PFAS in Biosolids

A Southern Arizona Case Study

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PIMA COUNTY
WASTEWATER RECLAMATION

PERFLUORINATED COMPOUNDS (PFCs)

- Fully fluorinated long chain organic compounds
- Family of anthropogenic chemicals used for decades to make products resistant to heat, oil stains, grease and water
- Perfluoroctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) most prevalent PFCs in the U.S.
- Regarded by EPA as an “emerging contaminant”

Characteristics of PFOS and PFOA

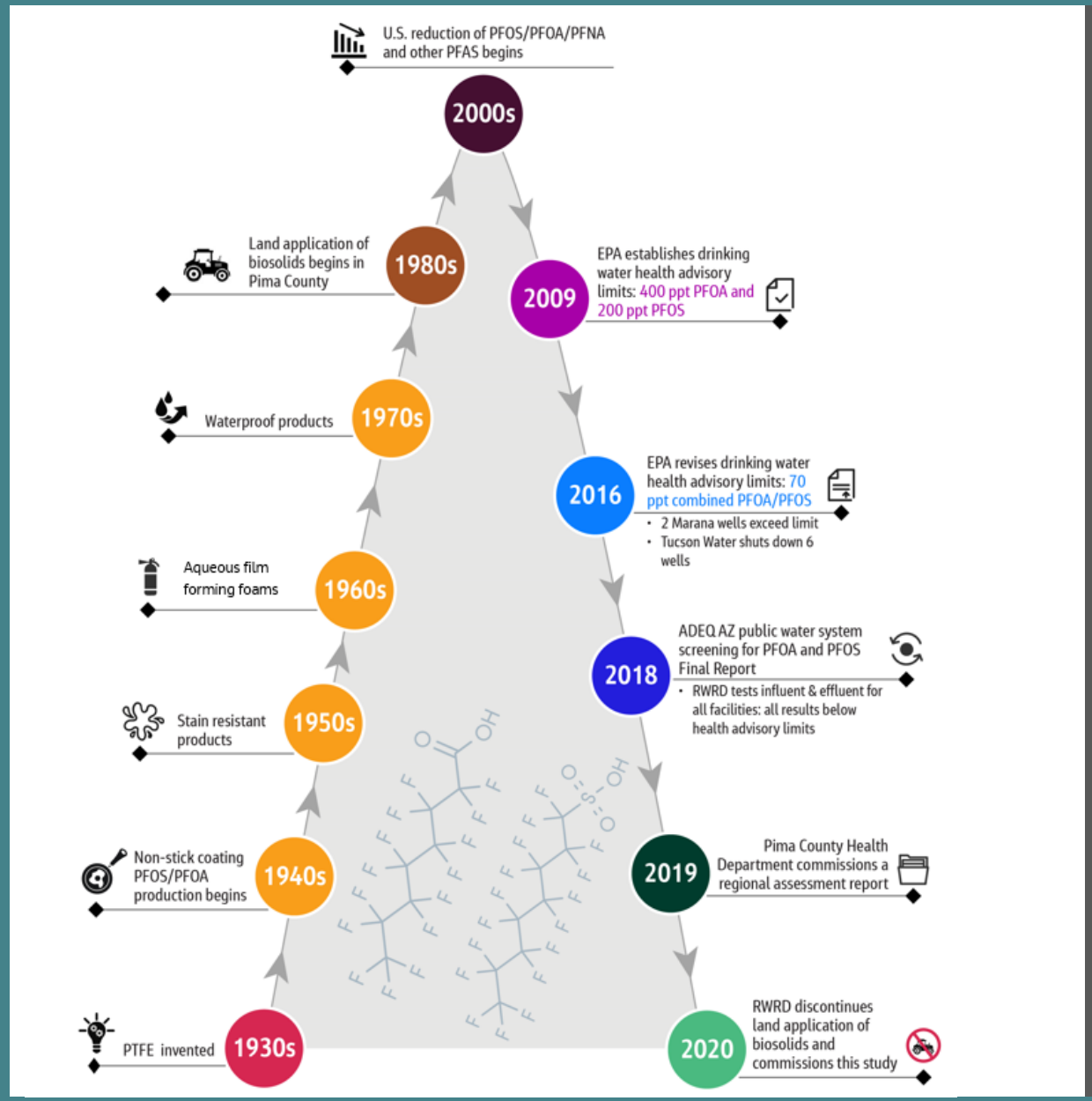
- Persistent in the environment, resistant to most microbial degradation processes
- Found in soil, sediments, and water
- Soluble and can migrate through soils
- All people in the U.S. thought to have PFCs in their blood
- Can stay within human body for many years

Household Exposure to PFCs

- Textiles
- Carpets
- Cleaning agents
- Leather
- Baking and sandwich papers
- Ski waxes
- Gloves
- Household dust

