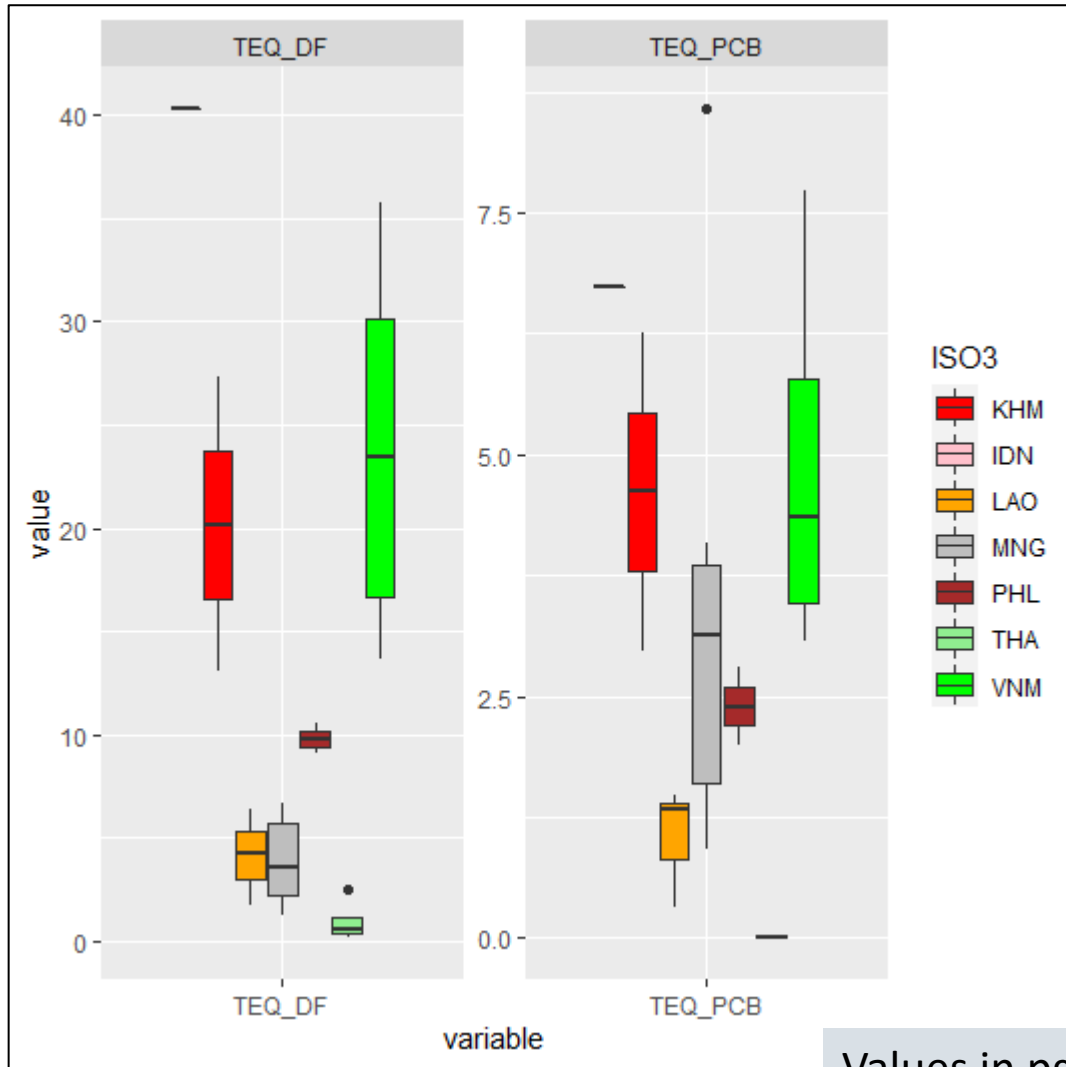
# Number and classification of samples (Asia)

	<b>IDN (N=1)</b>	<b>KHM (N=2)</b>	<b>LAO (N=3)</b>	<b>MNG (N=6)</b>	<b>PHL (N=2)</b>	<b>THA (N=4)</b>	<b>VNM (N=10)</b>	<b>Overall (N=28)</b>
<b>Region</b>								
<b>Asia</b>	1 (100%)	2 (100%)	3 (100%)	6 (100%)	2 (100%)	4 (100%)	10 (100%)	28 (100%)
<b>YYYY</b>								
<b>Y2017</b>	0 (0%)	0 (0%)	1 (33.3%)	4 (66.7%)	0 (0%)	0 (0%)	4 (40.0%)	9 (32.1%)
<b>Y2018</b>	1 (100%)	1 (50.0%)	1 (33.3%)	1 (16.7%)	1 (50.0%)	2 (50.0%)	5 (50.0%)	12 (42.9%)
<b>Y2019</b>	0 (0%)	1 (50.0%)	1 (33.3%)	1 (16.7%)	1 (50.0%)	2 (50.0%)	1 (10.0%)	7 (25.0%)
<b>Sample</b>								
<b>a</b>	1 (100%)	2 (100%)	2 (66.7%)	2 (33.3%)	2 (100%)	1 (25.0%)	1 (10.0%)	11 (39.3%)
<b>q</b>	0 (0%)	0 (0%)	1 (33.3%)	4 (66.7%)	0 (0%)	3 (75.0%)	9 (90.0%)	17 (60.7%)

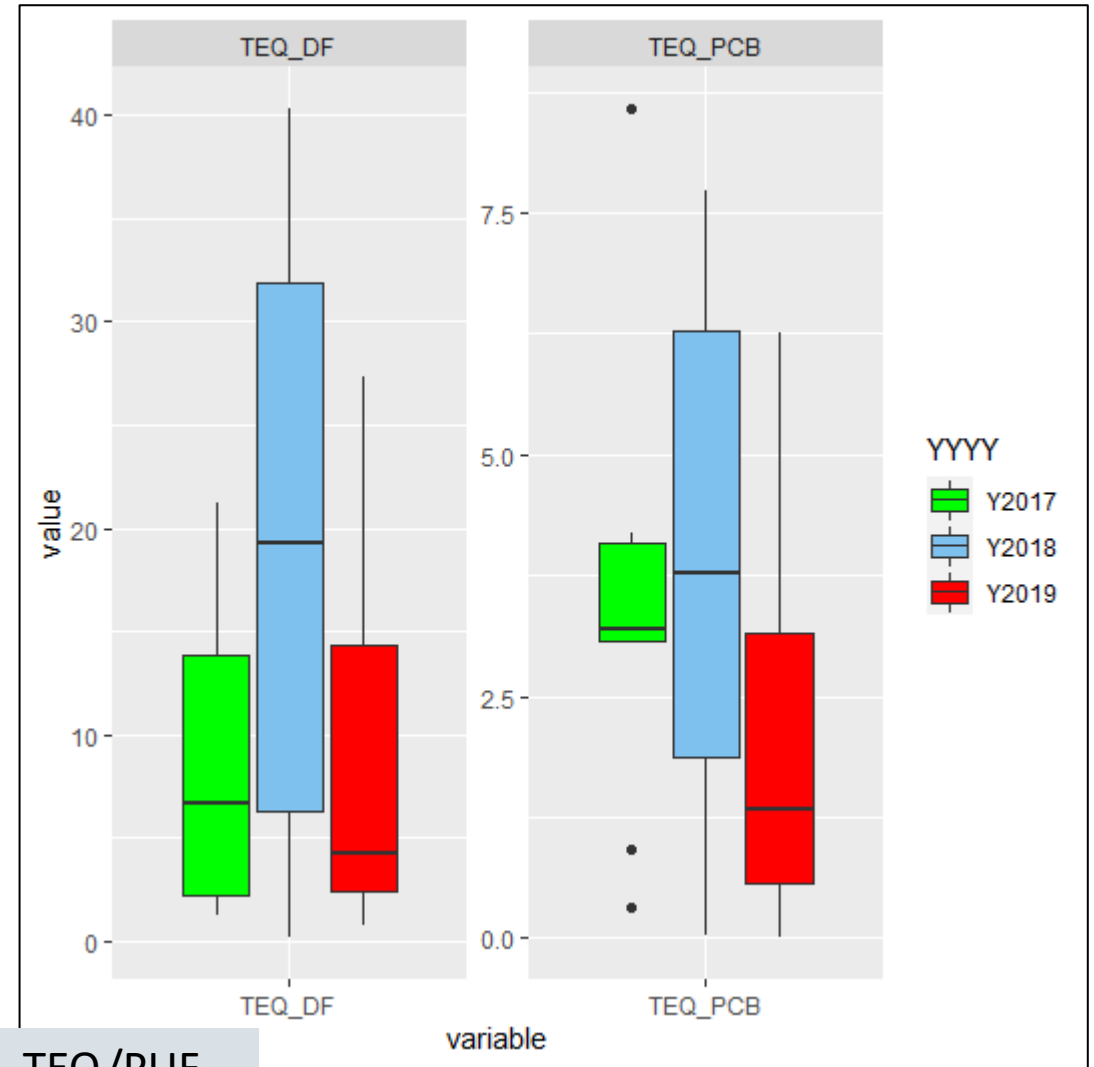
# Statistics for dl-POPs in PAS/PUFs – Asia (GMP2)

	IDN (N=1)	KHM (N=2)	LAO (N=3)	MNG (N=6)	PHL (N=2)	THA (N=4)	VNM (N=10)	Overall (N=28)
<b>DF (pg TEQ/PUF)</b>								
<b>Mean (SD)</b>	40.3 (NA)	20.2 (10.1)	4.15 (2.34)	3.88 (2.25)	9.80 (1.03)	0.966 (1.03)	23.8 (8.35)	13.5 (12.3)
<b>Median</b>	40.3	20.2	4.29	3.59	9.80	0.618	23.4	9.80
<b>[Min, Max]</b>	[40.3, 40.3]	[13.0, 27.3]	[1.73, 6.41]	[1.25, 6.64]	[9.07, 10.5]	[0.162, 2.47]	[13.6, 35.8]	[0.162, 40.3]
<b>PCB (pg TEQ/PUF)</b>								
<b>Mean (SD)</b>	6.74 (NA)	4.61 (2.32)	1.04 (0.627)	3.49 (2.78)	2.40 (0.568)	0.0159 (0.0148)	4.80 (1.74)	3.32 (2.51)
<b>Median</b>	6.74	4.61	1.32	3.13	2.40	0.0142	4.35	3.10
<b>[Min, Max]</b>	[6.74, 6.74]	[2.98, 6.25]	[0.321, 1.47]	[0.913, 8.57]	[1.99, 2.80]	[0.003105, 0.0324]	[3.08, 7.73]	[0.00315, 8.57]

