



For the Environment. For the People.



PFAS Congress - June 18th, 2025

Lucie ROBIN VIGNERON

Case study

Human Health Risk Assessment

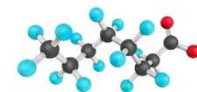
Old Paper Manufacture :

Stakes and Challenges



23/06/2025

Case study : Human Health Risk Assessment



1. Context of the study: old paper manufacture
2. Investigations and analyses
3. Human Health Risk Assessment study
4. Discussion

Case study : Human Health Risk Assessment

1. Context of the study: old paper manufacture



PFAS were used in the manufacture of coated paper, cardboard and packaging

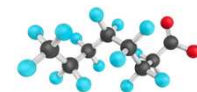
This case study concerns an old paper factory, which has been working more than 3 centuries and is suspected to have used PFAS in the manufacturing.

In addition, in the past, firefighting foam exercises occurred on the area.



Underground investigations
for the research of 66 PFAS in
Soil
Soil gas
Groundwater

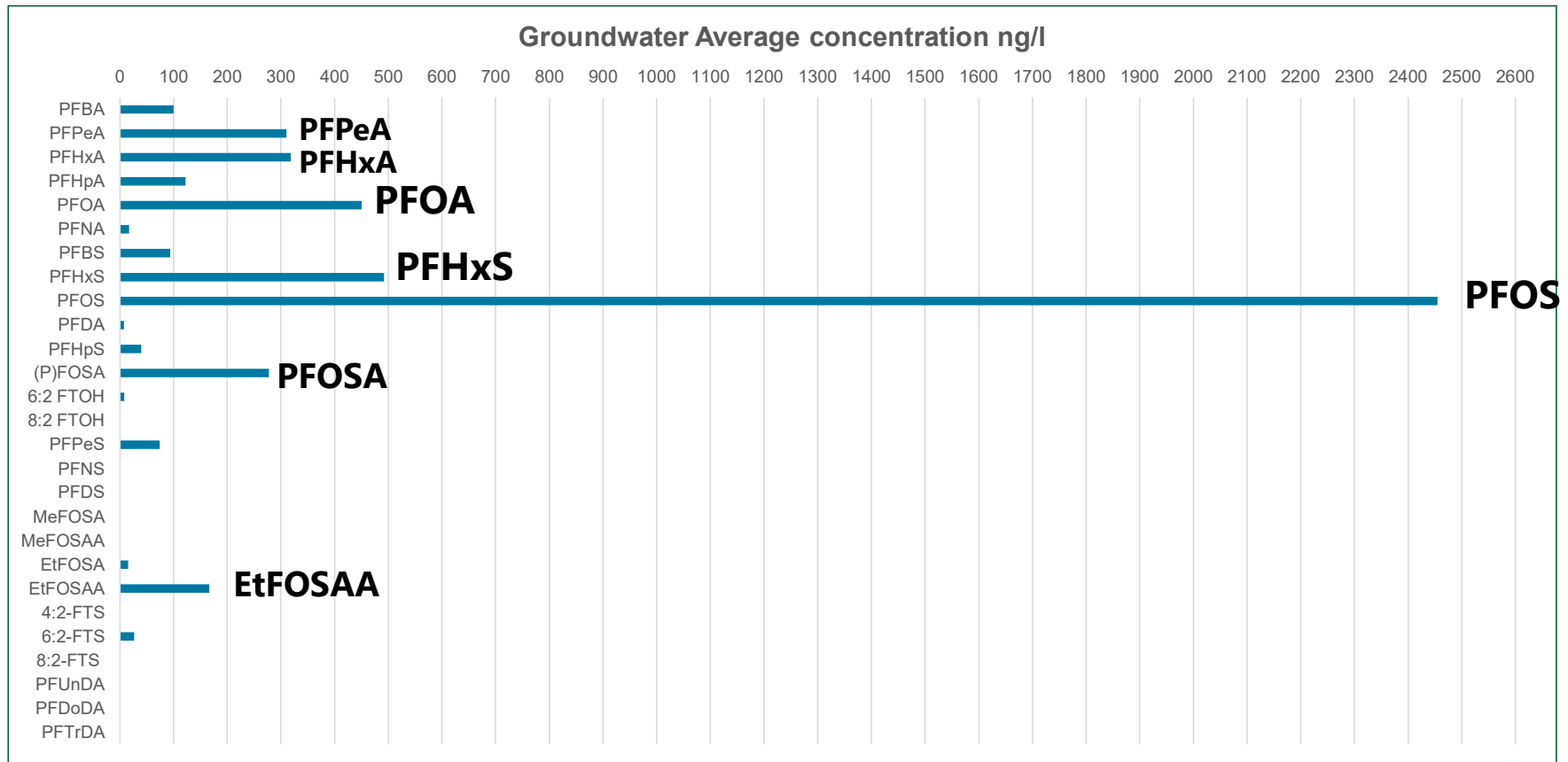
Case study : Human Health Risk Assessment



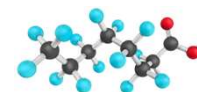
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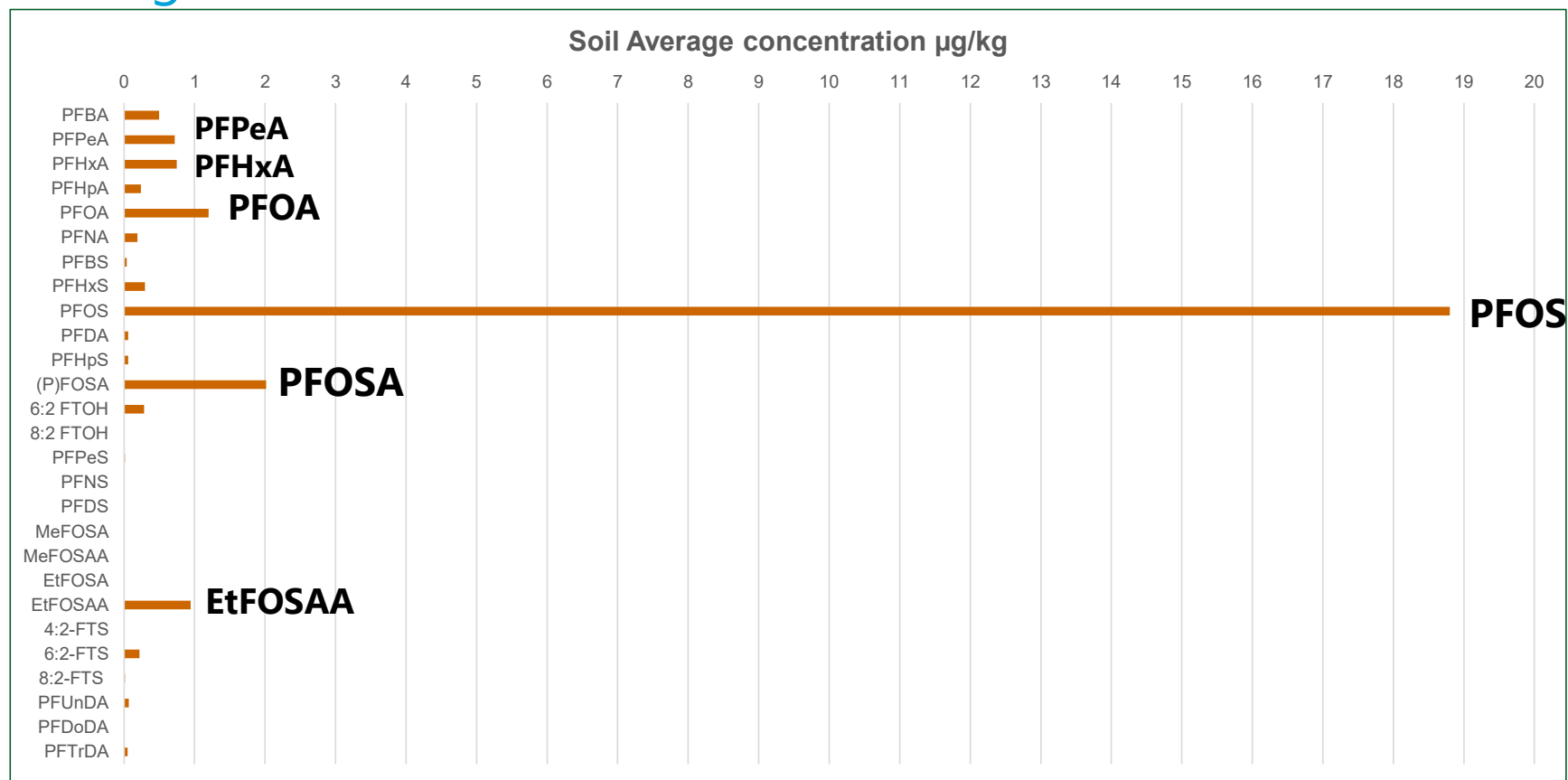
2. Investigations in groundwater