PFOS voluntarily phased out of production in the U.S. between 2000 and 2002

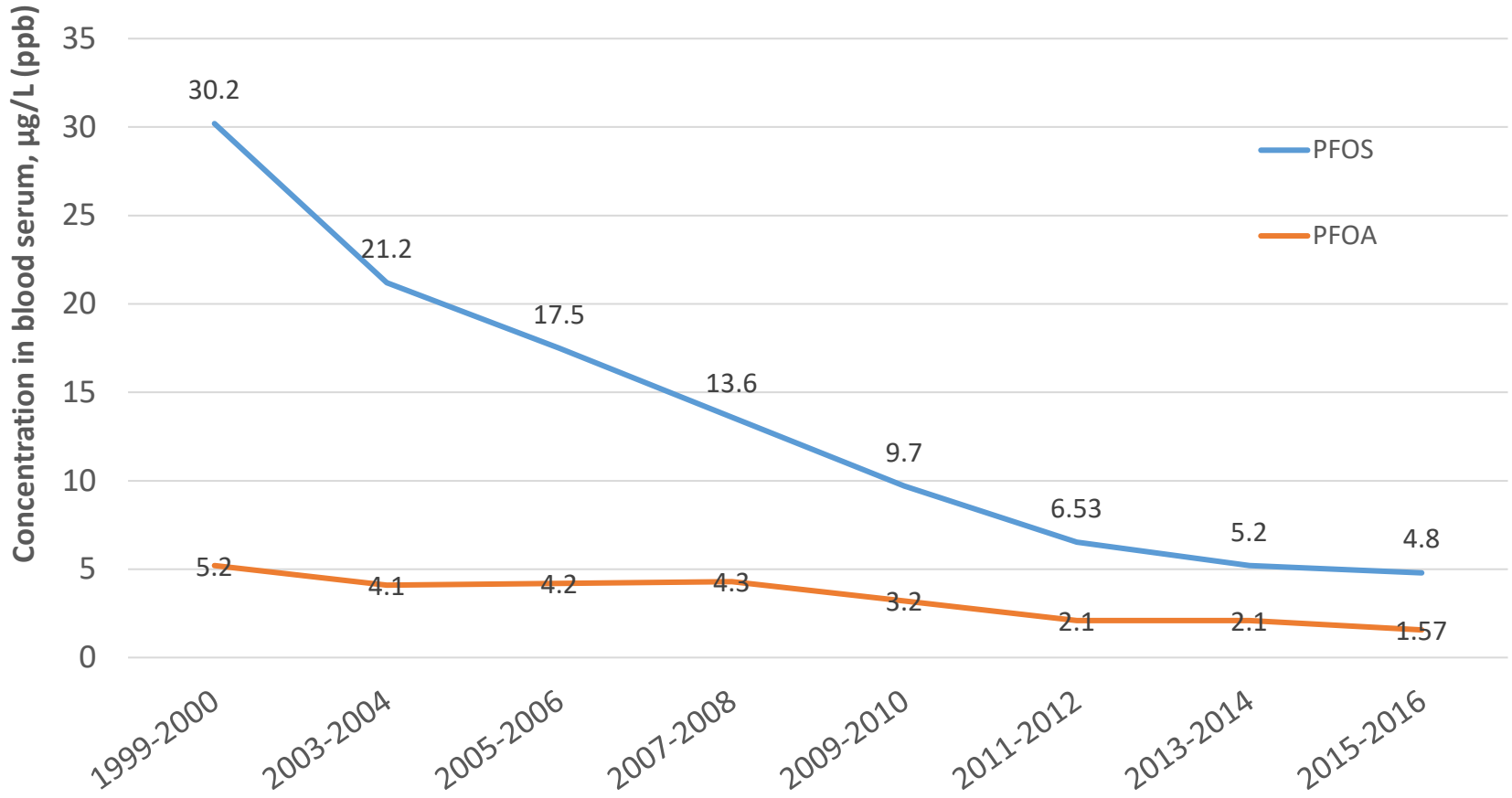
PFOA phased out by 8 major companies in the U.S. in 2006



PFAS Timeline

- >70 years of peak production prior to voluntary phase out & first HAL
- Lack of routine monitoring prior to 2016 HAL revision
- Ina Road WPCF begins operation 1977
- Land application of biosolids begins 1984