# Country

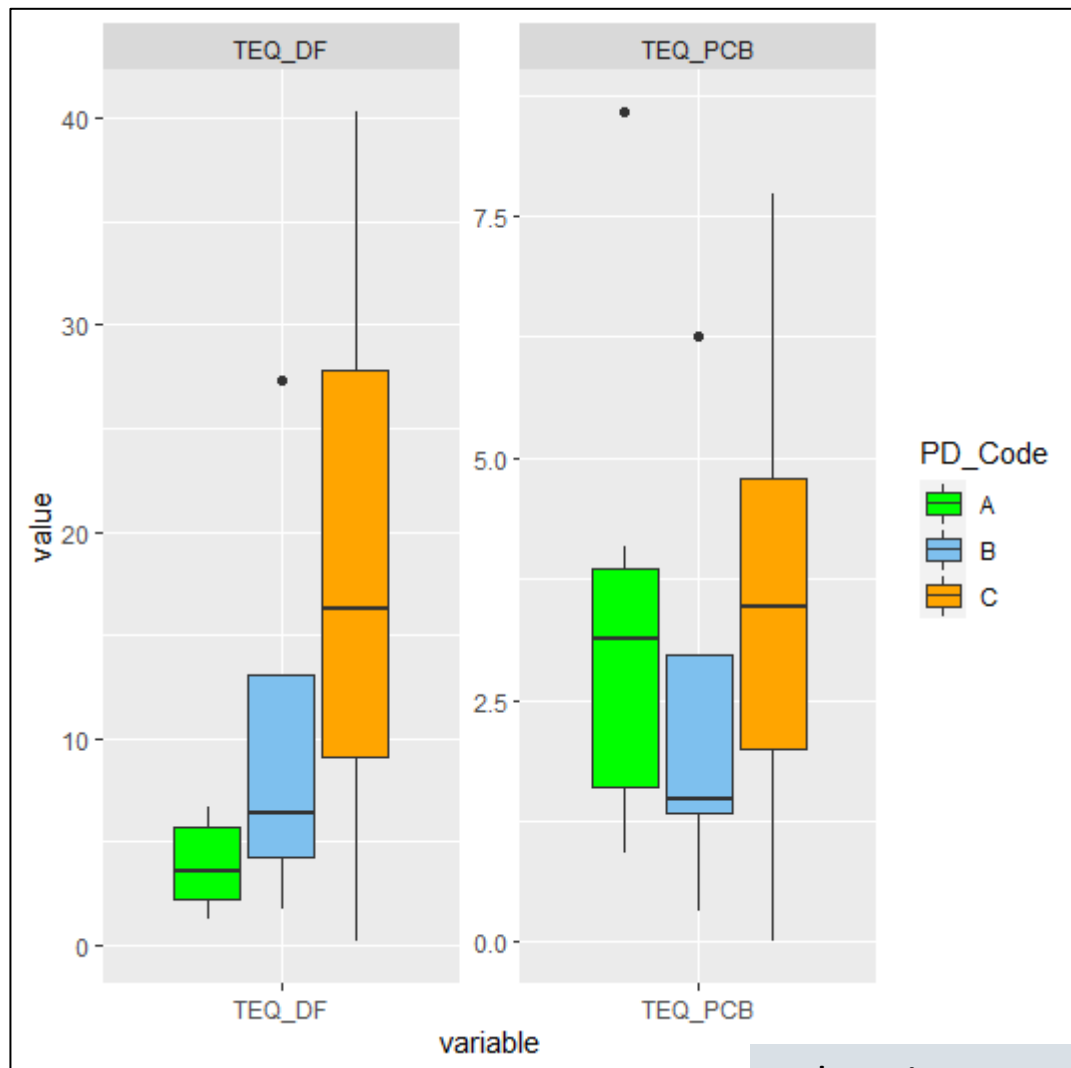


# Sampling year

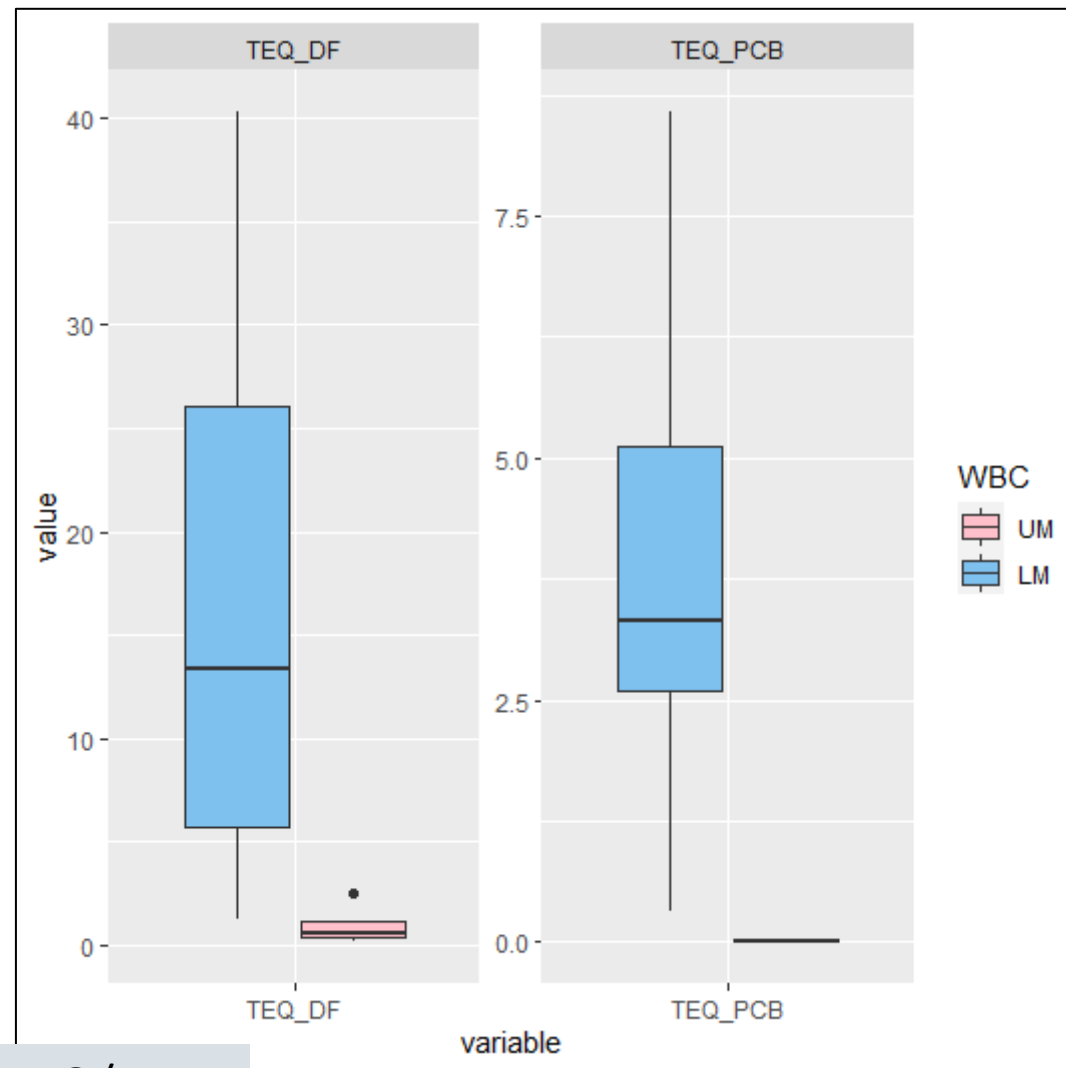


Values in pg WHO<sub>2005</sub>-TEQ/PUF

# Population density

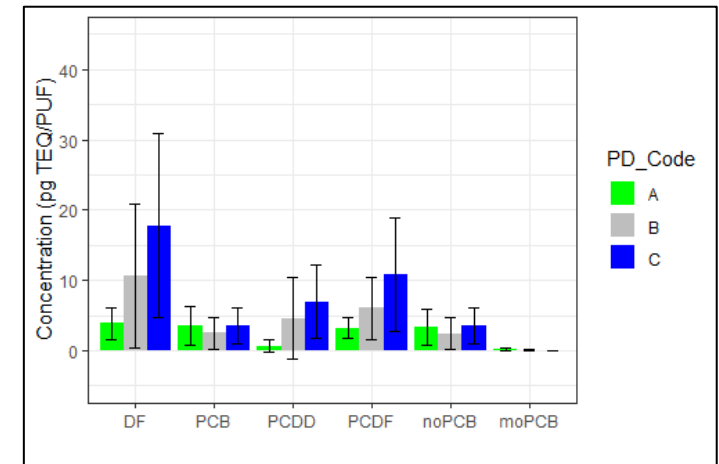
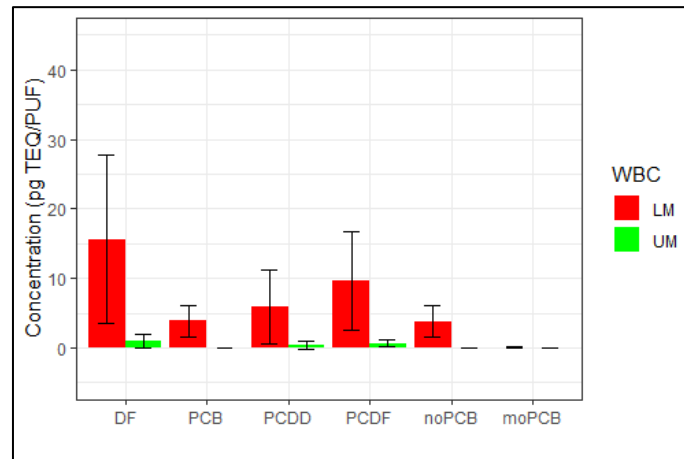
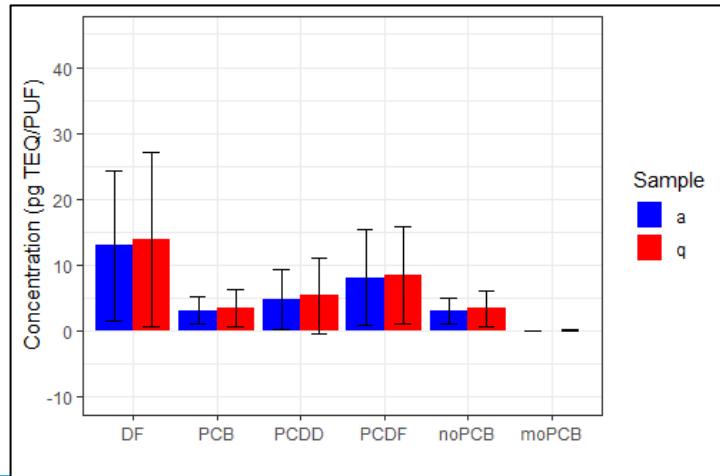
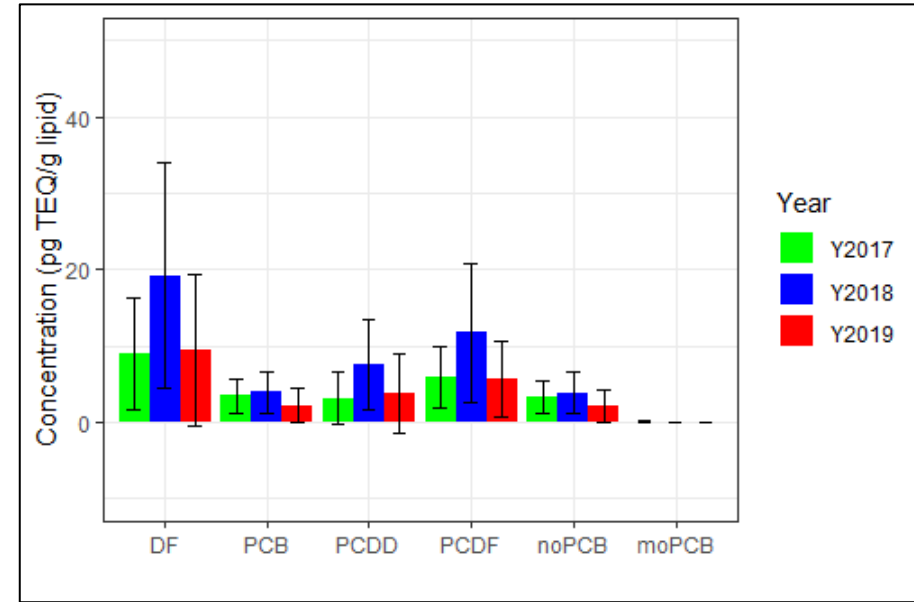
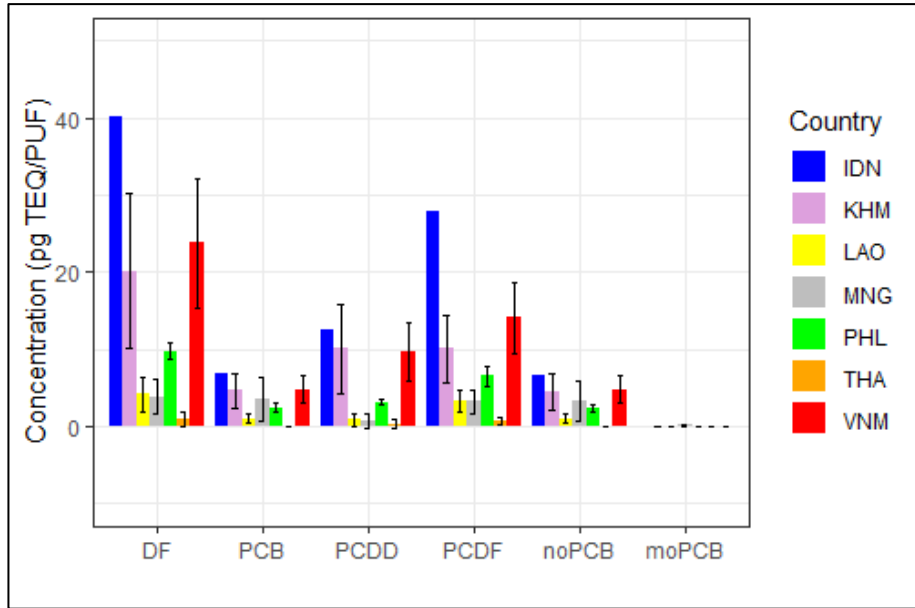