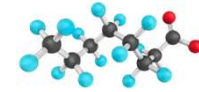
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2. Investigations in soil



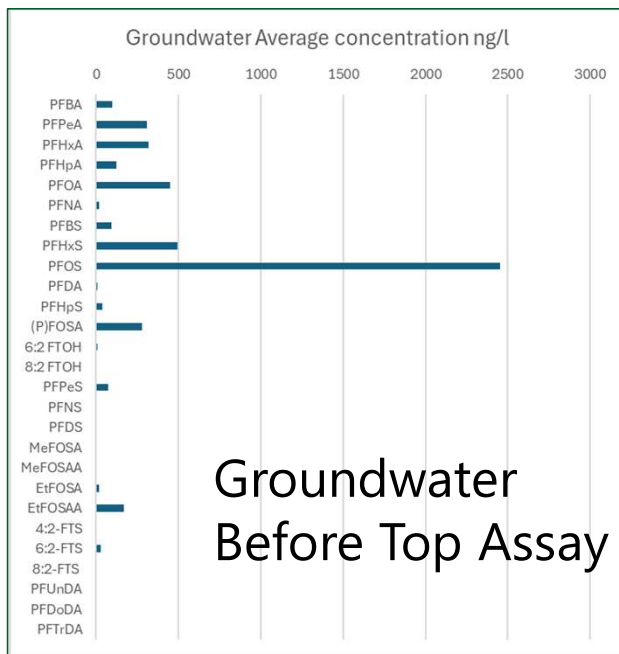
Case study : Human Health Risk Assessment



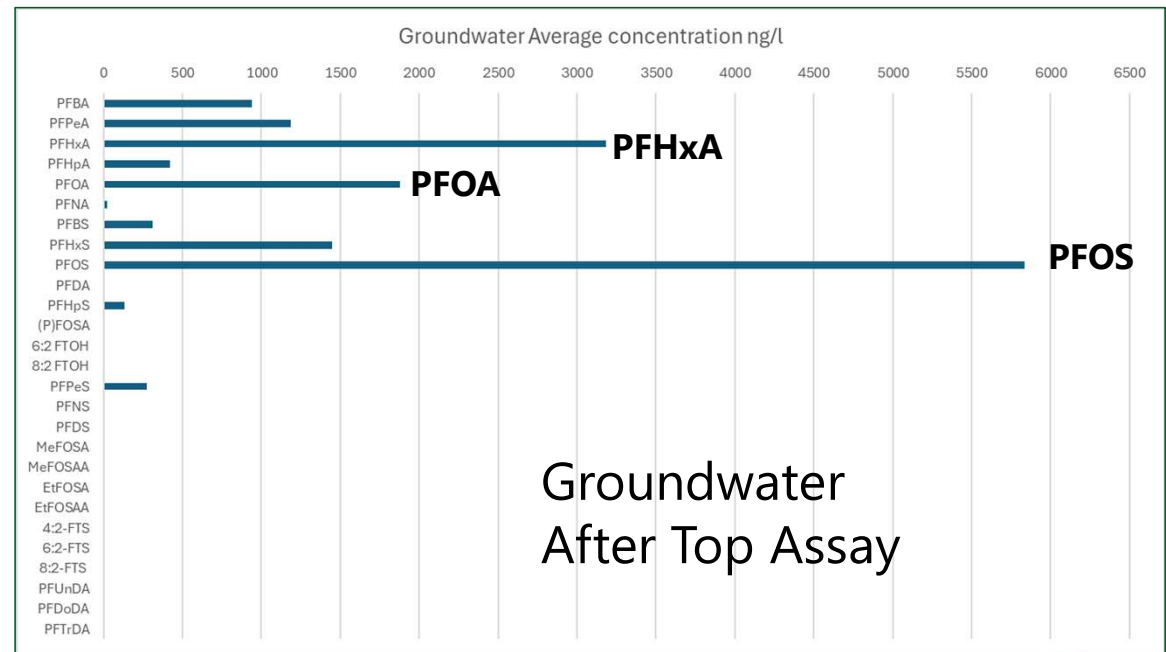
2. Investigations and analyses

Performing Top Assays (oxydation)

to increase the knowledge and the number of molecules taken into account : transformation of polyfluorinated in perfluorinated (increase of natural biotransformation)



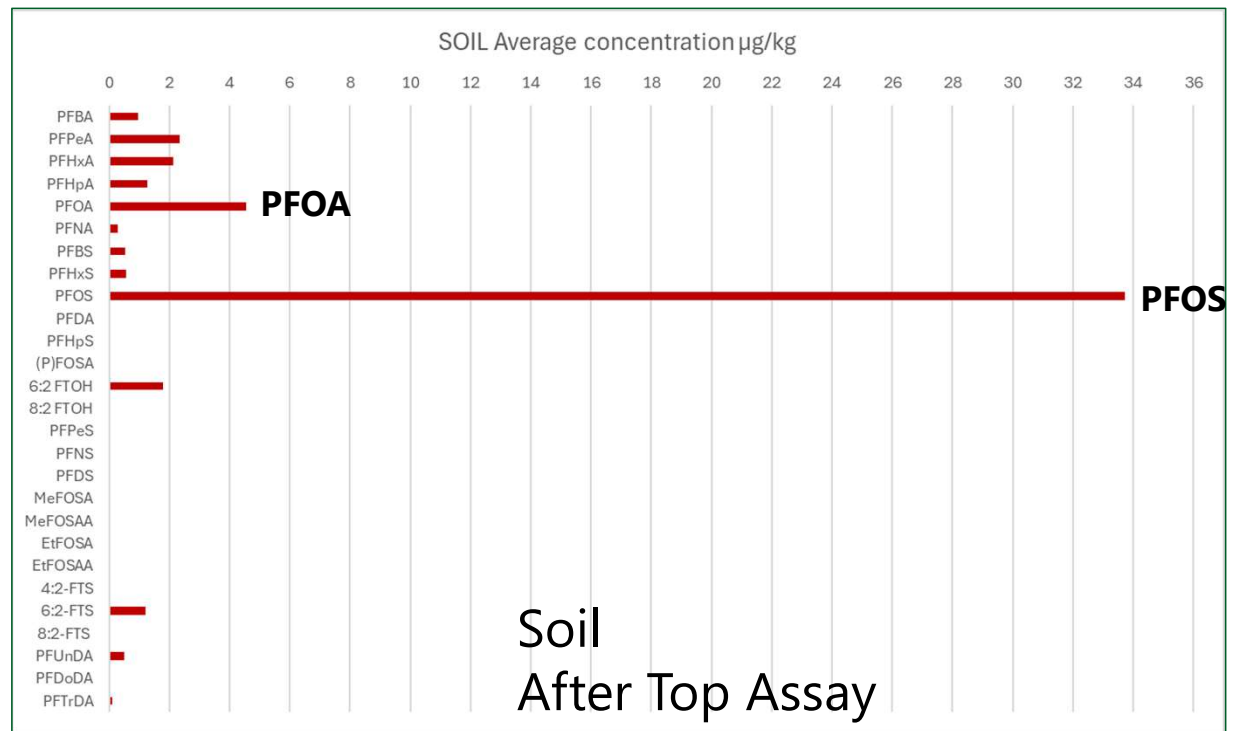
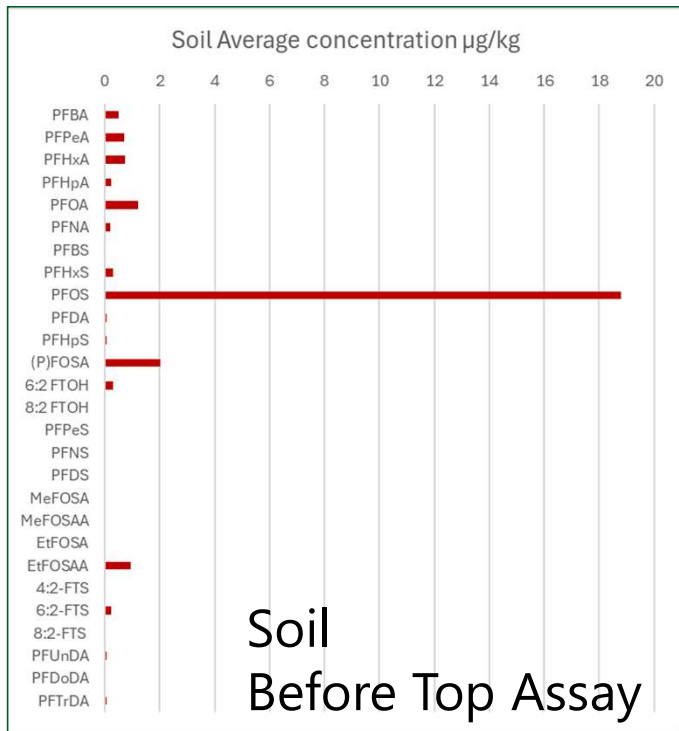
Groundwater
Before Top Assay