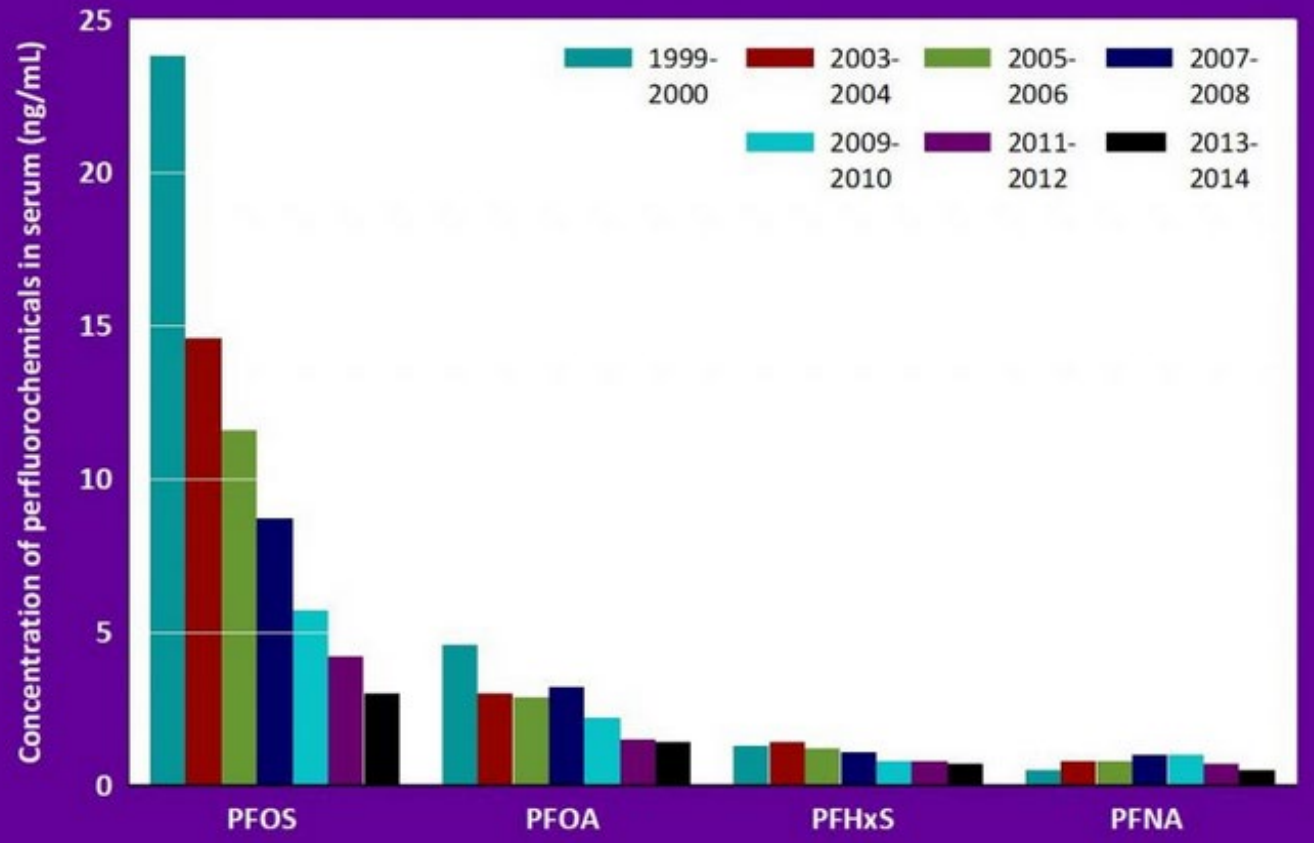
Blood Serum Levels, 1999 - 2016



Data Source: Centers for Disease Control and Prevention. Fourth Report on Human Exposure to Environmental Chemicals, Updated Tables, January 2019.

Indicator B6

Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2014



Data: Centers for Disease Control and Prevention, National Center for Health Statistics and National Center for Environmental Health, National Health and Nutrition Examination Survey

Note: To reflect exposures to women who are pregnant or may become pregnant, the estimates are adjusted for the probability (by age and race/ethnicity) that a woman gives birth.

America's Children and the Environment, Third Edition, Updated August 2017

CASE STUDY

Timeline: March – October 2020

Collaboration:

PIMA COUNTY
WASTEWATER RECLAMATION

NSF

Jacobs

RATIONALE FOR STUDY

- In Pima County, 100% of locally produced Class B biosolids land applied 1984 – 2020
- Class B biosolids contain trace amounts of PFAS
- Recent increased national concern over possible contamination of potable groundwater
- January 1, 2020, Pima County Board of Supervisors took conservative approach of enacting a temporary moratorium on land application of biosolids

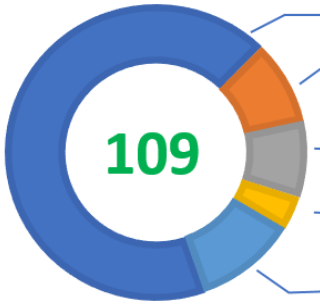
IMPACT OF MORATORIUM

- All biosolids in Pima County now being landfilled
- Doubled disposal costs for biosolids
- Removed availability of beneficial organic fertilizer to local farmers for agricultural production
- Provided impetus for this current study:
  GOAL: ***Fully evaluate the potential impact of land application on groundwater contamination by PFAS***

APPROACH

- Largest study on PFAS ever conducted
- Collaboration between Pima County Wastewater, University of Arizona and local farmers
- Agricultural sites identified where Class B biosolids land applied since 1984
- Known recorded land application rates
- Samples of soil, well water and biosolids collected and analyzed for a suite of PFAS compounds