# Income

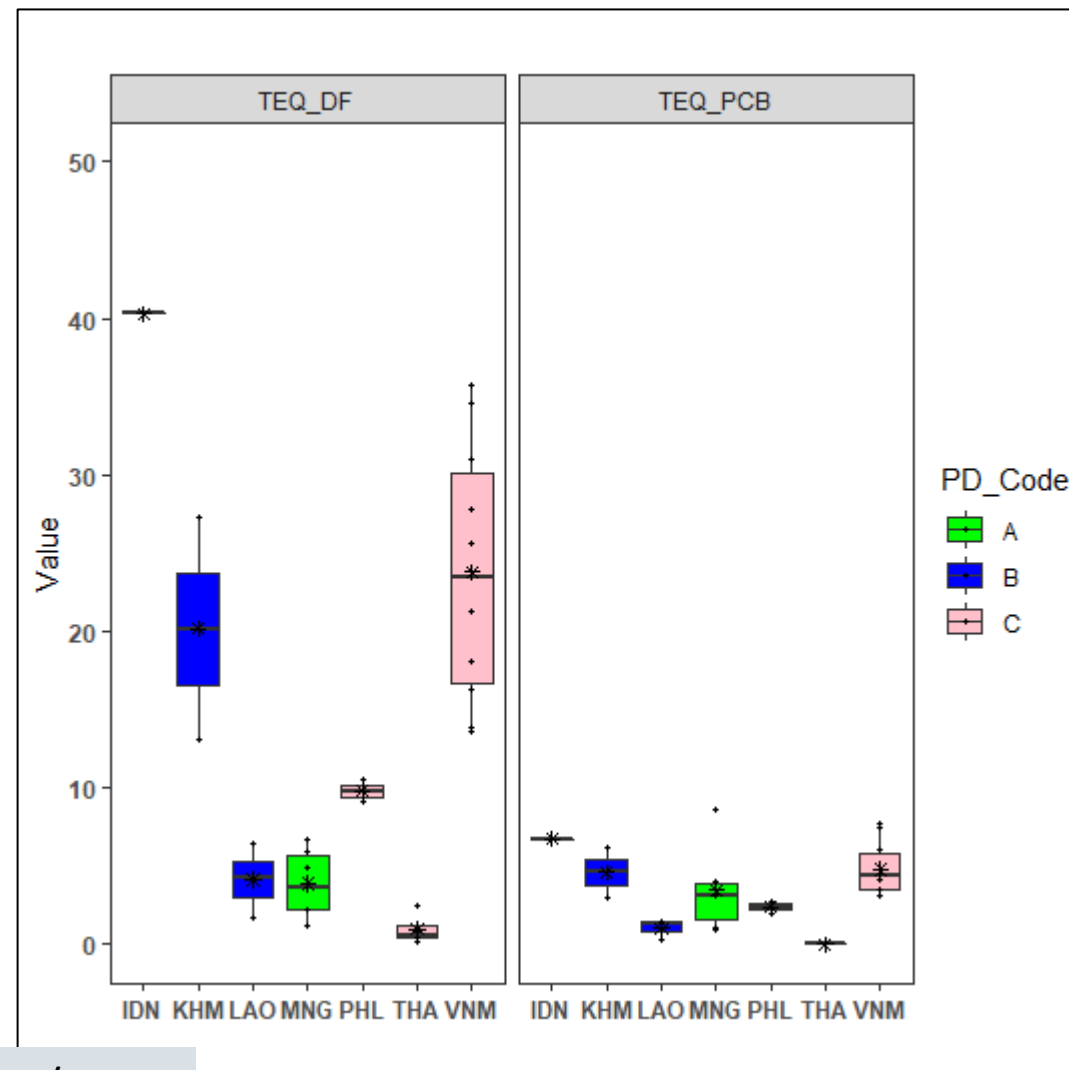
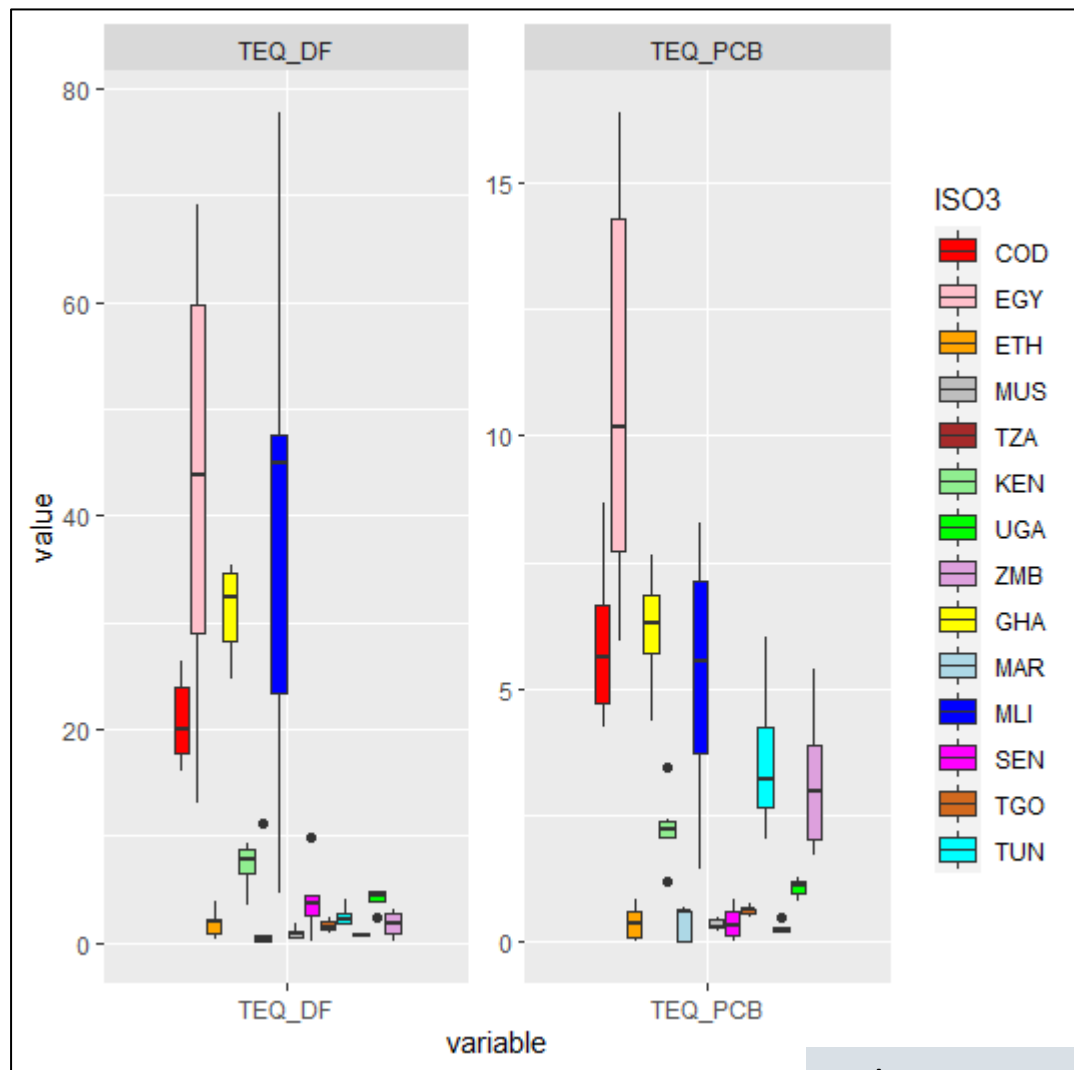


Values in pg WHO<sub>2005</sub>-TEQ/PUF

# Graphs for mean values (+SD) - Asia



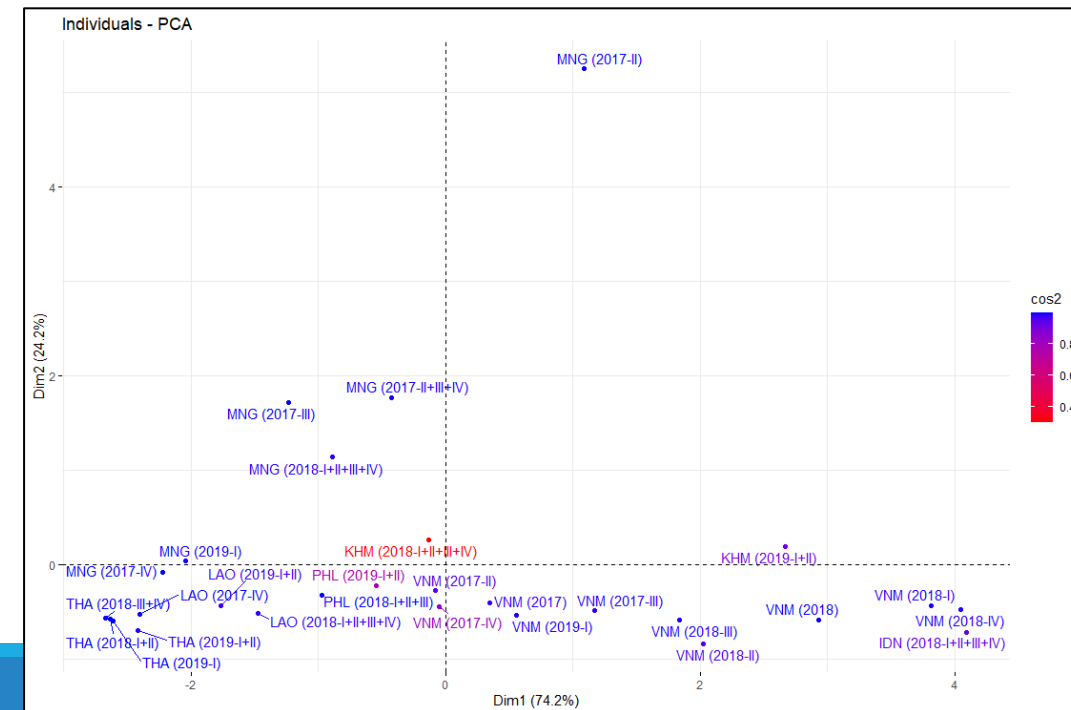
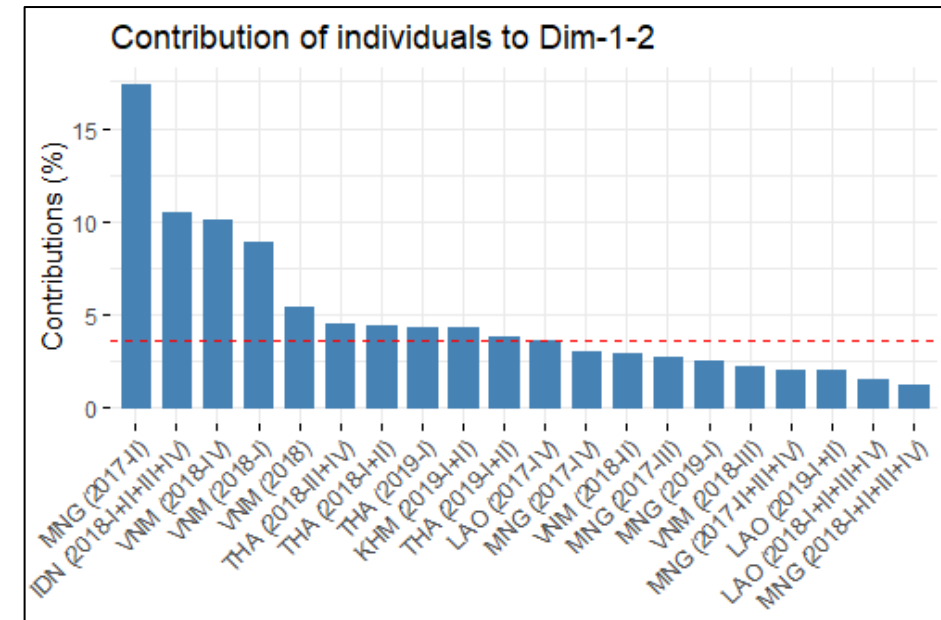
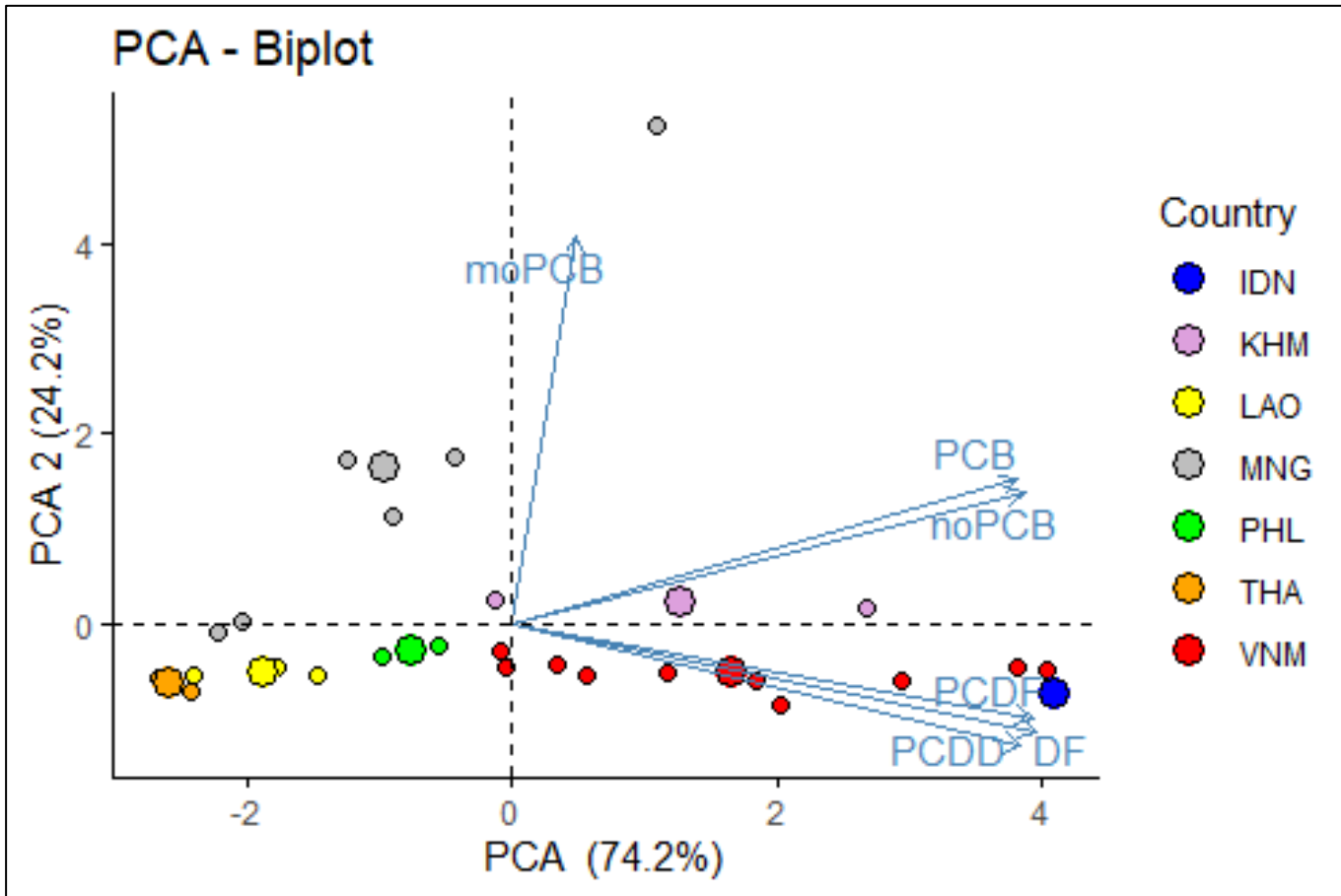
# TEQ<sub>PCDD/PCDF</sub> and TEQ<sub>PCB</sub> for country and pop-density