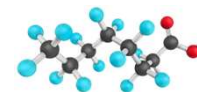
Groundwater
After Top Assay

Case study : Human Health Risk Assessment

2. Investigations and analyses



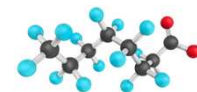
Case study : Human Health Risk Assessment



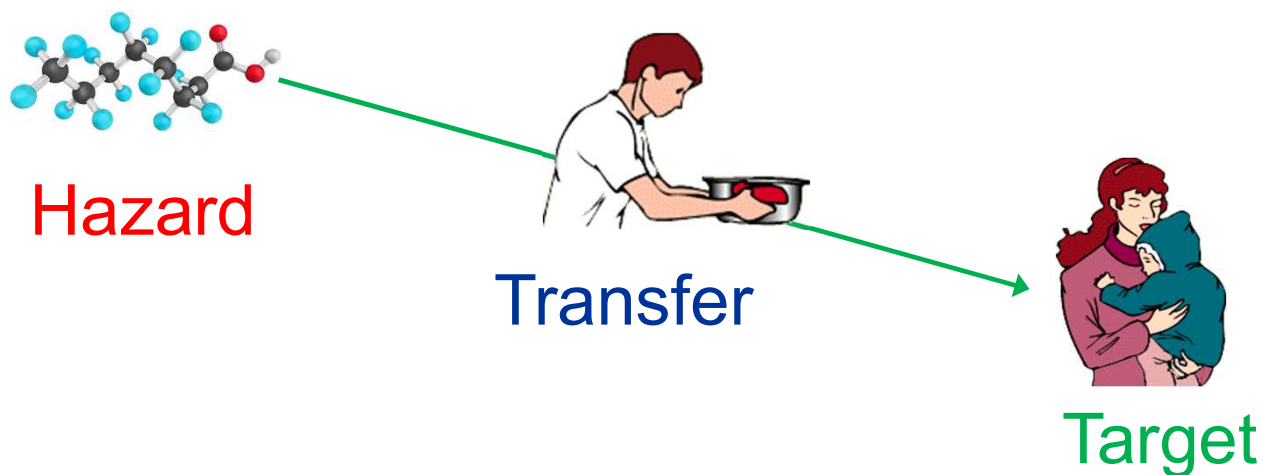
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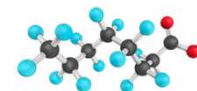
3. Human Health Risk Assessment study



$$R = f(H, T, T)$$



Case study : Human Health Risk Assessment



3. Human Health Risk Assessment study

The steps

Phase 1

Definition of pollutants taken into account

Phase 2

Definition of exposure scenarios and pathways:
Characteristics of the site's uses
Exposure Settings

Phase 3

Quantification of exposure – calculation of EDD

Phase 4

Quantification of exposure-based risks:
Definition of toxicities
Risk Quantification

Phase 5

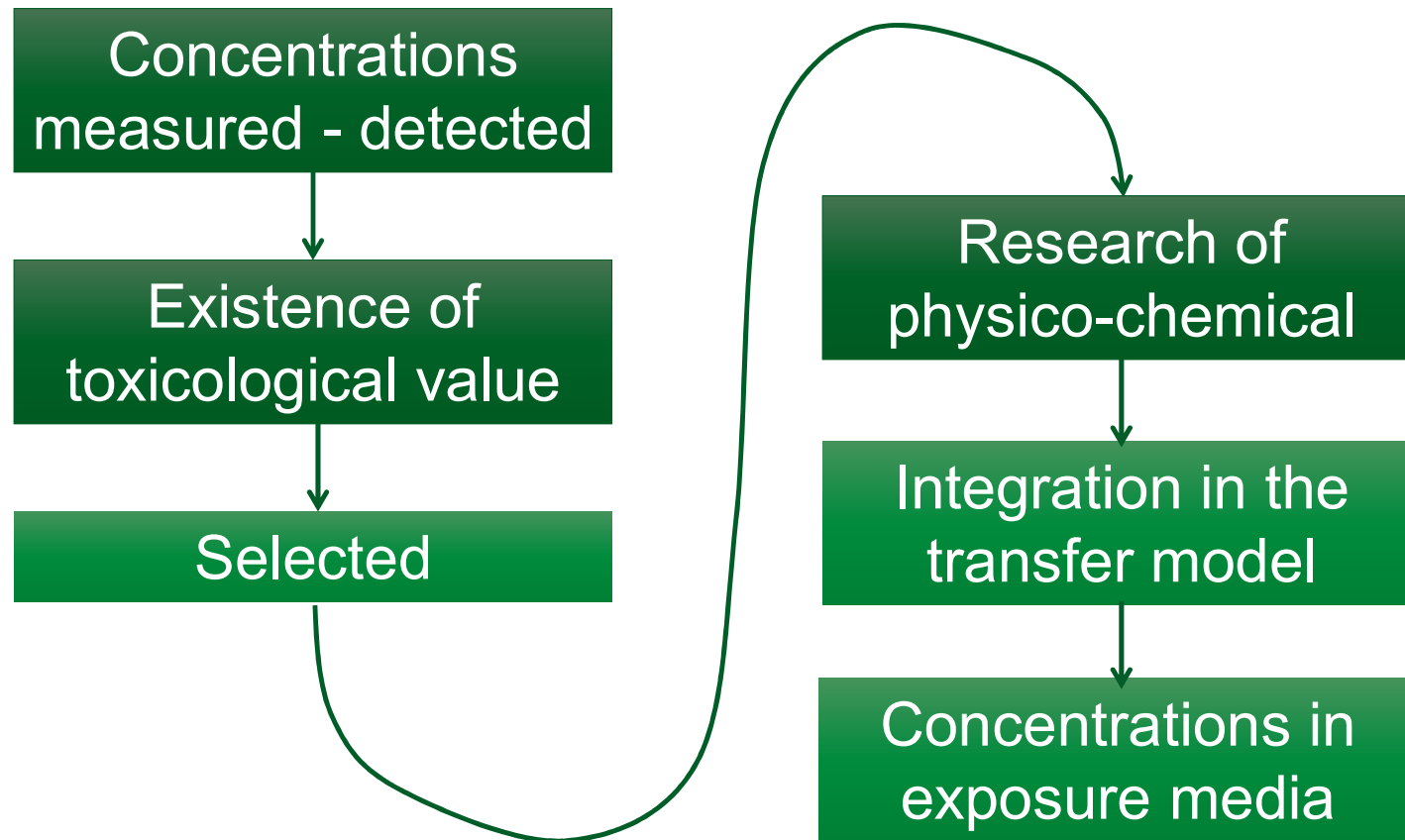
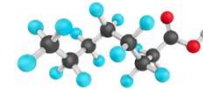
Study of uncertainties

Phase 6

Interpretation of calculated risks

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3. HHRA phase 1 : Pollutants



Case study : Human Health Risk Assessment



3. HHRA phase 1 : Pollutants

Selected substances and measured concentrations in soil and groundwater (under quantification limit in soil gas)