Sample Locations



73 Soil samples from 1’ 3’ and 6’ depth intervals

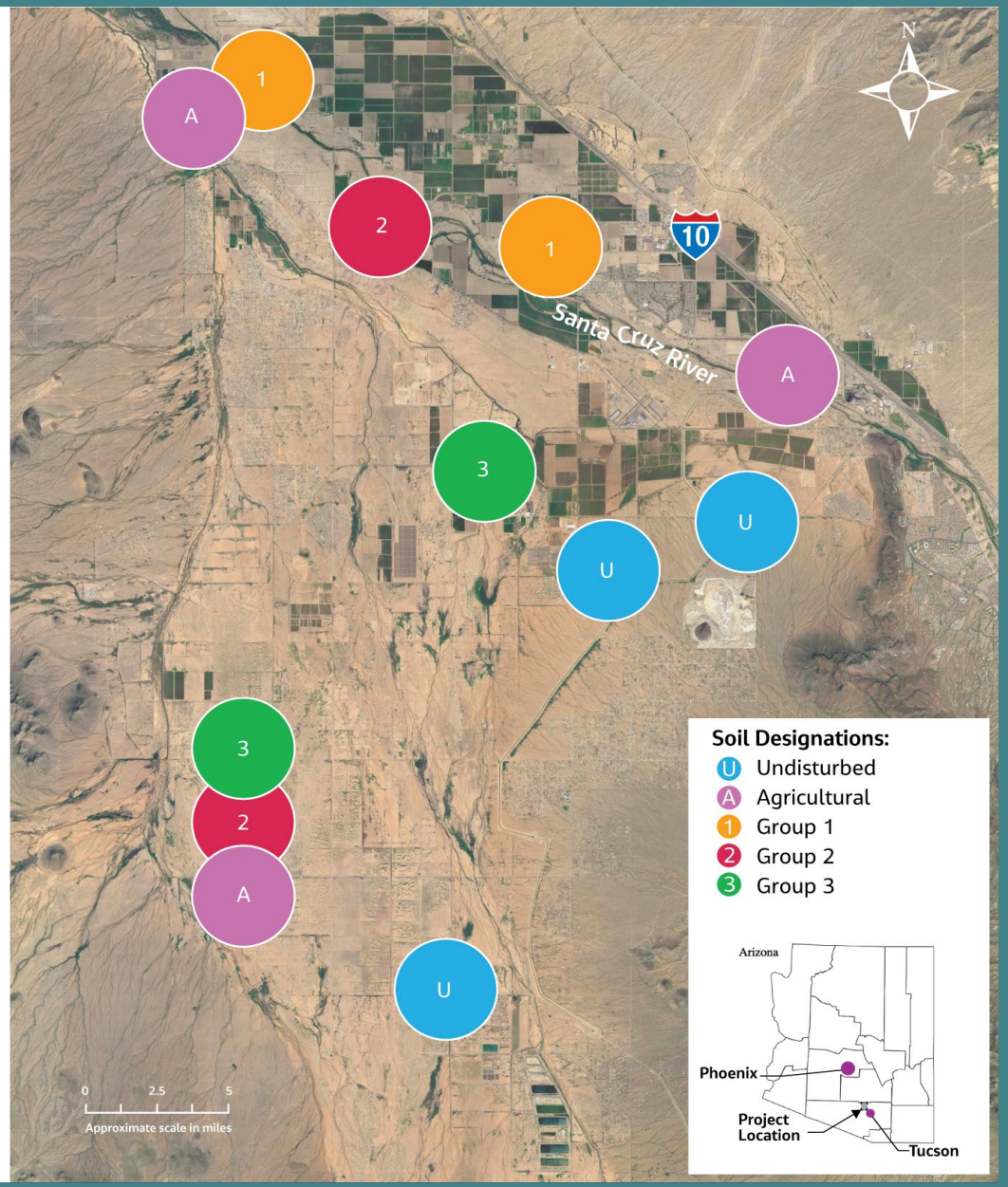
10 Wastewater samples from 5 treatment facilities

9 Irrigation wells associated with agricultural sites

4 Biosolids samples from Tres Rios WRF

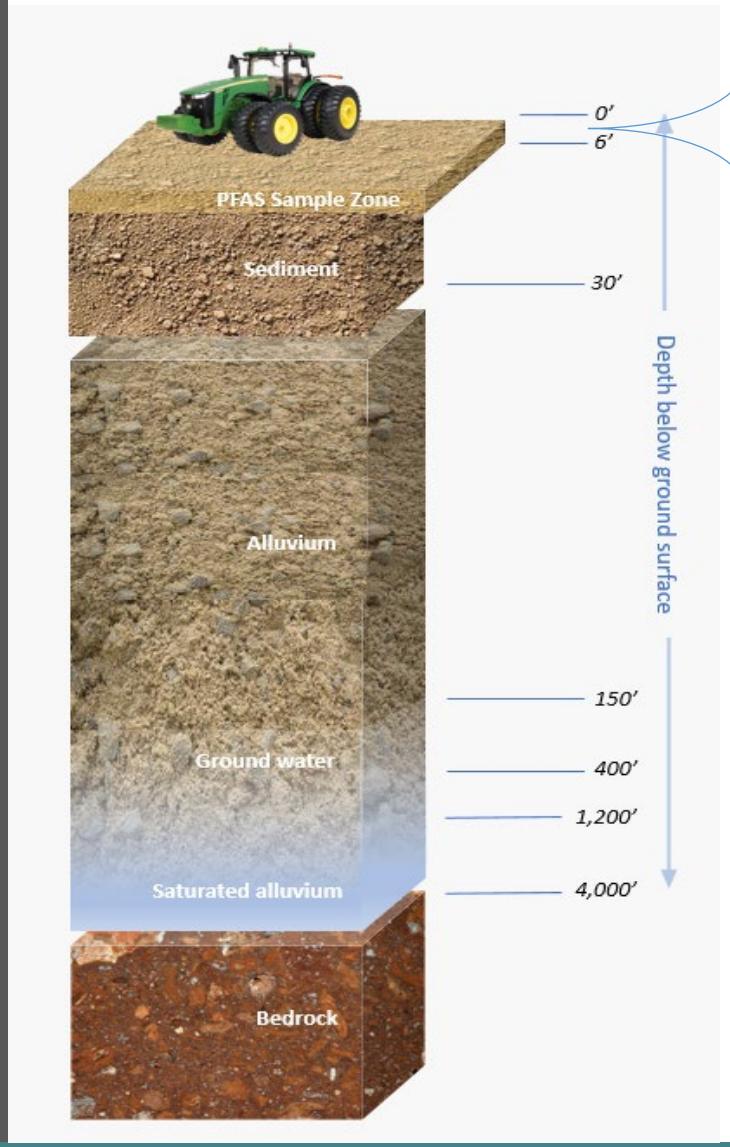
6 Field blanks
3 Equipment blanks
3 Chemicals used in treatment processes
1 Bighorn Fire ash