Values in pg WHO<sub>2005</sub>-TEQ/PUF



# Principal component analysis (PCA) for 6 partial TEQs

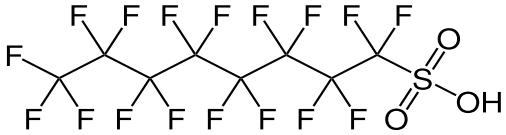

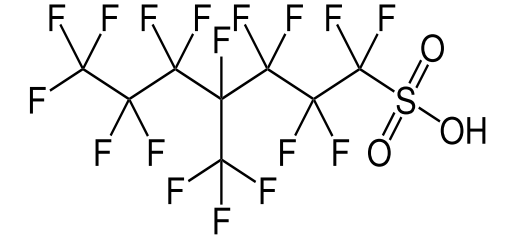
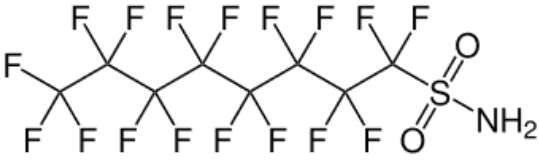


# PAS/PUF Results - PFAS

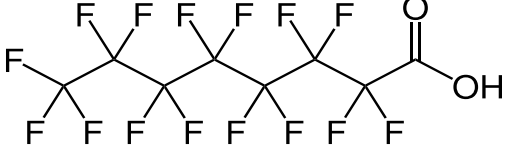
## B. Across All Projects

# Perfluoroalkane substances (PFAS)

## Perfluoroalkylsulfonic acids (PFSA)

	PFOS	PFHxS
L-PFOS		 L-PFHxS
br-PFOS		
FOSA (PFOS pre-cursor)		

## Perfluoroalkylcarboxylic acids (PFCA)

	PFOA
L-PFOA	

# Number/classification of samples GMP2 PFAS

Without outliers

	Africa (N=119)	Asia (N=46)	GRULAC (N=101)	PAC (N=43)	Overall (N=309)
<b>Region</b>					
Africa	119 (100%)	0 (0%)	0 (0%)	0 (0%)	119 (38.5%)
Asia	0 (0%)	46 (100%)	0 (0%)	0 (0%)	46 (14.9%)
GRULAC	0 (0%)	0 (0%)	101 (100%)	0 (0%)	101 (32.7%)
PAC	0 (0%)	0 (0%)	0 (0%)	43 (100%)	43 (13.9%)
<b>WBC</b>					
L	52 (43.7%)	0 (0%)	0 (0%)	0 (0%)	52 (16.8%)
LM	57 (47.9%)	40 (87.0%)	0 (0%)	20 (46.5%)	117 (37.9%)
UM	10 (8.4%)	6 (13.0%)	58 (57.4%)	15 (34.9%)	89 (28.8%)
H	0 (0%)	0 (0%)	43 (42.6%)	8 (18.6%)	51 (16.5%)
<b>PD_Code</b>					
A	11 (9.2%)	9 (19.6%)	34 (33.7%)	18 (41.9%)	72 (23.3%)
B	55 (46.2%)	14 (30.4%)	38 (37.6%)	13 (30.2%)	120 (38.8%)
C	43 (36.1%)	23 (50.0%)	19 (18.8%)	12 (27.9%)	97 (31.4%)
D	10 (8.4%)	0 (0%)	10 (9.9%)	0 (0%)	20 (6.5%)
<b>YYYY</b>					
Y2017	54 (45.4%)	9 (19.6%)	47 (46.5%)	15 (34.9%)	125 (40.5%)
Y2018	58 (48.7%)	29 (63.0%)	54 (53.5%)	26 (60.5%)	167 (54.0%)
Y2019	7 (5.9%)	8 (17.4%)	0 (0%)	2 (4.7%)	17 (5.5%)
<b>Sample</b>					
a	24 (20.2%)	8 (17.4%)	21 (20.8%)	9 (20.9%)	62 (20.1%)
q	95 (79.8%)	38 (82.6%)	80 (79.2%)	34 (79.1%)	247 (79.9%)

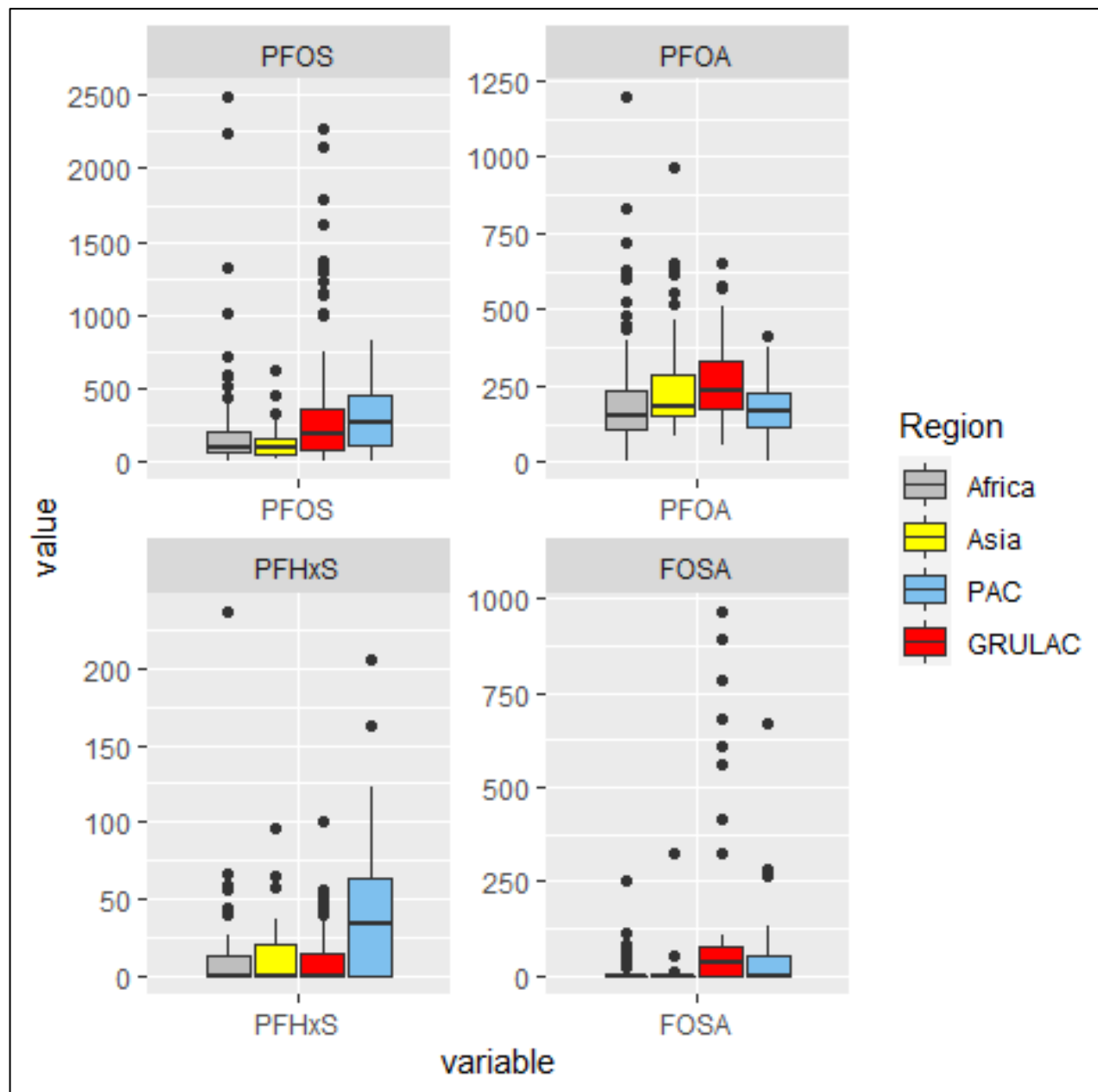
# Summary results PAS/PUFs for PFAS (without outliers)

	Africa (N=119)	Asia (N=46)	GRULAC (N=101)	PAC (N=43)	Overall (N=309)
<b>PFOS (pg/PUF)</b>					
Mean (SD)	203 (346)	139 (122)	376 (497)	297 (219)	261 (375)
Median [Min, Max]	98.1 [0, 2480]	101 [27.3, 634]	192 [0, 2260]	266 [0, 827]	128 [0, 2480]
Missing	5 (4.2%)	1 (2.2%)	10 (9.9%)	3 (7.0%)	19 (6.1%)
<b>PFOA (pg/PUF)</b>					
Mean (SD)	206 (177)	271 (194)	257 (125)	181 (86.5)	230 (157)
Median [Min, Max]	149 [0, 1190]	183 [83.1, 965]	233 [58.9, 655]	165 [0, 417]	187 [0, 1190]
Missing	10 (8.4%)	2 (4.3%)	5 (5.0%)	5 (11.6%)	22 (7.1%)
<b>PFHxS (pg/PUF)</b>					
Mean (SD)	8.96 (24.8)	13.4 (20.7)	9.72 (18.6)	41.6 (48.5)	14.5 (29.3)
Median [Min, Max]	0 [0, 237]	0 [0, 96.1]	0 [0, 101]	34.7 [0, 206]	0 [0, 237]
Missing	2 (1.7%)	2 (4.3%)	1 (1.0%)	0 (0%)	5 (1.6%)
<b>FOSA (pg/PUF)</b>					
Mean (SD)	16.5 (40.6)	24.6 (81.8)	138 (260)	68.5 (155)	64.3 (171)
Median [Min, Max]	0 [0, 251]	0 [0, 327]	34.9 [0, 964]	0 [0, 669]	0 [0, 964]
Missing	61 (51.3%)	30 (65.2%)	56 (55.4%)	20 (46.5%)	167 (54.0%)