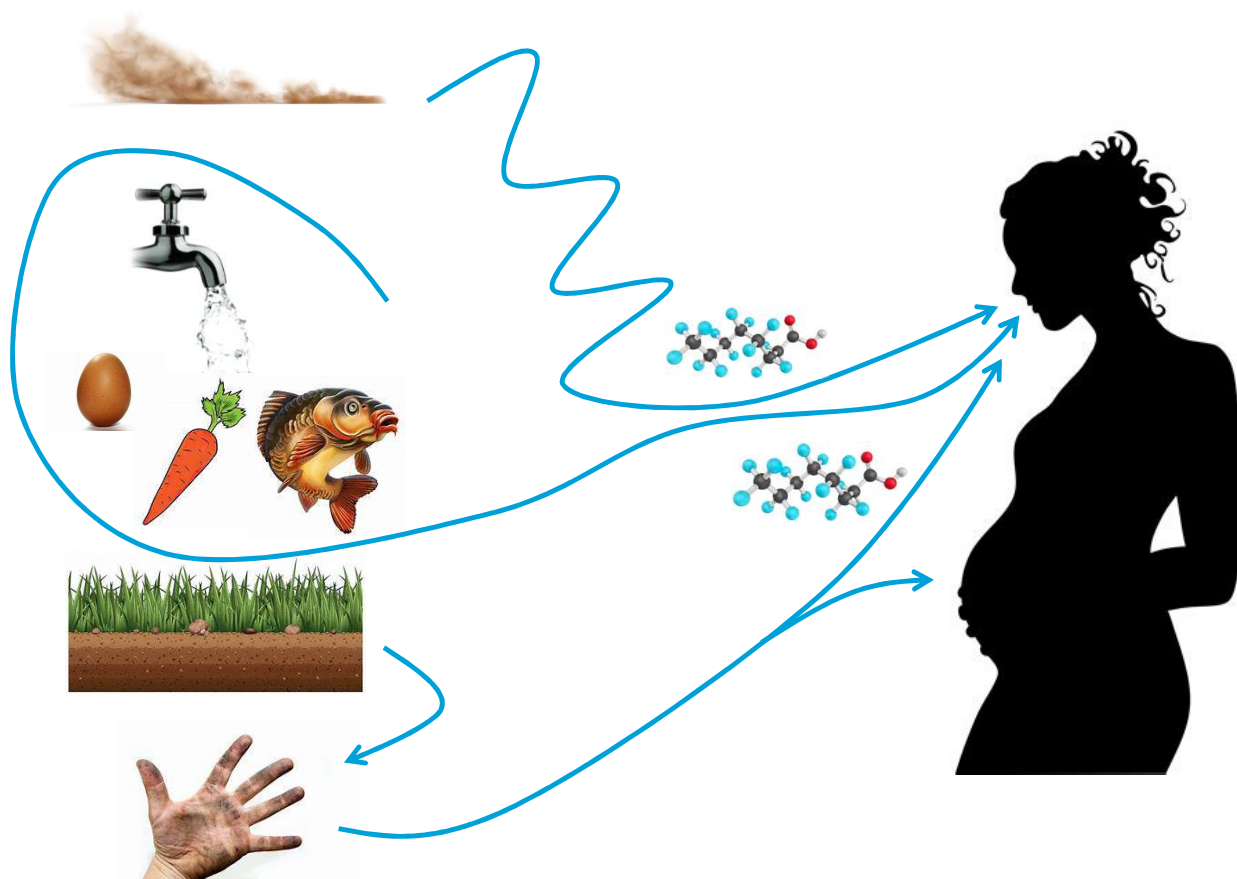
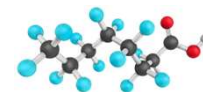
	Groundwater		Soil	
	Average concentration	Maximum concentration	Average concentration	Maximum concentration
	ng/l		µg/kg	
PFBA	100	350	0,500	2,33
PFPeA	310	1560	0,719	7
PFHxA	318	1850	0,747	6
PFHpA	123	560	0,240	1,22
PFOA	451	2220	1,20	7,2
PFNA	17,1	88	0,190	2,12
PFBS	93,7	1200	0,0402	0,49
PFHxS	492	6650	0,297	3,1
PFOS	2454	20400	18,8	120
PFDA	7,55	57	0,0589	0,48
PFHpS	39,7	490	0,0594	0,65
(P)FOSA	278	1990	2,02	42,9
6:2 FTOH	8,13	43	0,286	2,37
8:2 FTOH	0	0	0,00547	0,29

	Groundwater		Soil	
	Average concentration	Maximum concentration	Average concentration	Maximum concentration
	ng/l		µg/kg	
PFPeS	74,4	960	0,0157	0,18
PFNS	0,310	3	0	0
PFDS	0,0333	0,6	0	0
MeFOSA	1,13	13,2	0	0
MeFOSAA	1,40	11,5	0	0
EtFOSA	15,3	119	0	0
EtFOSAA	167	2090	0,944	35
4:2-FTS	0	0	0	0
6:2-FTS	26,6	238	0,218	1,84
8:2-FTS	0,144	2,6	0,0157	0,45
PFUnDA	1,37	12,3	0,0668	1,76
PFDoDA	0,206	1,9	0	0
PFTTrDA	0	0	0,0526	2,23

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Case study : Human Health Risk Assessment

3. HHRA phase 2&3 : Exposure definition



**Total
Exposure
Daily Dose**

EDD_{tot} =

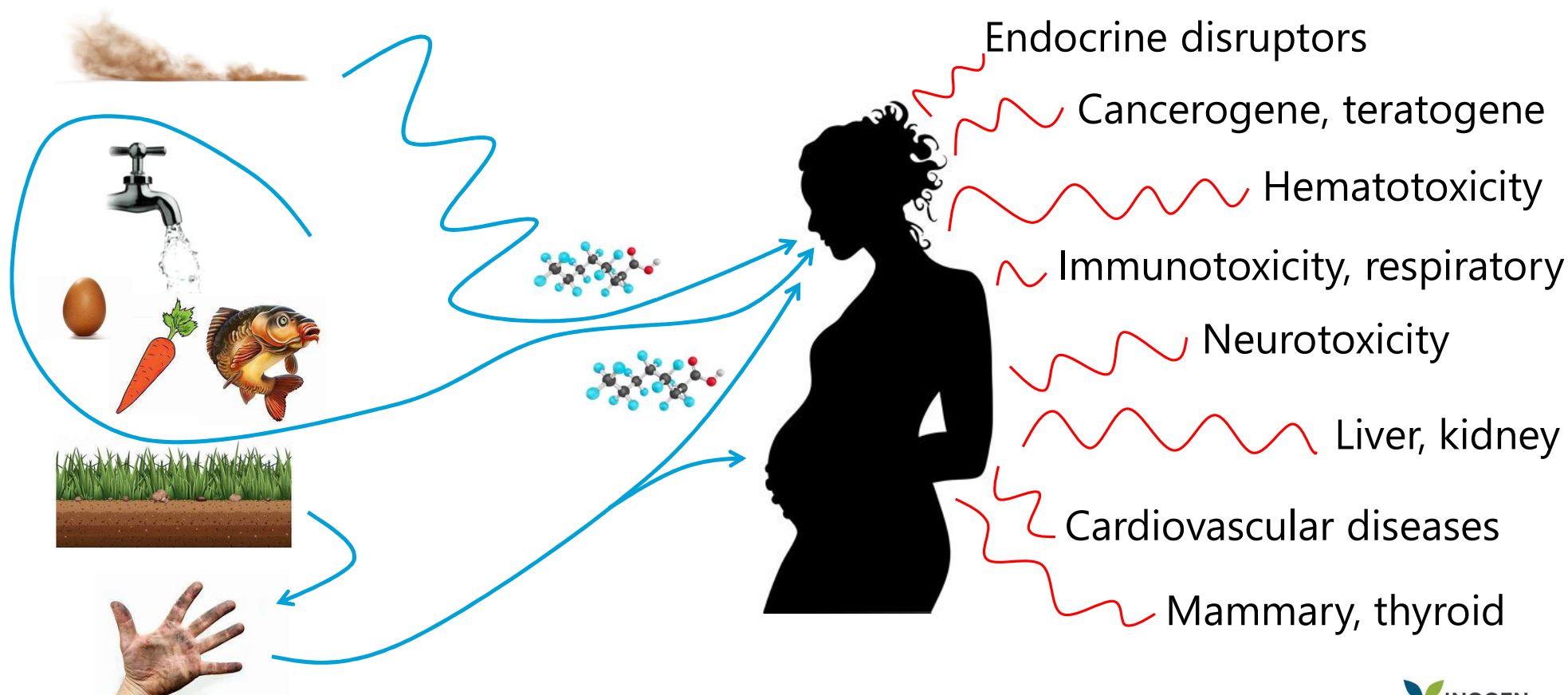
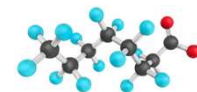
EDD_{ing} +

EDD_{inh} +

EDD_{skin}

Case study : Human Health Risk Assessment

3. HHRA phase 4 : Toxicity definition



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Case study : Human Health Risk Assessment