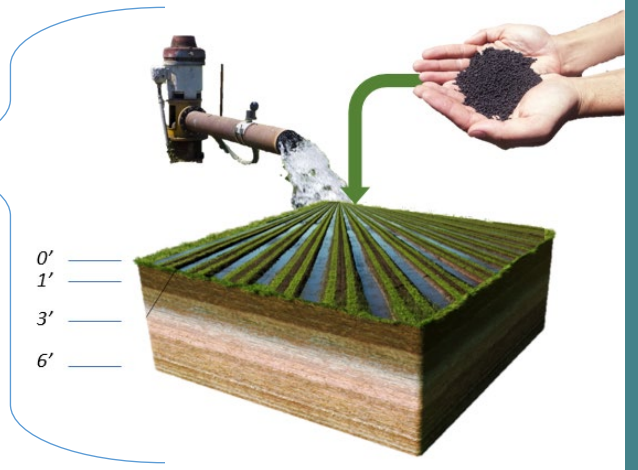
Soil Designation	Agricultural	Irrigated	Biosolids Applied	Application Years
Undisturbed	-	-	-	-
Agricultural	✓	✓	-	-
Group 1	✓	✓	≤ 20 tons/acre	4 - 9
Group 2	✓	✓	21-30 tons/acre	12 – 20
Group 3	✓	✓	> 30 tons/acre	6 - 9



Soil Sampling

- Soil sampling utilized a hand augers
- Sample depths of 1’, 3’, and 6’ below the surface
- Strict protocol followed to prevent PFAS contamination





PFAS in Biosolids: A Southern Arizona Case Study

PFAS IN BIOSOLIDS				
Location	**TRES RIOS WRF**			
Sample Date	**7/16/2020**	**7/16/2020**	**7/27/2020**	**7/27/2020**
Units				
PFAS Contaminant	**µg/kg (ppb)**			
DONA	ND	ND	ND	ND
F-53B (Major)	ND	ND	ND	ND
F-53B (Minor)	ND	ND	ND	ND
GenX	ND	ND	ND	ND
NEtFOSAA	ND	ND	ND	**11**
NMeFOSAA	21	22	23	**18**
PFBS	1.9	1.4	6.5	ND
PFDA	**12**	**13**	**12**	**12**
PFDoA	8	7.3	7.4	**6.5**
PFHpA	ND	ND	ND	0.15
PFHxS	3.7	3.5	15	ND
PFHxA	4.2	4.0	4.1	**2.0**
PFNA	ND	2.0	2.0	**1.1**
PFOS	**34.0**	**36**	**27**	**14**
PFOA	ND	ND	ND	**1.2**
PFTeA	3.2	3.3	ND	ND
PFTriA	ND	ND	ND	ND
PFUnA	2.3	2.1	2.4	**1.8**
Moisture	**81.7%**	**82.0%**	**81.0%**	**80.7%**

Notes:
µg/kg dry = micrograms of contaminant per kilogram of dry biosolids also equivalent to parts per billion (ppb).
Black indicates values above the method reporting limit (MRL).

	AGRICULTURAL SITES			GROUP 1		GROUP 2		GROUP 3	
Contaminant	ng/L (ppt)			ng/L (ppt)		ng/L (ppt)		ng/L (ppt)	
DONA	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-53B (Major)	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-53B (Minor)	ND	ND	ND	ND	ND	ND	ND	ND	ND
GenX	ND	ND	ND	ND	ND	ND	ND	ND	ND
NEtFOSAA	ND	ND	ND	ND	ND	ND	ND	ND	ND
NMeFOSAA	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFBS	**10**	ND	**3.8**	ND	1.4	ND	0.68	0.68	**3.6**
PFDA	1.9	ND	ND	ND	ND	ND	ND	ND	0.57
PFDoA	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFHpA	**5.3**	ND	**3.2**	0.28	0.98	ND	0.26	ND	1.9
PFHxS	**34**	0.30	**20**	0.24	**7.7**	**0.3**	0.76	0.52	**7.0**
PFHxA	**14**	ND	8.6	ND	1.9	ND	ND	**2.2**	**6.9**
PFNA	**3.4**	ND	0.57	ND	0.28	ND	ND	ND	0.63
PFOS	**80**	ND	**26**	ND	**11**	**0.53**	ND	ND	**15**
PFOA	**20**	ND	**9.1**	ND	**3.1**	ND	0.81	ND	**5.0**
PFTeA	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFTriA	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFUnA	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: ND indicates not-detected. ng/L = ppt
Black indicates values above the method detection limit (MDL)
Blue values indicate values above the method reporting limit (MRL)