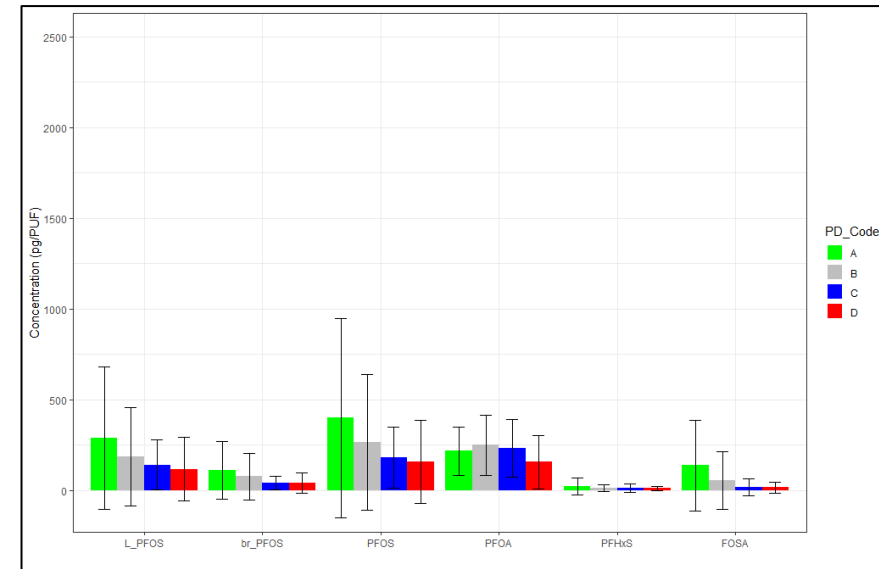
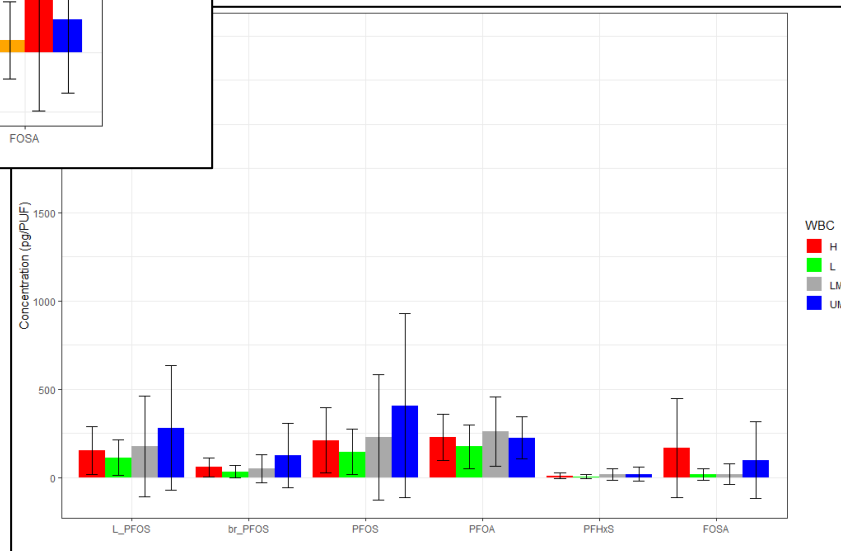
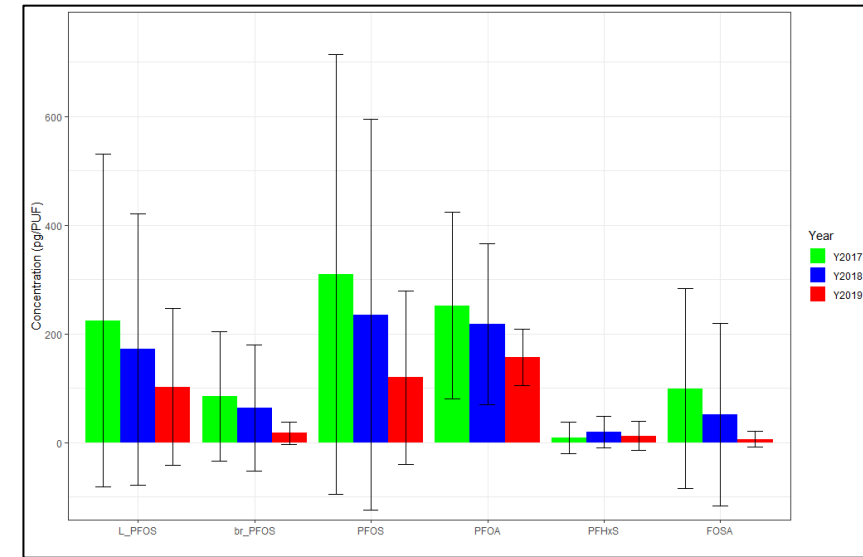
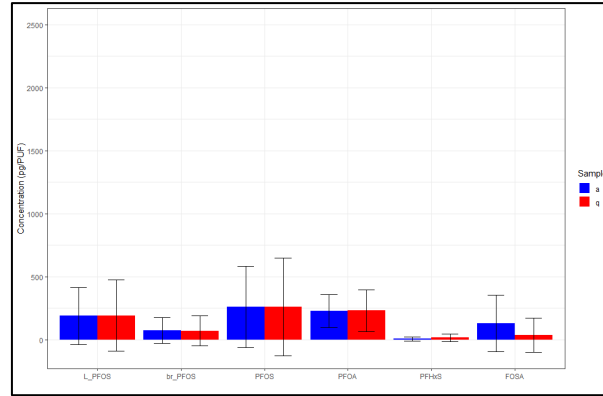
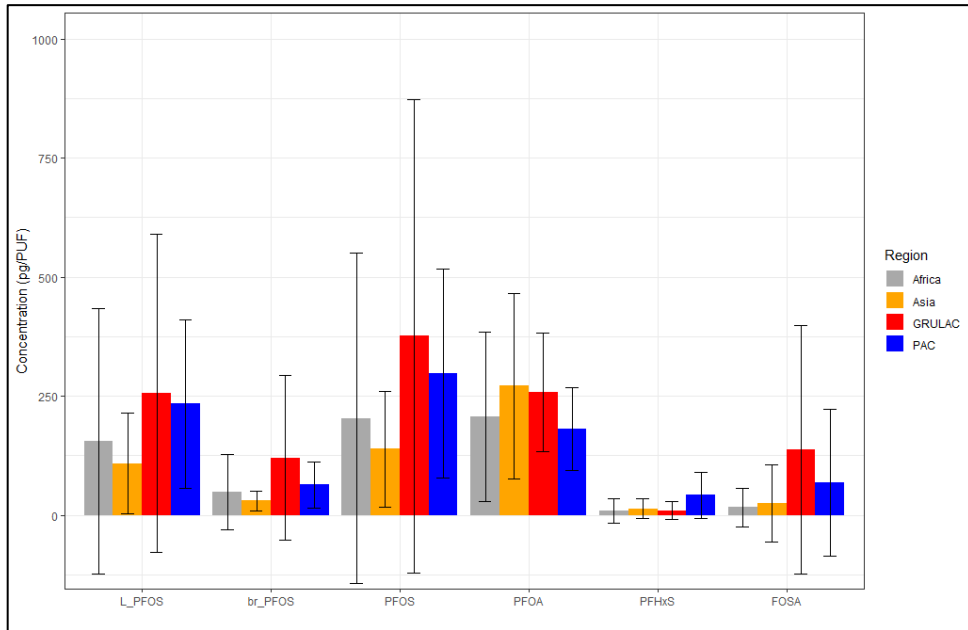
# PAS/PUFs

## Air (n=309)

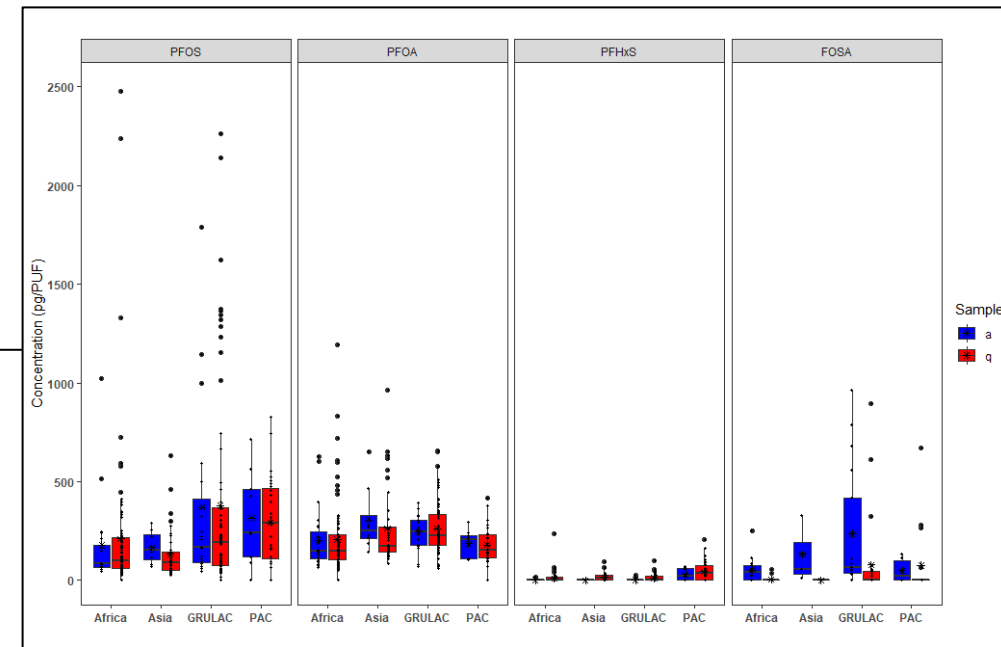
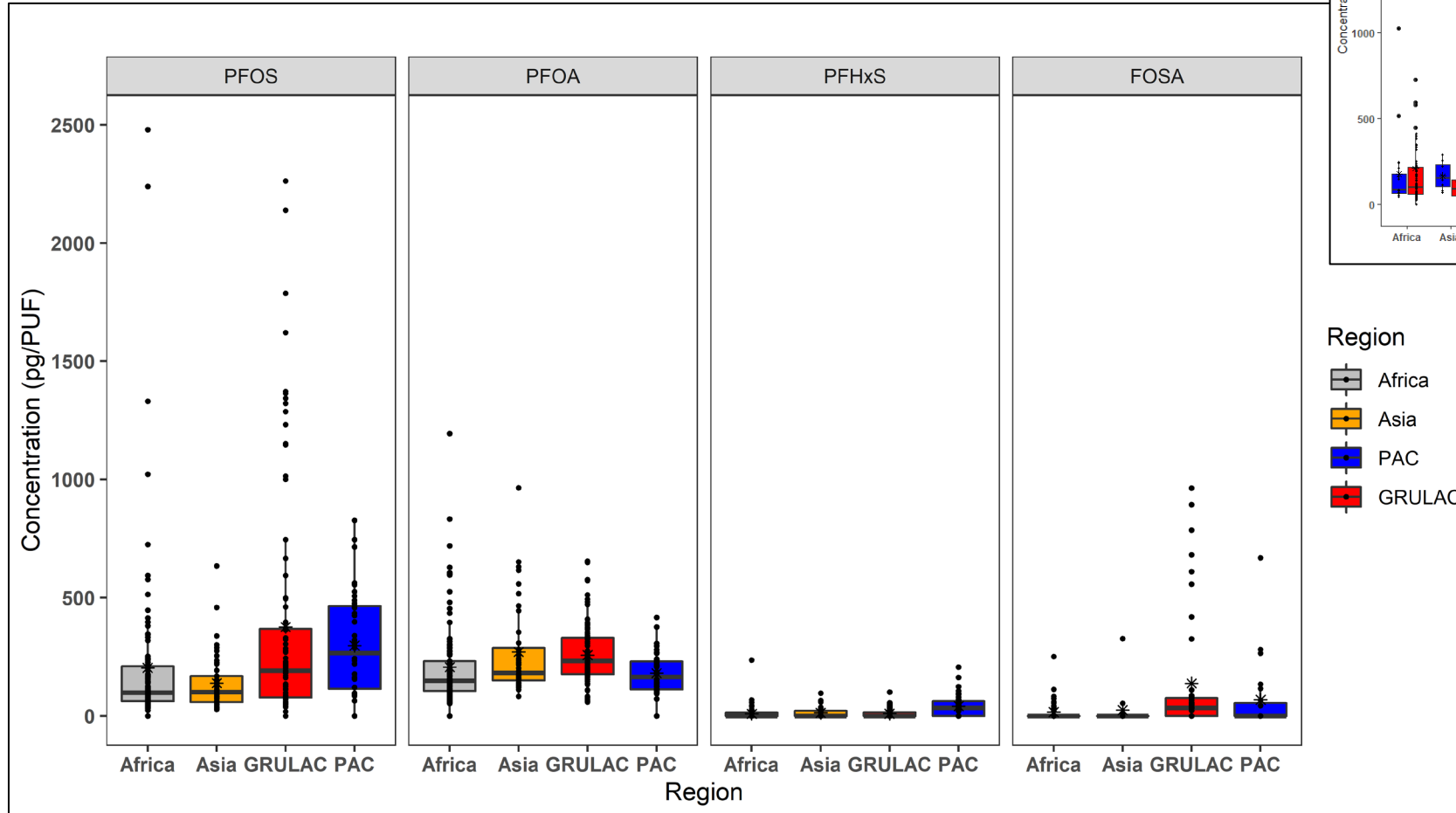
Values in pg/PUF and  
3 months exposure