3. HHRA phase 4 : Toxicity definition

Substance	CAS Nr.	Cancerogen / not cancerogen	Chronic toxicological value			Species	Sigle	Security Factor	Organization
			Exposure path	Target organ	Value				
PFBA	375-22-4	NC	oral	Hepatic	1 µg/kg/d	Rate	RfD	POD _{HED} / 900	TCEQ 2023 US-EPA IRIS 2022
			inhalation	Hepatic	3,5 µg/m ³	Rate	RfC	from oral value	TCEQ 2023
PFPeA	2706-90-3	NC	oral	Hepatic	0,5 µg/kg/d	Rate	RfD	POD _{HED} / 90	TCEQ 2023
PFHxA	307-24-4	NC	oral	Hepatic	0,5 µg/kg/d	Rate	RfD	POD _{HED} / 90	TCEQ 2023 US-EPA IRIS 2023
PFHpA	375-85-9	NC	oral	Hepatic	25 ng/kg/d	Rate	DJT	Extrapolation of DJT of Health Canada	ANSES 2017 TCEQ 2023
PFOA	335-67-1	NC	oral	Hematologic	0,86 ng/kg/d	Rate	TDI	BMDL 5	UBA 2023 BFR & EFSA 2018
				Hepatic, Mammar, Hematologic	12 ng/kg/d	Mice	RfD	LOAEL / (81*300)	TCEQ 2023
				Immune, developmental and cardiovascular	0,03 ng/kg/d	Epidemio	RfD	Several studies	US-EPA 2024
			inhalation	Hepatic	4,1 ng/m ³	Rate	RfC	NOAEL / (81*3000)	TCEQ 2023
		C	oral	Testicular tumors	2,52 (mg/kg/d) ⁻¹	Epidemio	SF	-	New Jersey 2017
				Renal cell carcinoma	0,0293 (ng/kg/d) ⁻¹	Epidemio	SF	-	US-EPA 2024
PFNA	375-95-1	NC	oral	Hematologic	2,5 ng/kg/d	Mouse	RfD	NOAEL / 300	US-EPA IRIS 2019 New Hampshire DES 2019
			inhalation	Lung, respiratory system	28 ng/m ³	Rate	RfC	NOAEL / (81*30000)	US-EPA IRIS 2019 TCEQ 2023

Case study : Human Health Risk Assessment

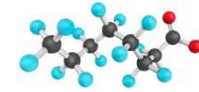


3. HHRA phase 4 : Toxicity definition

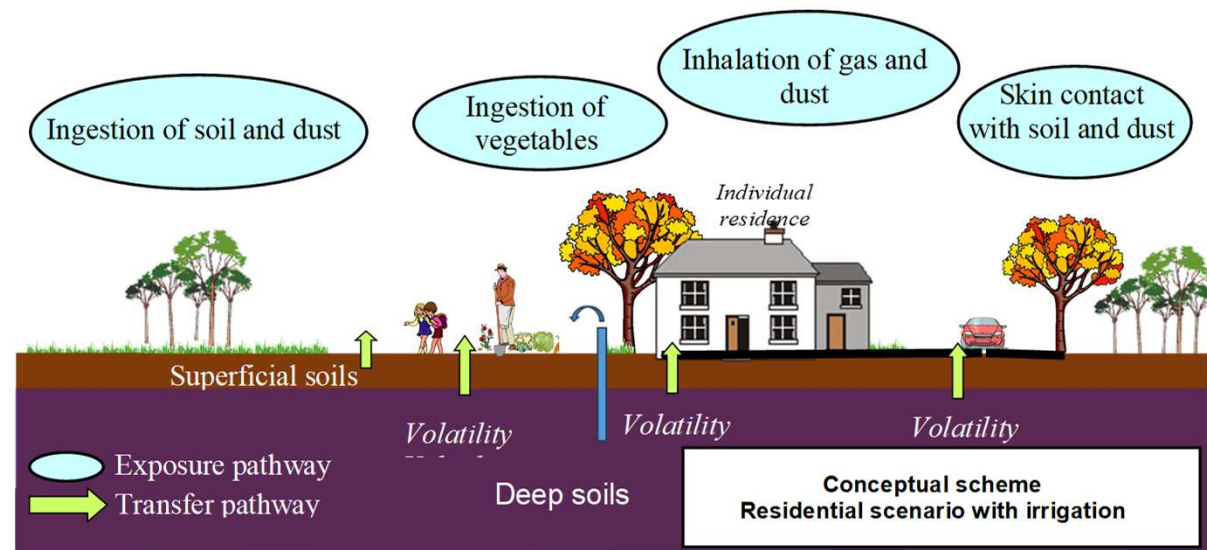
Substance	CAS Nr.	Cancerogen / not cancerogen	Chronic toxicological value			Species	Sigle	Security Factor	Organization
			Exposure path	Target organ	Value				
PFDA	335-76-2	NC	oral	Hepatic	15 ng/kg/d	Rate	RfD	LOAEL / (81*1000)	TCEQ 2023
				Immune / developmental	0,002 ng/kg/d	Rate	RfD	BMDL / 30	US-EPA IRIS 2024
			inhalation	Hepatic	53 ng/m ³	Rate	RfC	from oral value	TCEQ 2023
PFBS	375-73-5	NC	oral	Hematologic and renal	1,4 µg/kg/d	Rate	RfC	NOAEL / (142*300)	TCEQ 2023
			inhalation		4,9 µg/m ³	Rate	RfC	from oral value	TCEQ 2023
PFHxS	355-46-4	NC	oral	Hematologic and thyroidal	3,8 ng/kg/d	Rate	RfC	LOAEL / (263*300)	TCEQ 2023
			inhalation		13 ng/m ³	Rate	RfC	from oral value	TCEQ 2023
PFHpS	375-92-8		oral	Hepatic	0,43 ng/kg/d	Rate	TDI	Potency Factor : 0,6-2	UBA 2020, EFSA 2018, BfR 2018
PFOS	1763-23-1	NC	oral	Hepatic	1,86 ng/kg/d	Monkey	TDI	NOAEL	UBA 2020 BfR & EFSA 2018
			inhalation	Thyroidal, neurological and foetal development	81 ng/m ³	Rate	RfC	from oral value (23 ng/kg/j)	TCEQ 2023
PFOSA	754-91-6	NC	oral	Mammary glands	12 ng/kg/d	Mice	RfD	Same than PFOA NOAEL/(81*300)	TCEQ 2023
			inhalation		4,1 ng/m ³	Rate	RfC	same than PFOA NOAEL/(81*3000)	TCEQ 2023
6:2 FTOH	647-42-7	NC	oral	Hepatotoxic	43 ng/kg/d	Rate	RfD	RPF based on PFOA's RfD x 0,02	RIVM / Bil et al. 2020 & 2021
8:2 FTOH	678-39-7	NC	oral	Hepatotoxic	21,5 ng/kg/d	Rate	RfD	RPF based on PFOA's RfD x 0,04	RIVM / Bil et al. 2020 & 2021

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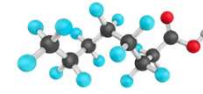
3. HHRA phase 4 : Risk quantification



- Site of old paper fabric
- Development project for several scenarios
 - ✓ Residential with private garden and consumption
 - ✓ Residential with collective green areas
 - ✓ Kinder garden with private garden and consumption
 - ✓ Green area
 - ✓ Commercial / Industrial



Case study : Human Health Risk Assessment

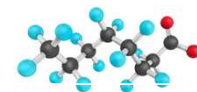


3. HHRA phase 4 : Risk quantification

- Sampling of soils, soil gas and groundwater
- Réalisation of Top Assays : Analyse of 66 PFAS before and after Top Assay
- Modeling of Exposure Daily Doses and Risk Quantification for
 - ✓ The defined 5 scenarios
 - ✓ With measured average concentrations and maximal concentrations
 - ✓ With concentrations before Top Assay and after Top Assay
 - ✓ By taking into account the uncertainties of the laboratory (30 to 40% according to the molecule)
 - ✓ In total 40 different risk modelisation / quantifications
 - ✓ Calculation of Maximal Acceptable Concentrations for each PFAS molecule, each medium (soil, groundwater) and each scenario

Case study : Human Health Risk Assessment

3. HHRA phase 4 : Risk quantification



Acceptable risks are:

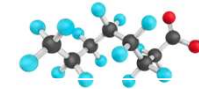
Carcinogenic $EIR = EDD \times UR < 10^{-5}$

Non carcinogenic $RI = EDD / RfD (RfC) < 1$

EIR:	Excess Individual Risk
RI:	Risk Index
EDD:	Exposure Daily Dose
UR (IUR):	Unit Risk (Inhalation Unit Risk)
RfD (RfC):	Reference Dose (Reference Concentration)