Groundwater Results

- PFAS detected in nearly all irrigation sources
- PFAS concentrations higher in irrigation sources never receiving biosolids
- Highest PFAS concentration in irrigation source farthest removed from the Santa Cruz River

Characteristics

- No agriculture
- No irrigation
- No biosolids
- No PFAS contamination
- Influenced by wind and rain only

Undisturbed Soil Results

Depth	Surface	1’	3’	6’
Contaminant	µg/kg (ppb)			
DONA	ND	ND	ND	ND
F-53B (Major)	ND	ND	ND	ND
F-53B (Minor)	ND	ND	ND	ND
GenX	ND	ND	ND	ND
NEtFOSAA	ND	ND	ND	ND
NMeFOSAA	ND	ND	ND	ND
PFBS	ND	ND	ND	ND
PFDA	ND	ND	ND	ND
PFDoA	ND	ND	ND	ND
PFHpA	ND	ND	ND	ND
PFHxS	ND	ND	ND	ND
PFHxA	ND	ND	ND	ND
PFNA	ND	ND	ND	ND
PFOS	ND	ND	ND	ND
PFOA	ND	ND	ND	ND
PFTeA	ND	ND	ND	ND
PFTriA	ND	ND	ND	ND
PFUnA	ND	ND	ND	ND
Moisture		5.1%	5.8%	5.5%

Notes:
ND indicates not-detected at the MDL

No Biosolids

Depth	1'	3'	6'	PFAS present in
Contaminant	µg/kg (ppb)			Irrigation Wells
DONA	ND	ND	ND	
F-53B (Major)	ND	ND	ND	
F-53B (Minor)	ND	ND	ND	
GenX	ND	ND	ND	
NEtFOSAA	ND	ND	ND	
NMeFOSAA	ND	ND	ND	
PFBS	0.03	ND	ND	✓
PFDA	0.05	ND	ND	✓
PFDoA	ND	ND	ND	
PFHpA	0.05	0.03	0.04	✓
PFHxS	0.07	0.06	0.09	✓
PFHxA	0.09	0.06	0.05	✓
PFNA	0.08	ND	ND	✓
PFOS	1.85 ± 1.2	0.59 ± 0.37	0.25 ± 0.17	✓
PFOA	0.26 ± 0.14	0.18 ± 0.12	0.22 ± 0.09	✓
PFTeA	ND	ND	ND	
PFTriA	ND	ND	ND	
PFUnA	ND	ND	ND	
Moisture	10.9%	12.1%	12.3%	
PFOS Attenuation	**N/A**	**63%**	**84%**	

≤20 Tons of Biosolids

4-9 year application

Depth	1′	3′	6′	PFAS present in	
Contaminant	µg/kg (ppb)			Biosolids	Irrigation Wells
DONA	ND	ND	ND		
F-53B (Major)	ND	ND	ND		
F-53B (Minor)	ND	ND	ND		
GenX	ND	ND	ND		
NEtFOSAA	ND	ND	ND		
NMeFOSAA	ND	ND	ND		
PFBS	ND	0.08	0.04	✓	✓
PFDA	0.10	ND	ND	✓	
PFDoA	ND	ND	ND	✓	
PFHpA	0.08	0.06	ND	✓	✓
PFHxS	0.10	0.17	0.04	✓	✓
PFHxA	0.14	0.11	ND	✓	✓
PFNA	0.06	ND	ND	✓	✓
PFOS	1.58 ± 1.76	0.29 ± 0.20	ND	✓	✓
PFOA	0.32 ± 0.33	0.26 ± 0.26	ND	✓	✓
PFTeA	ND	ND	ND	✓	
PFTriA	ND	ND	ND		
PFUnA	ND	ND	ND	✓	
Moisture	7.8%	9.5%	9.9%		
PFOS Attenuation	N/A	**82%**	**100%**		

21-30 Tons of Biosolids

12-20 year application

Depth	1′	3′	6′	PFAS present in	
Contaminant	µg/kg (ppb)			Biosolids	Irrigation Wells
DONA	ND	ND	ND		
F-53B (Major)	ND	ND	ND		
F-53B (Minor)	ND	ND	ND		
GenX	ND	ND	ND		
NEtFOSAA	ND	ND	ND		
NMeFOSAA	ND	ND	ND		
PFBS	0.17	0.10	0.12	✓	✓
PFDA	0.56	0.06	0.05	✓	
PFDoA	0.04	ND	ND	✓	
PFHpA	0.09	0.09	0.06	✓	✓
PFHxS	0.03	0.04	0.05	✓	✓
PFHxA	0.13	0.09	0.09	✓	
PFNA	0.43	0.12	ND	✓	
PFOS	3.11 ± 2.06	0.64 ± 0.31	0.22 ± 0.09	✓	✓
PFOA	0.47 ± 0.29	0.49 ± 0.18	1.65 ± 2.38	✓	✓
PFTeA	ND	ND	ND	✓	
PFTriA	ND	ND	ND		
PFUnA	ND	ND	ND	✓	
Moisture	5.3%	10.5%	10.2 %		
PFOS Attenuation	N/A	**79%**	**93%**		