# Mean values with SD (n=309)



# Overview PFAS by region and sample (n=309)



Region

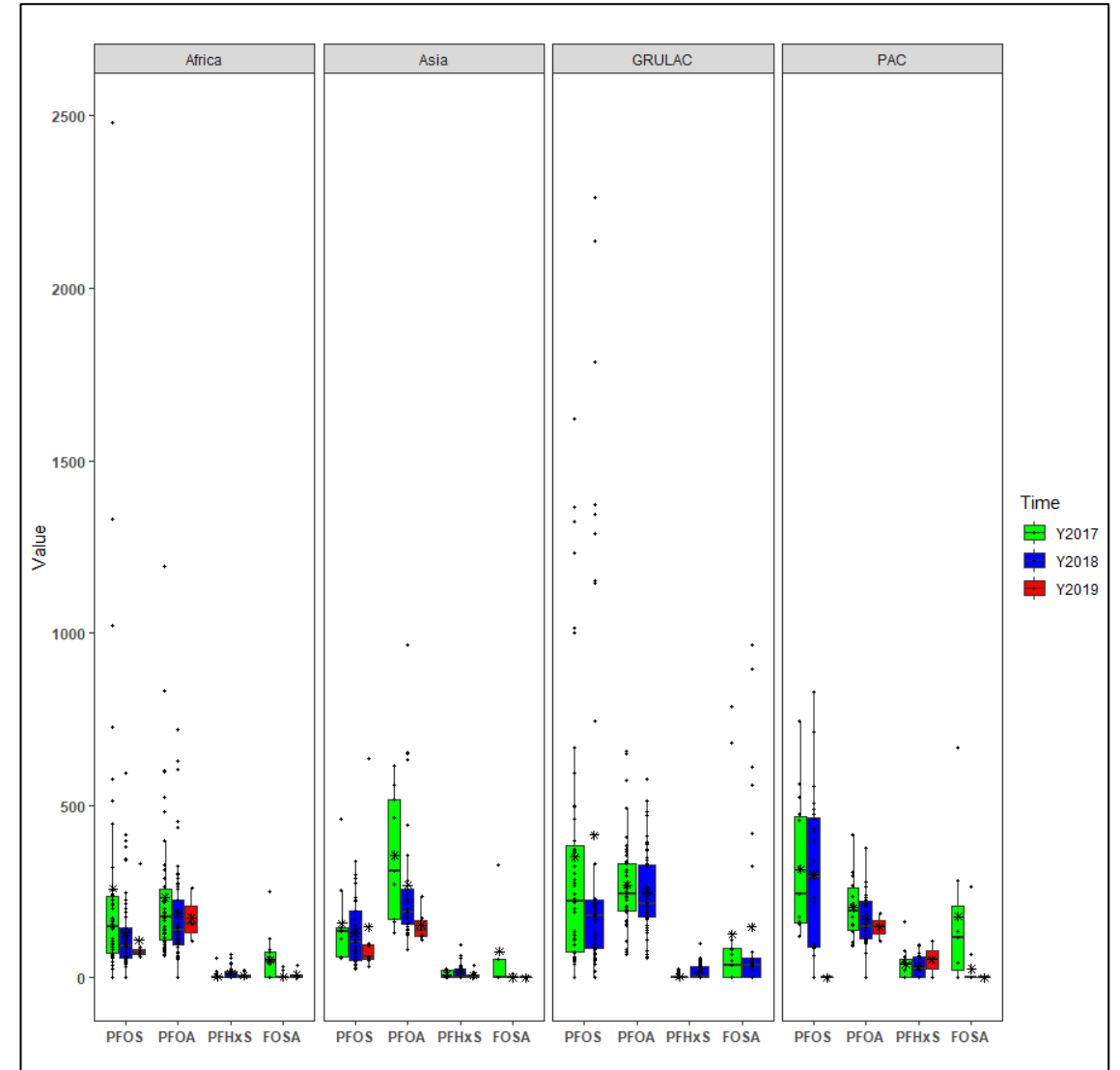
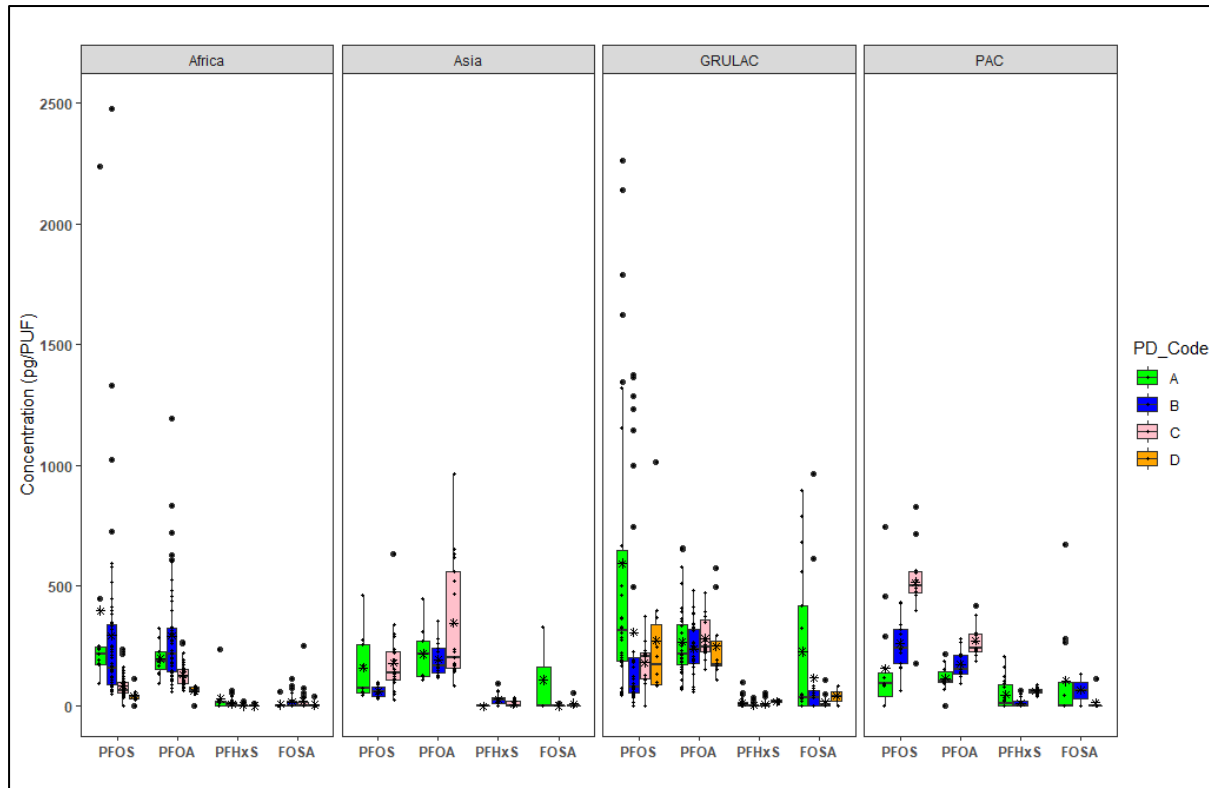
- Africa
- Asia
- PAC
- GRULAC

a = annual samples; e.g., up to 4 PUFs combined, amount divided by the number of PUFs, adjusted to 3 months

q = quarterly PUFs, 1 PUF and 3 months exposure

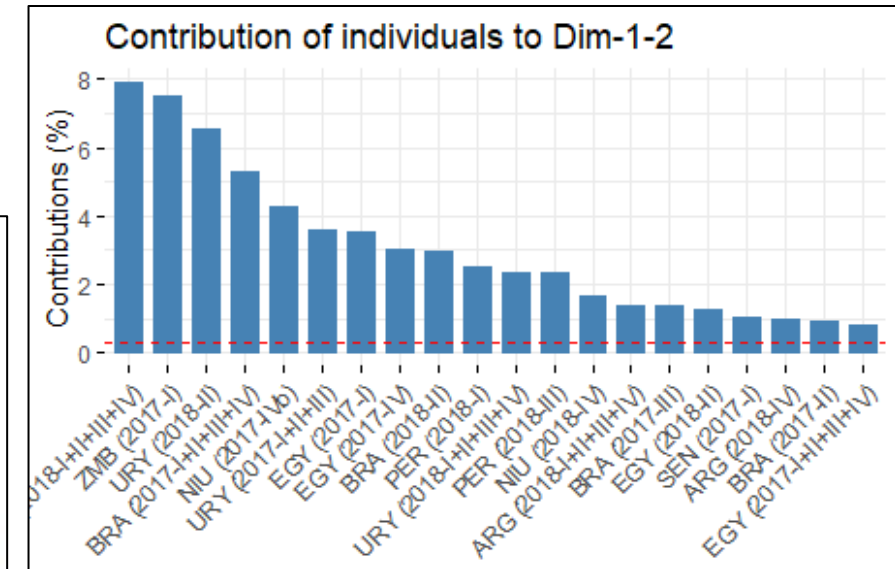
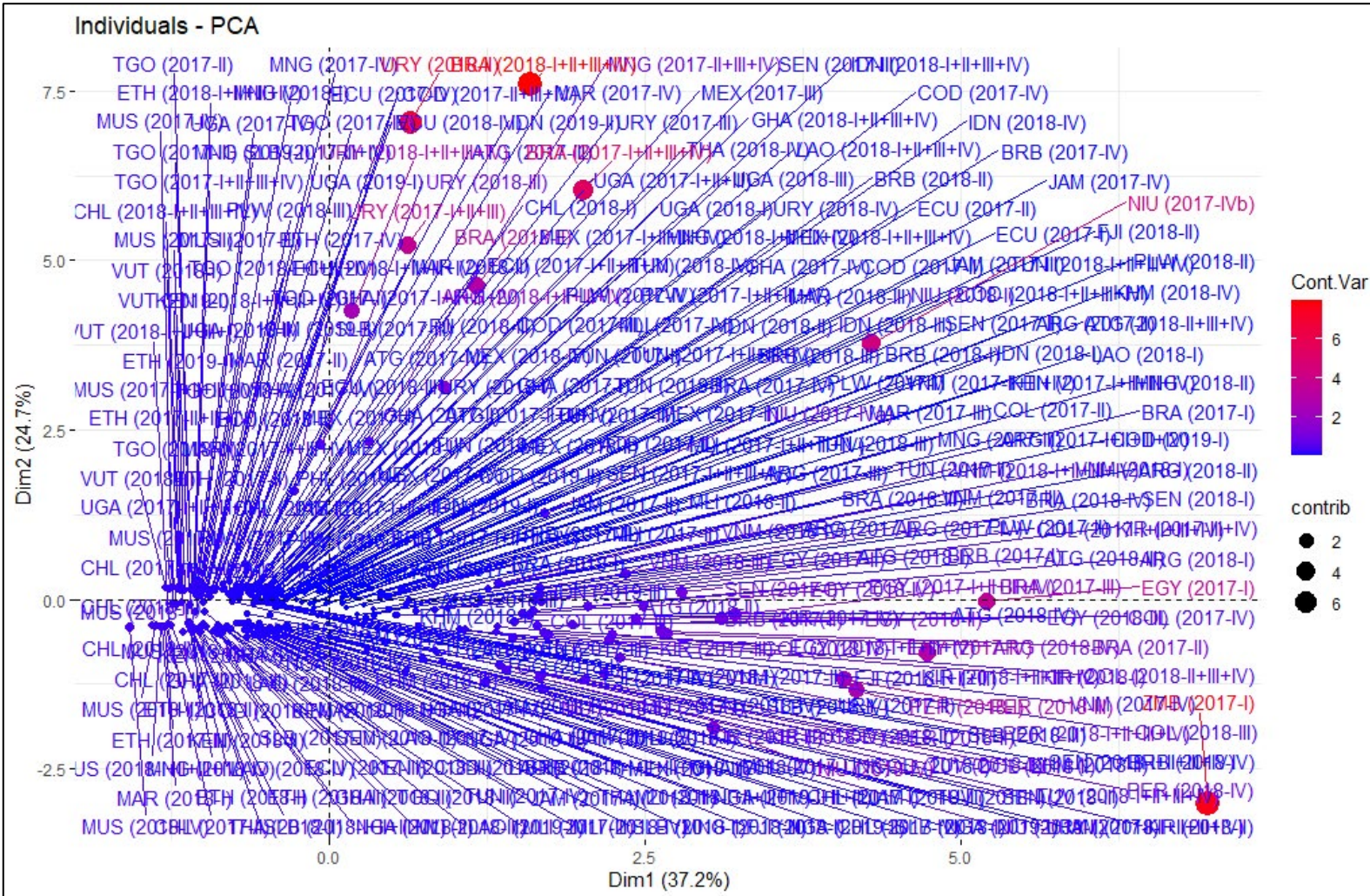