Case study : Human Health Risk Assessment

3. HHRA phase 4 : Risk quantification



SZENARIO 1: Wohnbebauung mit Hausgarten mit Nutzung					
Ziel:					
RISKO:	ERWACHSENER		KIND		ER + K
	Systemisch (nicht kanzerogen)	Kanzerogen	Systemisch (nicht kanzerogen)	Kanzerogen	
1	PFBA	0,00127	-	0,00368	-
2	PFPeA	0,00244	-	0,00658	-
3	PFHxA	0,00107	-	0,00331	-
4	PFHpA	0,00375	-	0,0101	-
5	PFOA	18,8	5,67E-03	58,5	4,41E-03
6	PFNA	0,0167	-	0,0511	-
7	PFBS	0,00000884	-	0,0000274	-
8	PFHxS	0,500	-	1,55	-
9	PFOS	30,3	-	94,6	-
10	PFDA	0,000150	-	0,000478	-
11	PFHpS	0,0653	-	0,203	-
12	(P)FOSA	0,0294	-	0,0898	-
13	6:2 FTOH	0,000127	-	0,000417	-
14	8:2 FTOH	0,00000208	-	0,00000739	-
15	PFPeS	0,000347	-	0,00108	-
16	PFNS	0,000000000000790	-	0,000000000000174	-
17	PFDS	0,000000000000158	-	0,000000000000347	-
18	MeFOSA	0,000000000000180	-	0,000000000000396	-
19	MeFOSAA	0,000000000000149	-	0,000000000000327	-
20	EtFOSA	0,000000000000160	-	0,000000000000352	-
21	EtFOSAA	0,0000275	-	0,000221	-
22	4:2-FTS	0,00000000	-	0,00000000	-
23	6:2-FTS	0,000156	-	0,000715	-
24	8:2-FTS	0,000000921	-	0,00000736	-
25	PFUnDA	0,0000649	-	0,000221	-
26	PFDoDA	0,000000000000493	-	0,000000000000109	-
27	PFTrDA	0,000872	-	0,00272	-
Summe karzinogener Risiken		(lim. : 1,00E-05)	5,67E-03	4,41E-03	1,01E-02
Summe nicht karzinogener Risiken		(lim. : 1,00)			
Neurologisches System(4+9)		30,3	-	94,6	-
Hepatisches System (1+2+3+5+10+11+15+16+18 bis 24)		18,9	-	58,7	-
Nieren System (7)		0,00000884	-	0,0000274	-
Hämatologisches System (6+7+8)		0,516	-	1,59	-
Immunsystem (5+8+9)		49,6	-	155	-
Atmungssystem (6)		0,0167	-	0,0511	-
Fötale Entwicklung (9)		30,3	-	94,6	-
Gewichtsreduzierung, Entwicklung (5+9+17+25+26+27)		49,1	-	153	-
Kardiovaskulär (5+9)		49,1	-	153	-
Schilddrüse (8+9)		30,7	-	96,1	-
Mammär (12)		0,0294	-	0,0898	-
Hepatoxizität (13+14)		0,000129	-	0,000424	-
Hormonell (17+25+26+27)		0,000937	-	0,00294	-

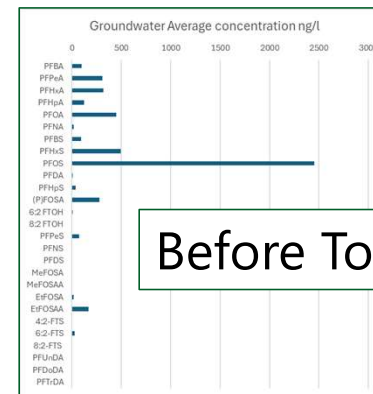
Residential Scenario Before Top Assay

Non-cancer systemic risks

155 >> 1,00 Not acceptable

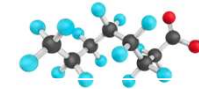
Non-threshold carcinogenic risks

1,01E-02 >> 1,00E-05 Not acceptable



Case study : Human Health Risk Assessment

3. HHRA phase 4 : Risk quantification



SZENARIO 1: Wohnbebauung mit Hausgarten mit Nutzung					
Ziel:					
RISKO:		ERWACHSENER		KIND	
		Systemisch (nicht kanzerogen)	Kanzerogen	Systemisch (nicht kanzerogen)	Kanzerogen
1	PFBA	0,00245	-	0,00710	-
2	PFPeA	0,00791	-	0,0214	-
3	PFHxA	0,00305	-	0,00945	-
4	PFHpA	0,0200	-	0,0538	-
5	PFDA	71,5	2,15E-02	222	1,68E-02
6	PFNA	0,0259	-	0,0784	-
7	PFBS	0,000117	-	0,000361	-
8	PFHxS	0,963	-	2,99	-
9	PFOS	54,3	-	170	-
10	PFDA	0,000000753	-	0,00000166	-
11	PFHpS	0,00110	-	0,00243	-
12	(P)FOSA	0,00000664	-	0,0000146	-
13	6:2 FTOH	0,000800	-	0,00263	-
14	8:2 FTOH	0,00000000	-	0,00000000	-
15	PFPeS	0,000152	-	0,000333	-
16	PFNS	0,0000000000	-	0,0000000000	-
17	PFDS	0,0000000000	-	0,0000000000	-
18	MeFOSA	0,0000000341	-	0,0000000750	-
19	MeFOSAA	0,000000000	-	0,000000000	-
20	EtFOSA	0,00000000	-	0,00000000	-
21	EtFOSAA	0,0000000830	-	0,000000183	-
22	4:2-FTS	0,00000000	-	0,00000000	-
23	6:2-FTS	0,000858	-	0,00393	-
24	8:2-FTS	0,00000000	-	0,00000000	-
25	PFUnDA	0,000483	-	0,00165	-
26	PFDoDA	0,0000000000	-	0,000000000	-
27	PFTriDA	0,00180	-	0,00562	-
Summe karzinogener Risiken		(lim. : 1,00E-05)	2,15E-02	1,68E-02	3,83E-02
Summe nicht karzinogener Risiken		(lim. : 1,00)			
Neurologisches System(4+9)		54,3	-	170	-
Hepatisches System (1+2+3+5+10+11+15+16+18 bis 24)		71,5	-	222	-
Nieren System (7)		0,000117	-	0,000361	-
Hämatologisches System (6+7+8)		0,989	-	3,07	-
Immunsystem (5+8+9)		127	-	395	-
Atmungssystem (6)		0,0259	-	0,0784	-
Fötale Entwicklung (9)		54,3	-	170	-
Gewichtsreduzierung, Entwicklung (5+9+17+25+26+27)		126	-	392	-
Kardiovaskulär (5+9)		126	-	392	-
Schilddrüse (8+9)		55,2	-	173	-
Mammär (12)		0,00000664	-	0,0000146	-
Hepatotoxisch (13+14)		0,000800	-	0,00263	-
Hormonell (17+25+26+27)		0,00228	-	0,00726	-

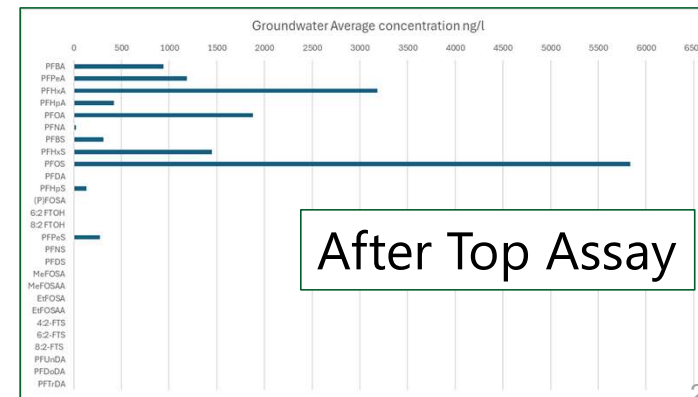
Residential Scenario After Top Assay

Non-cancer systemic risks

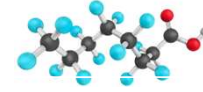
395 >> 1,00 Not acceptable

Non-threshold carcinogenic risks

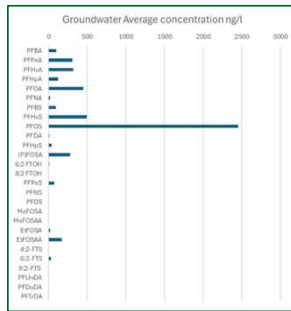
3,83E-02 >> 1,00E-05 Not acceptable



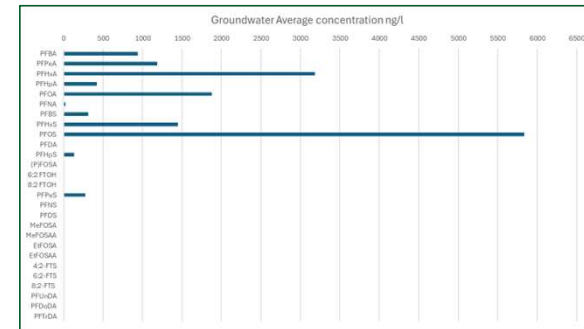
3. HHRA phase 4 : Risk quantification



Residential Scenario Before Top Assay



Residential Scenario After Top Assay



Non-cancer systemic risks

155 >> 1,00 \longrightarrow 395 >> 1,00

Non-threshold carcinogenic risks

$$1,01\text{E-}02 \gg 1,00\text{E-}05 \longrightarrow 3,83\text{E-}02 \gg 1,00\text{E-}05$$