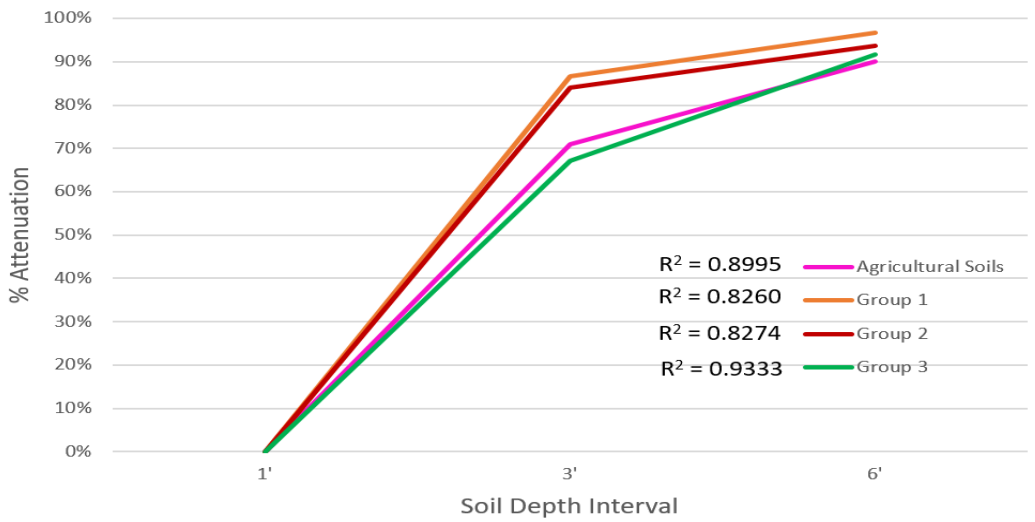
>30 Tons of Biosolids

6-9 year application

Depth	1′	3′	6′	PFAS present in	
Contaminant	µg/kg (ppb)			Biosolids	Irrigation Wells
DONA	ND	ND	ND		
F-53B (Major)	ND	ND	ND		
F-53B (Minor)	ND	ND	ND		
GenX	ND	ND	ND		
NEtFOSAA	ND	ND	ND		
NMeFOSAA	ND	ND	ND		
PFBS	0.37	0.20	0.14	✓	✓
PFDA	0.98	0.11	0.15	✓	✓
PFDoA	0.24	ND	0.08	✓	
PFHpA	0.19	0.16	0.24	✓	✓
PFHxS	0.12	0.15	0.16	✓	✓
PFHxA	0.51	0.22	0.13	✓	✓
PFNA	0.43	0.15	0.05	✓	✓
PFOS	4.13 ± 1.86	1.22 ± 1.36	0.46 ± 0.46	✓	✓
PFOA	0.84 ± 0.48	1.32 ± 1.43	0.51 ± 0.61	✓	✓
PFTeA	0.09	ND	ND	✓	
PFTriA	ND	ND	ND		
PFUnA	0.10	ND	ND	✓	
Moisture	9.5%	8.9%	10%		
PFOS Attenuation	**N/A**	**84%**	**90%**		

PFAS Attenuation

% Attenuation		No Biosolids Agriculture Only			≤20 tons/acre Group 1 Soils				21-30 tons/acre Group 2 Soils			>30 tons/acre Group 3 Soils				
		3 locations			4 locations				3 locations			5 locations				
	3'	67%	85%	75%	89%	84%	93%	91%	60%	81%	92%	55%	67%	84%	87%	93%
	6'	85%	-	95%	95%	97%	-	-	85%	93%	-	86%	94%	92%	-	97%