# Overview PFAS by year and PD (n=309)

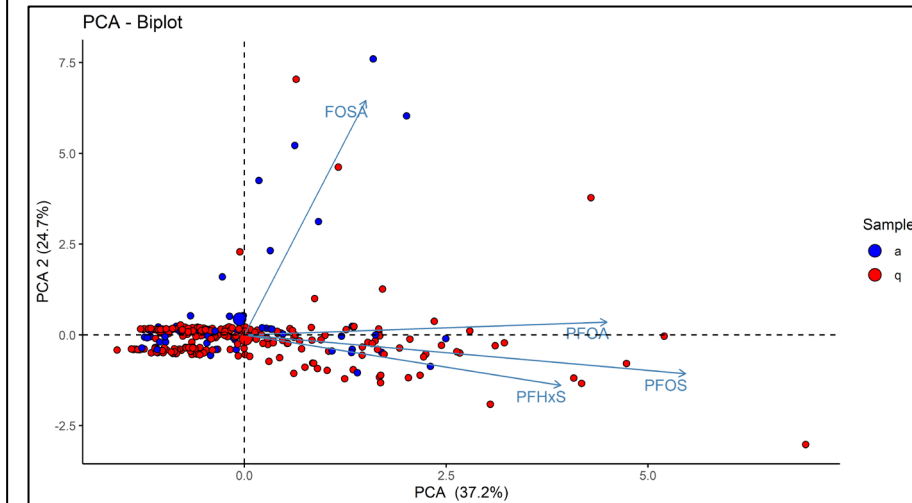


Values in pg/PUF and  
3 months exposure

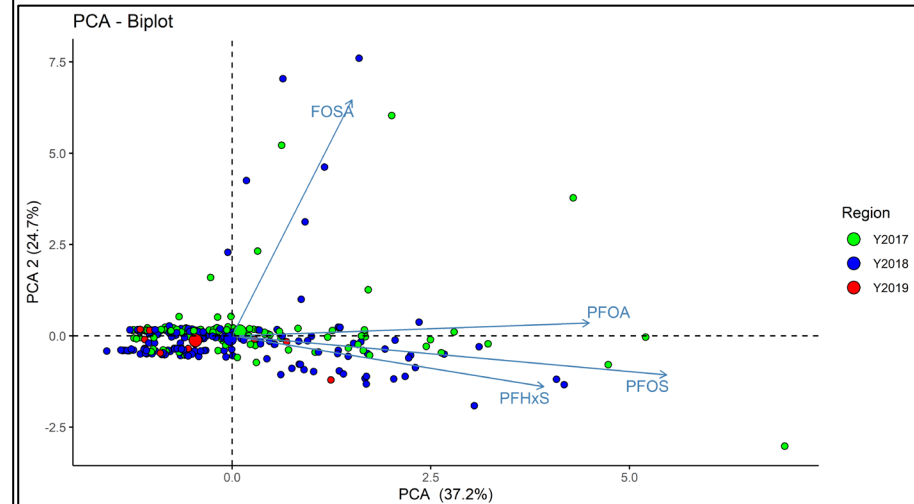
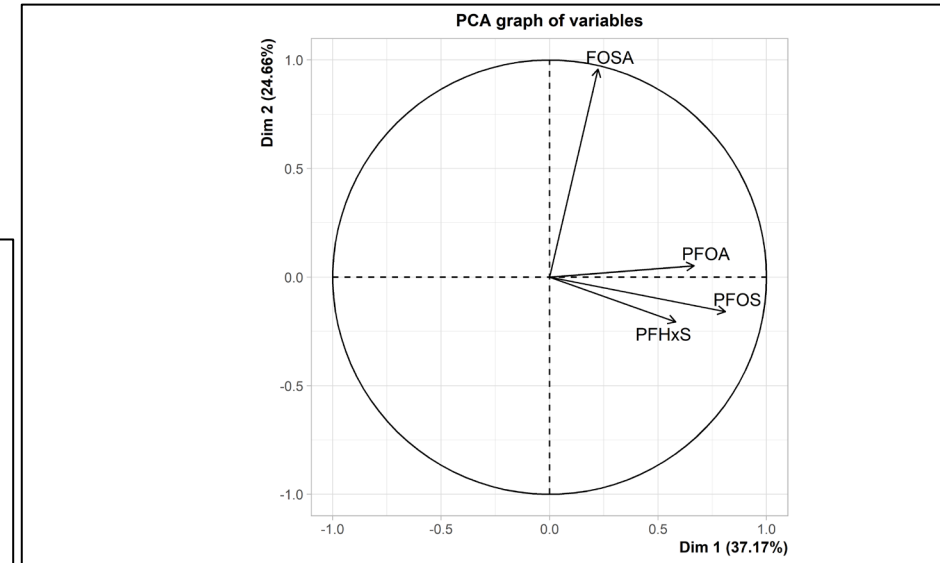
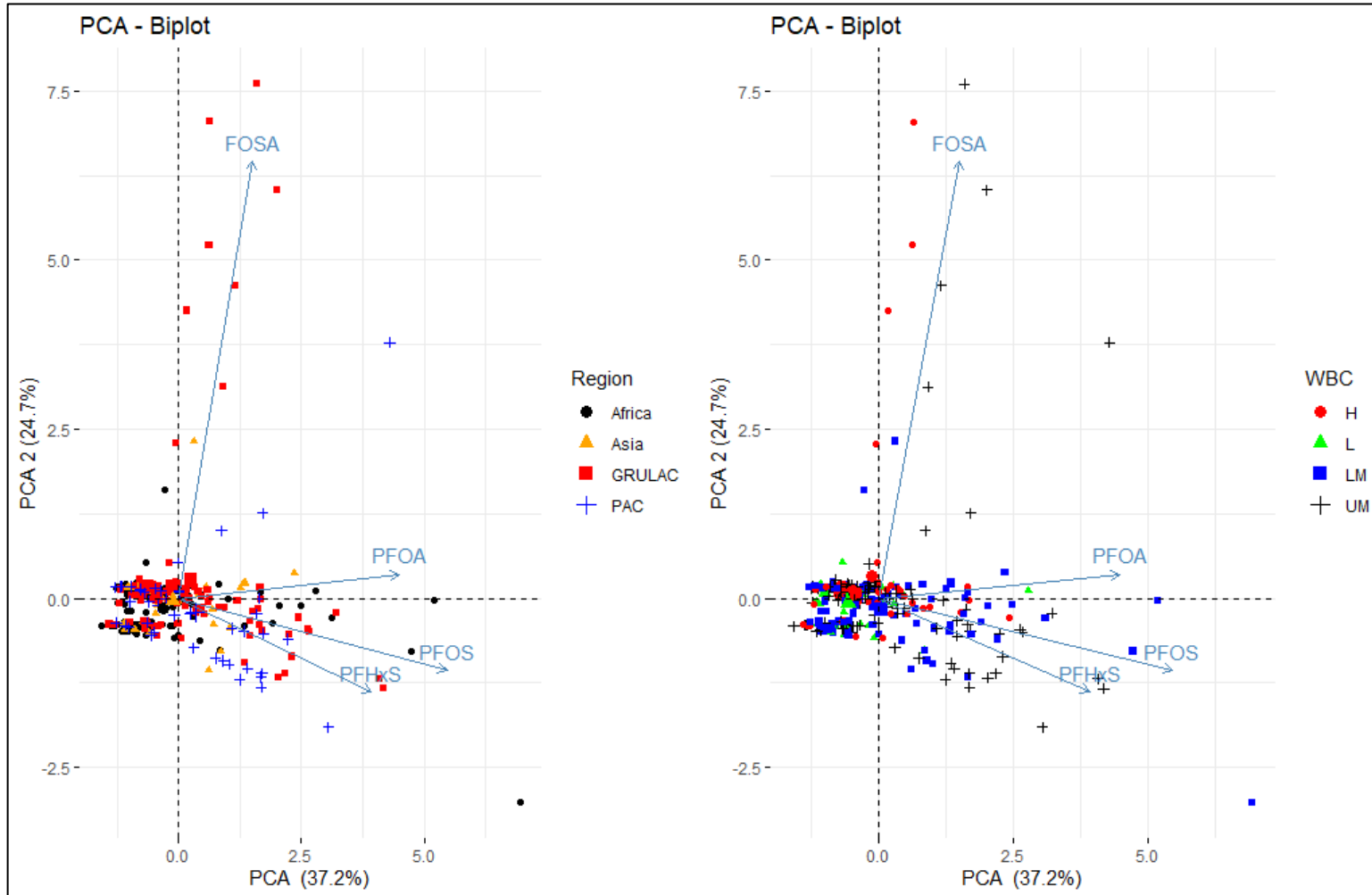
# PCA biplot for region (n=309)



No Asian country among top 20 main contributors



# PCA biplots



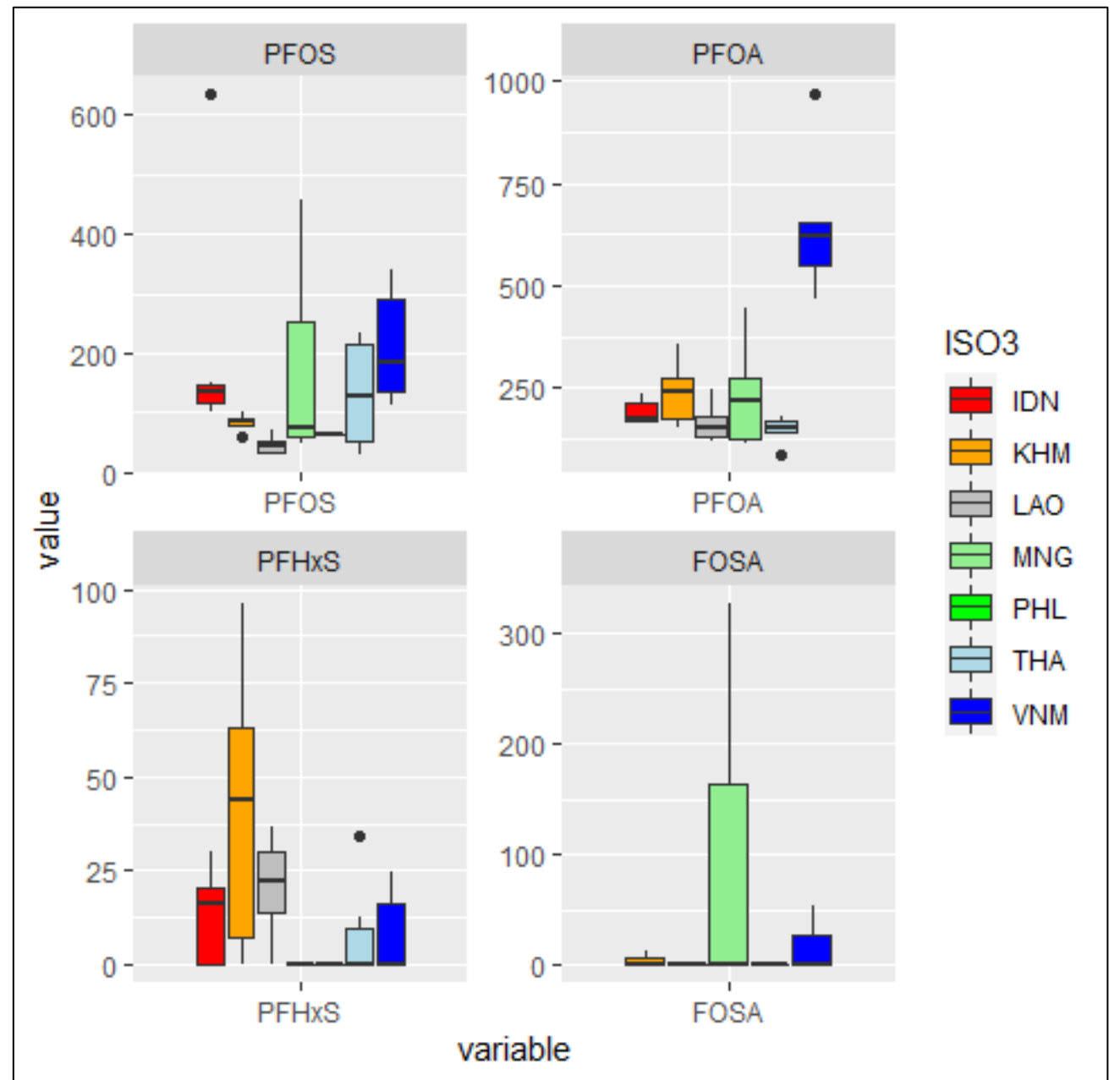
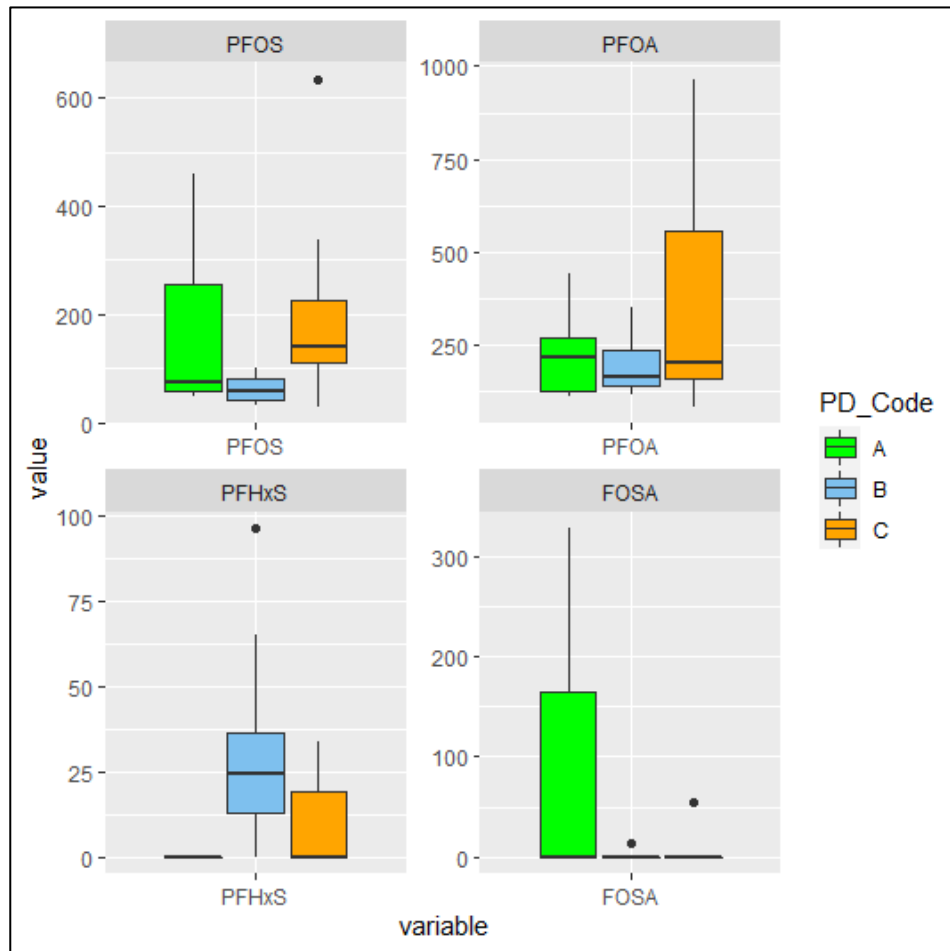
# PFAS Results