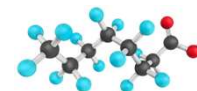
Case study : Human Health Risk Assessment



3. HHRA phase 5 : Uncertainties

Maximal non-cancer systemic risks	Residential with private garden and consumption	Residential with collective green area	Kinder garden with private garden and consumption	Collective green area	Commercial / Industrial
Average concentrations before Top Assay	155	1,34	77,5	0,429	0,311
Average concentrations after Top Assay	395	2,90	198	0,920	0,669
Average concentrations+ Labor uncertainties before Top Assay	203	1,73	102	0,551	0,400
Average concentrations+ Labor uncertainties after Top Assay	499	3,61	250	1,15	0,838

Case study : Human Health Risk Assessment



3. HHRA phase 5 : Uncertainties

Labor analyses

30% to 40% uncertainties !
Weak reproductibility

Toxicological values

PFOA :
11 non-carcinogen tox values from 0,03 to 100 ng/kg/d !
4 carcinogen different toxicological values

Pollutants

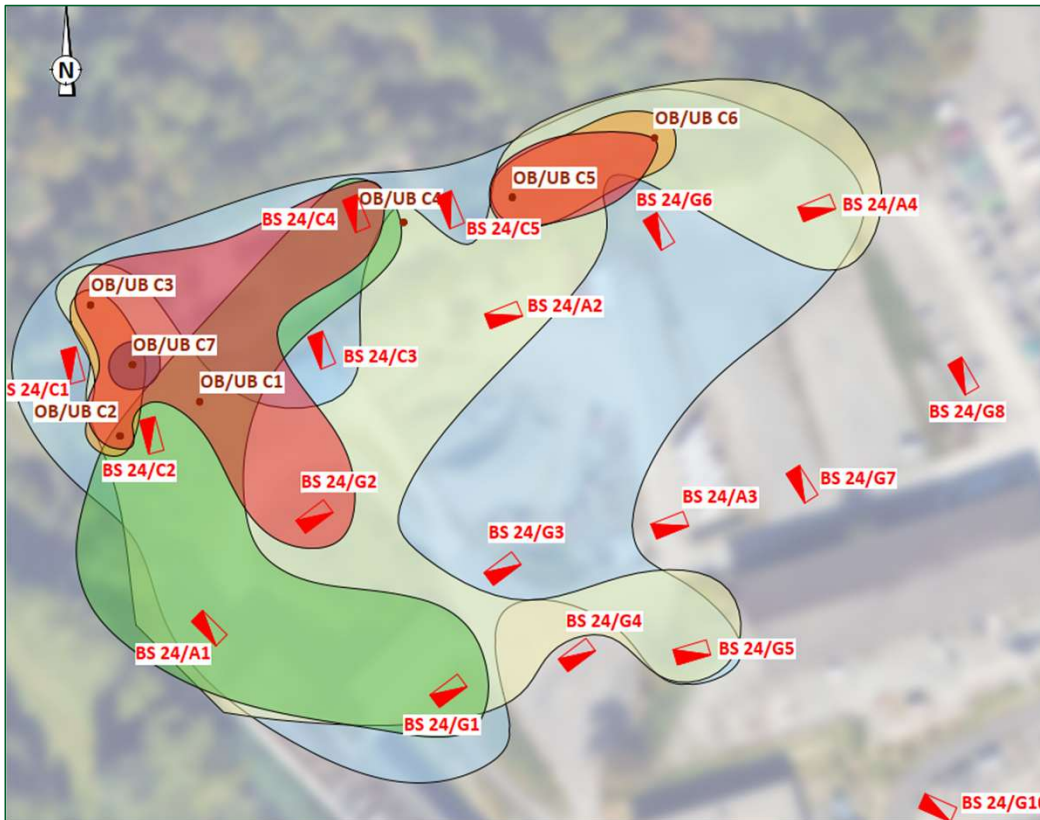
Around 10 000 molecules or more
60 to 70 can be analysed in “routine”
Around 30 can be taken into account in an HHRA



This uncertainty can be reduced by performing
Top Assays for ex (with also big laboratory
uncertainties)







Case study : Human Health Risk Assessment

3. HHRA phase 6 : Interpretation



Residential with private garden and consumption

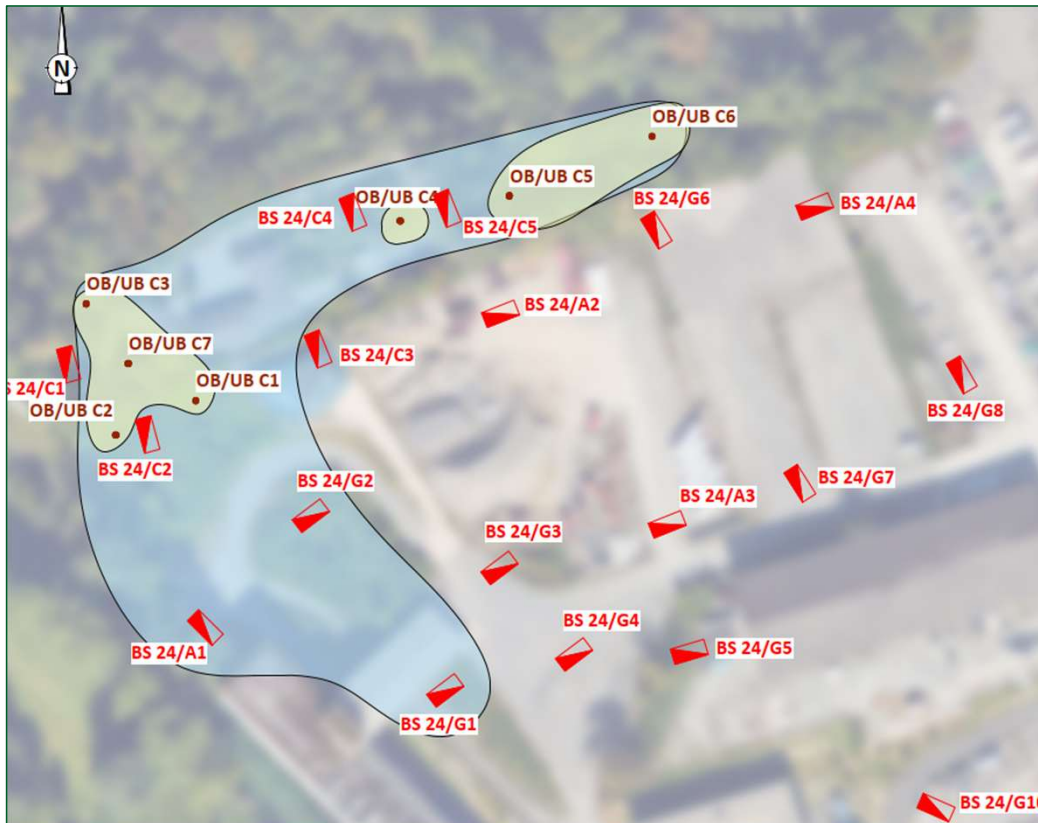
PFAS exceeding limit values from HHRA calculation
Soil (0 – 2 m)

-  PFOA $\geq 0,0004 \text{ mg/kg}^{(1)}$
-  PFNA $\geq 0,0004 \text{ mg/kg}^{(1)}$
-  PFHxS $\geq 0,0004 \text{ mg/kg}^{(1)}$
-  PFOS $\geq 0,0004 \text{ mg/kg}^{(1)}$
-  PFHpS $\geq 0,0004 \text{ mg/kg}^{(1)}$
-  PFOSA $\geq 0,002 \text{ mg/kg}^{(1)}$