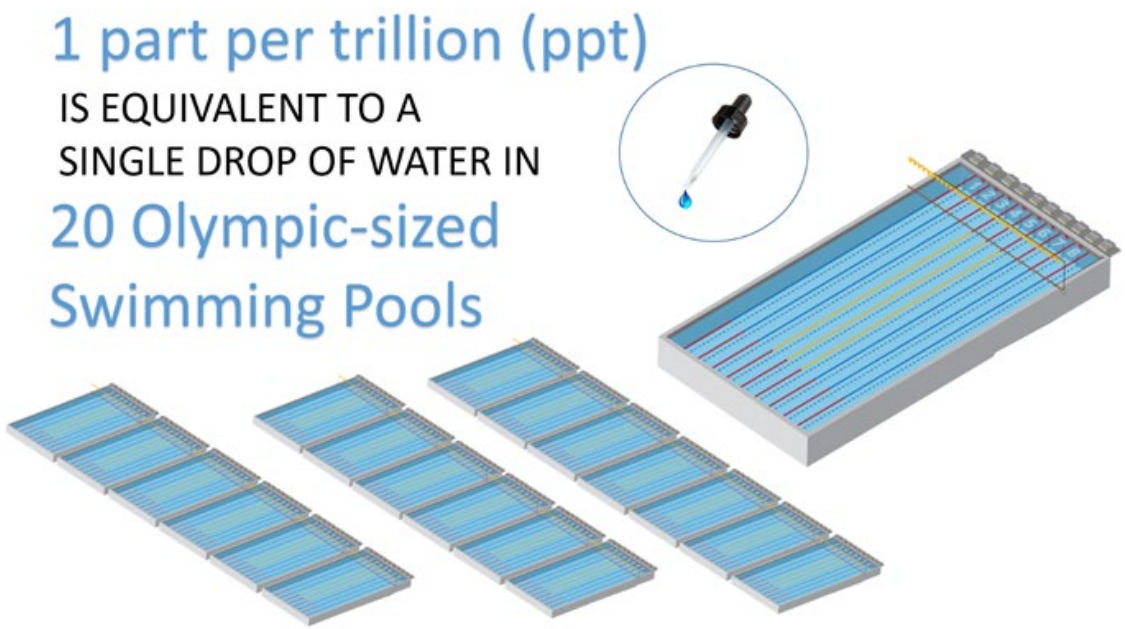


- Strong correlation for adsorption of PFAS
- Retained in the first few feet
- Minimal migration below 6’ depth
- 90% - 97% attenuation for all soil groups

mg/L = ppm (parts per million) • 1 ppm is the equivalent of one second every 11.6 days

µg/kg = ppb (parts per billion)
ng/g = ppb (parts per billion) • 1 ppb is the equivalent of one second in 32 years

ng/L = ppt (parts per trillion) • 1 ppt is the equivalent of one second in 32,000 years

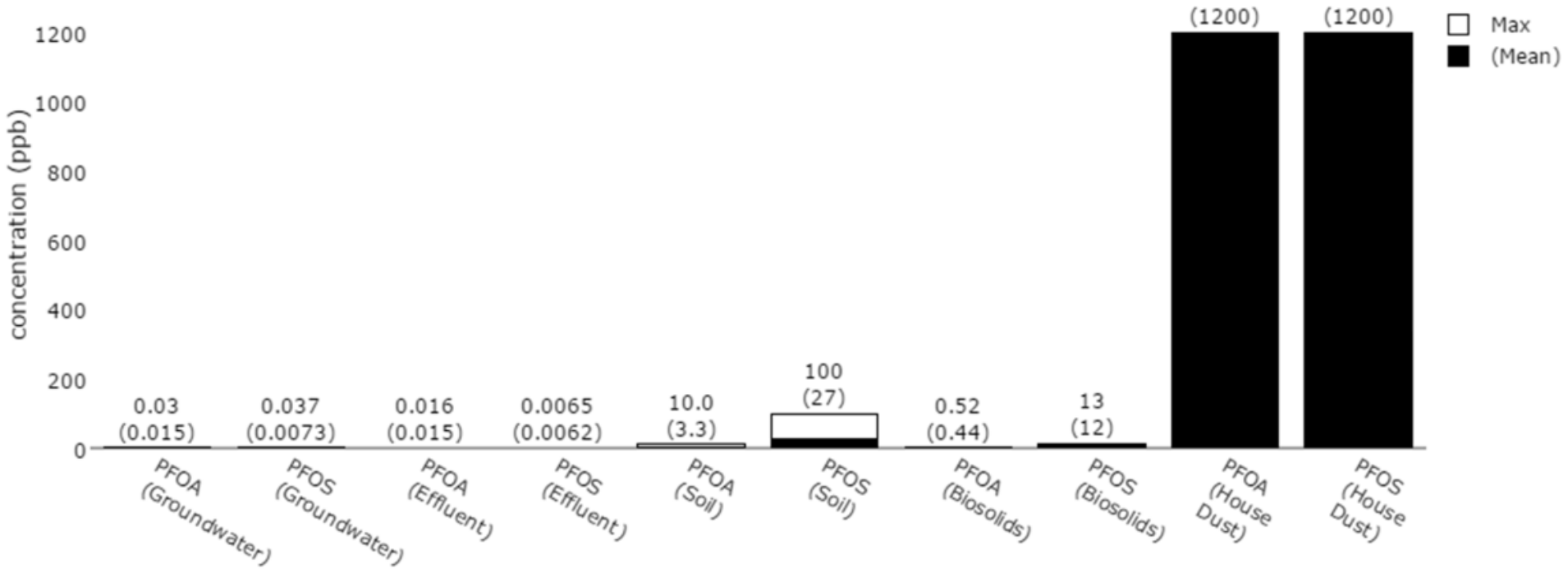


PFAS Concentrations

• Wastewater effluent	8 - 40 ppt
• DW health advisory limit	70 ppt
• Olive oil	1,800 ppt
• Landfill leachate	2,200 ppt
• Biosolids	28,000 ppt
• Food packaging	54,000 ppt
• Dust in day care centers	201,000 ppt
• Sunscreen	6,500,000 ppt
• AFFF	10,000,000,000 ppt

KERN COUNTY CASE

PFOA and PFOS in effluent, soil, and biosolids measured at Green Acres Farm, 2015, compared with PFOA and PFOS concentrations in household dust*



*Household dust measurements from Trudel et al. *Risk Analysis, Vol. 28, No. 2, 2008*

CONCLUSIONS

- Input of PFAS from long-term land application of biosolids minimal
- PFAS presence in irrigation sources likely contributes to detection in soils
- PFAS on soils with biosolids slightly higher than agricultural soils without biosolids
- PFAS concentrations rapidly decrease with depth
- 90% - 97% attenuation below 6‘
- Minimal migration below 6‘
- Potential for groundwater contamination is minimal