## B.1 Asia Region

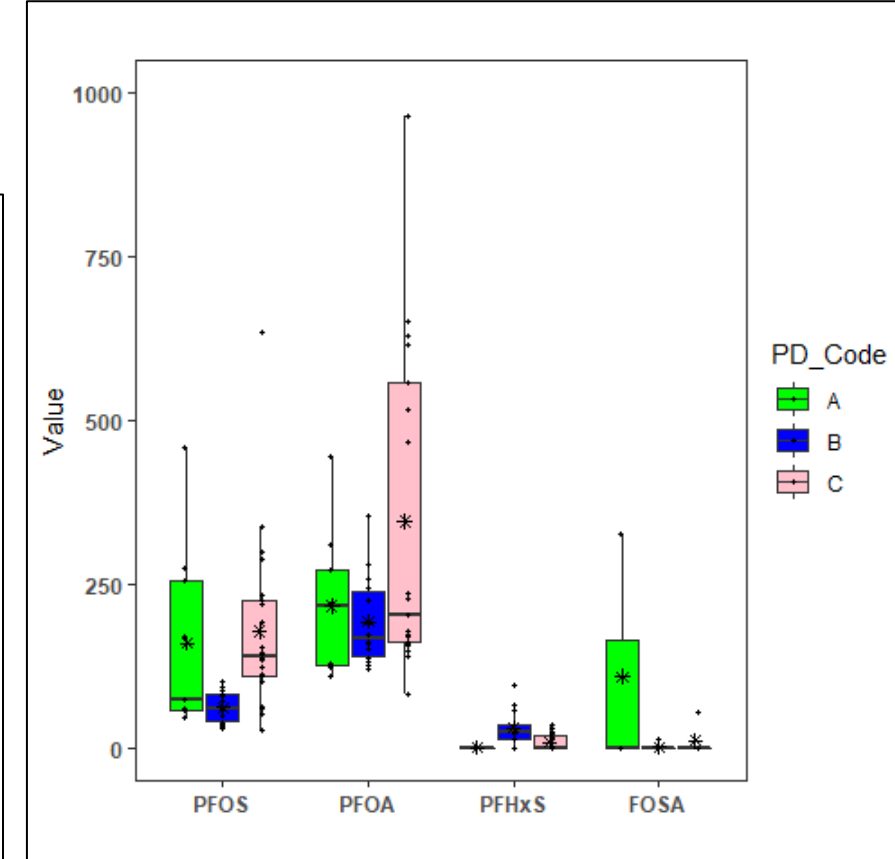
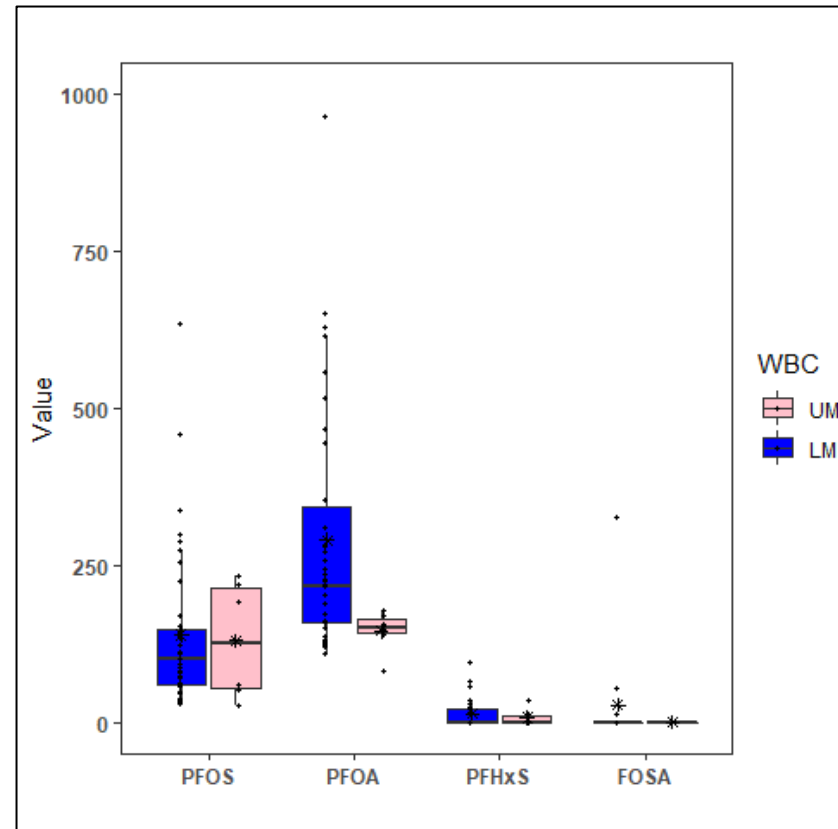
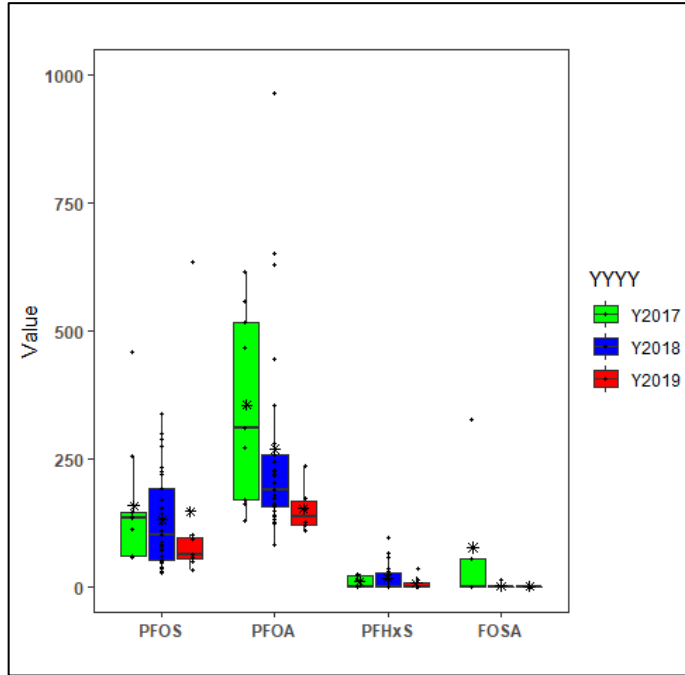
Country name	ISO-3	Project Region	WBC 2017	WBC 2018	PD 2017	PD 2018
Cambodia	KHM	Asia	LM	LM	B	B
Indonesia	IDN	Asia	LM	LM	C	C
Lao PDR	LAO	Asia	LM	LM	B	B
Mongolia	MNG	Asia	LM	LM	A	A
Philippines	PHL	Asia	LM	LM	C	C
Thailand	THA	Asia	UM	UM	C	C
Vietnam	VNM	Asia	LM	LM	C	C

# PFAS Overview

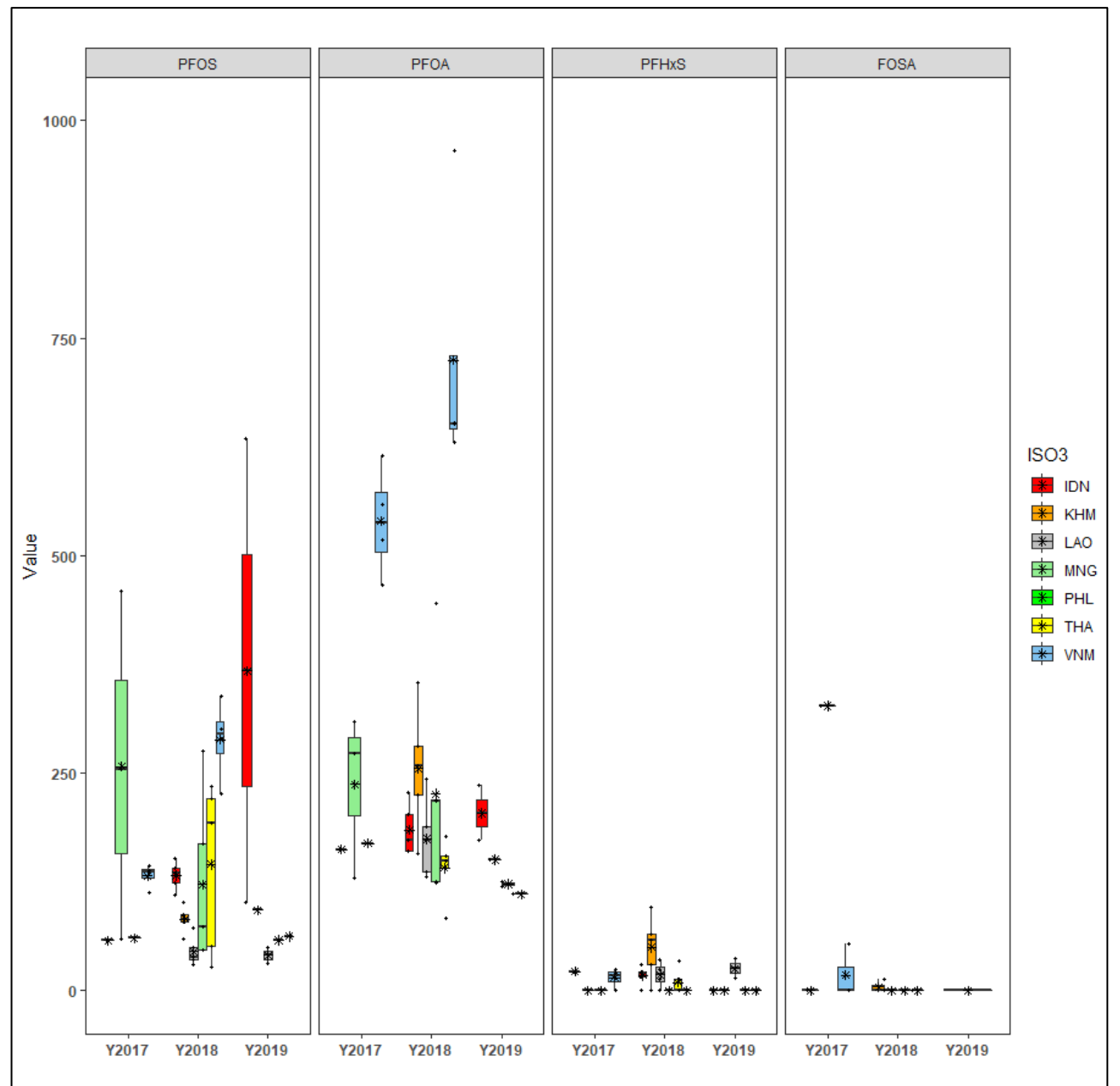
## Asia (pg/g PUF)



# PFAS Asia



# 4 PFAS per year and country (pg/g PUF)



## Acknowledgment:

- This work was funded through a grant from UN Environment (funds from the Global Environment Facility – GEF) “Supporting implementation of the Global Monitoring Plan on POPs” to Örebro University;
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- Thanks to Dr. Leo W.Y. Yeung for PFASs QA/QC, Siamak Sobhanei, Mohammad Sadia, and Abeer Baabish for PFAS lab work at MTM Research Centre, Örebro University;
- Thanks to all national teams for providing the samples.

# Thank you !