⁽¹⁾: EGW - Szenario 1

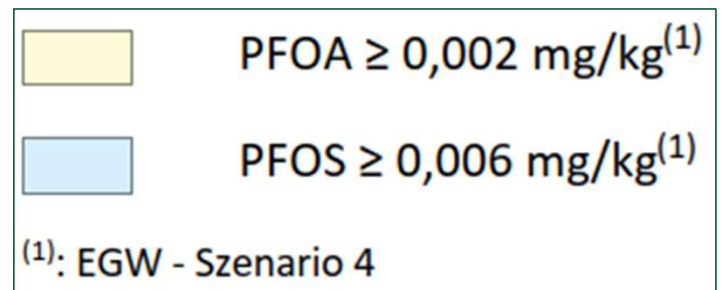
Case study : Human Health Risk Assessment

3. HHRA phase 6 : Interpretation



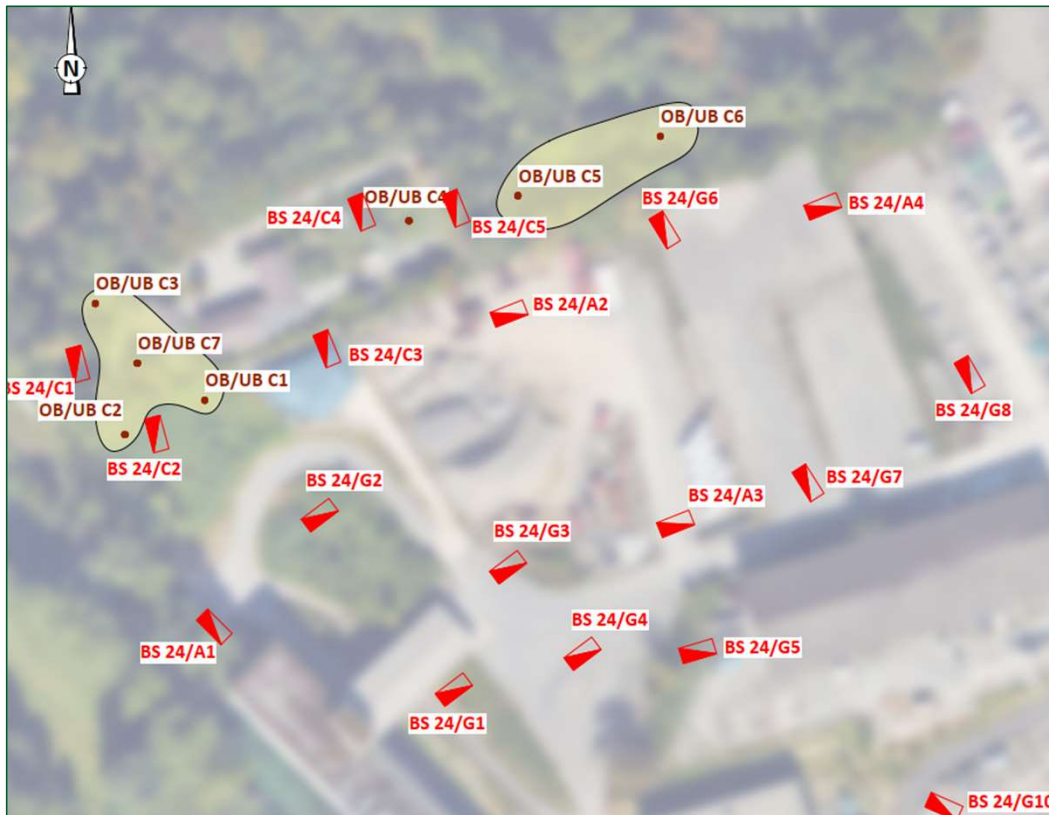
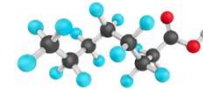
Collective green area

PFAS exceeding limit values
from HHRA calculation
Soil (0 – 2 m)



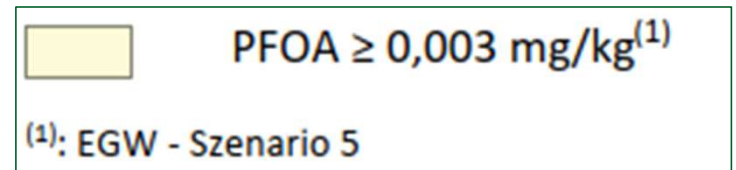
Case study : Human Health Risk Assessment

3. HHRA phase 6 : Interpretation



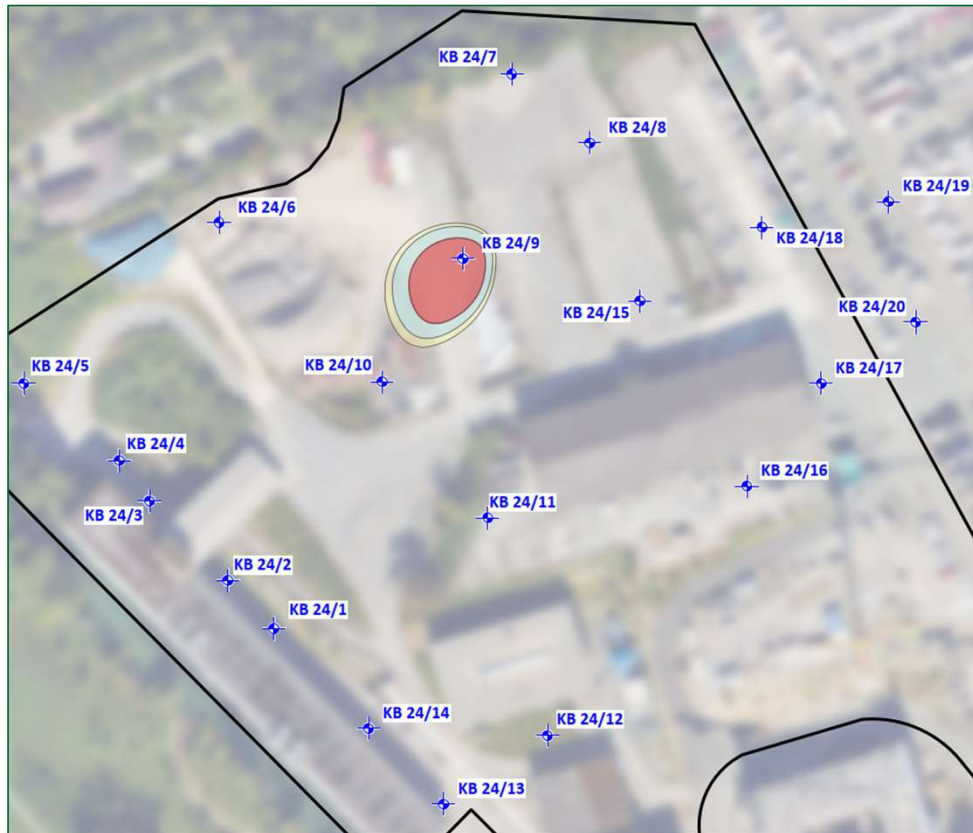
Commercial / Industrial

PFAS exceeding limit values
from HHRA calculation
Soil (0 – 2 m)






Case study : Human Health Risk Assessment

3. HHRA phase 6 : Interpretation

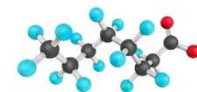


Residential with private garden

PFAS exceeding limit values
from HHRA calculation
Groundwater

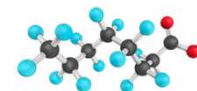
	PFOA $\geq 2\,000^{(1)}$ ng/l
	PFHxS $\geq 6\,000^{(1)}$ ng/l
	PFOS $\geq 20\,000^{(1)}$ ng/l

Case study : Human Health Risk Assessment



1. Context of the study: old paper manufacture
2. Investigations and analyses
3. Human Health Risk Assessment study
4. Discussion

Case study : Human Health Risk Assessment



4. Discussion

Uncertainties

Different sampling protocols lead to different results
A lot of bias during sampling, conservation
Limited number of molecules analysed
30% to 40% labor uncertainties / low reproductibility

Knowledge

Sampling and analysis processes
Toxicity, toxicological values
New molecules (TFA in pesticides, etc...) changing the approach
Laboratory tests can increase the number of molecules taken into account : Top Assay (oxidation), Lysimeter (aging with bacteries...)

Site management

Human Risk quantification studies with PFAS face a lot of uncertainties, lacks and evolutions
Very useful for site management by defining threshold values, areas of risk, development limits, areas for remediation



Thank you

If you have more questions...



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