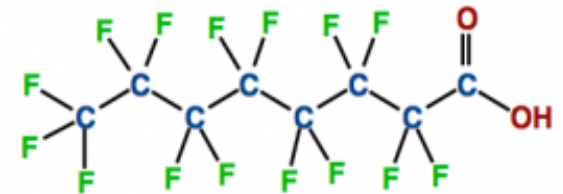


# HEALTH RISK ASSESSMENT OF POLY- AND PERFLUOROALKYL SUBSTANCES IN SOILS AND CROPS FROM THE LAND APPLICATION OF BIOSOLIDS



*Linda Hall, PhD; Tina Hoang, MS; Robert Scofield, MPH DEnv*

*Miami, Florida - May 23, 2017*

*Battelle Fourth International Symposium on Bioremediation and Sustainable Technologies*

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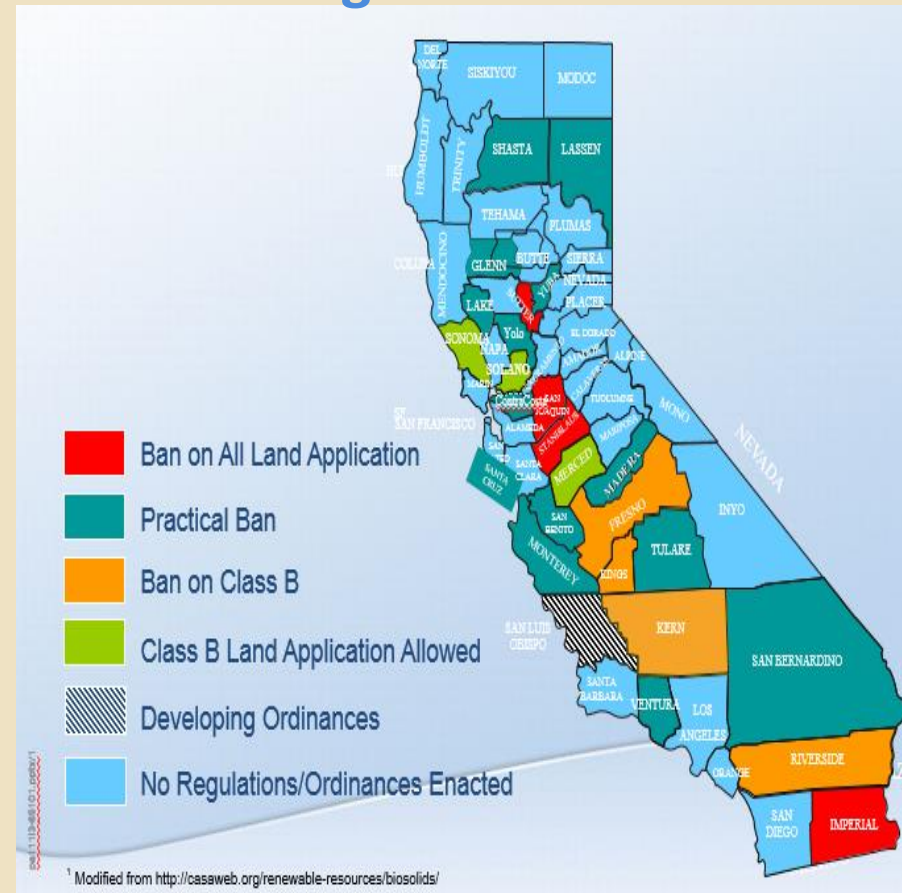
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# BIOSOLIDS IN THE UNITED STATES

- Land-application – the primary method of biosolids disposal in the US
  - > 4,000,000 dry tons applied annually
  - Cost-effective
- Increasing resistance to land application
  - Local ordinances seek to ban
  - PFASs a common concern
- No federal regulations for PFASs in effluent, sludge, biosolids

## Biosolids regulation in California




# POLY- AND PERFLUOROALKYL SUBSTANCES (PFASs) IN THE ENVIRONMENT

## *Stable*

- Highly-fluorinated hydrocarbons
- Stable, persistent; some are bioaccumulative
- Resistant to biodegradation, photolysis, hydrolysis

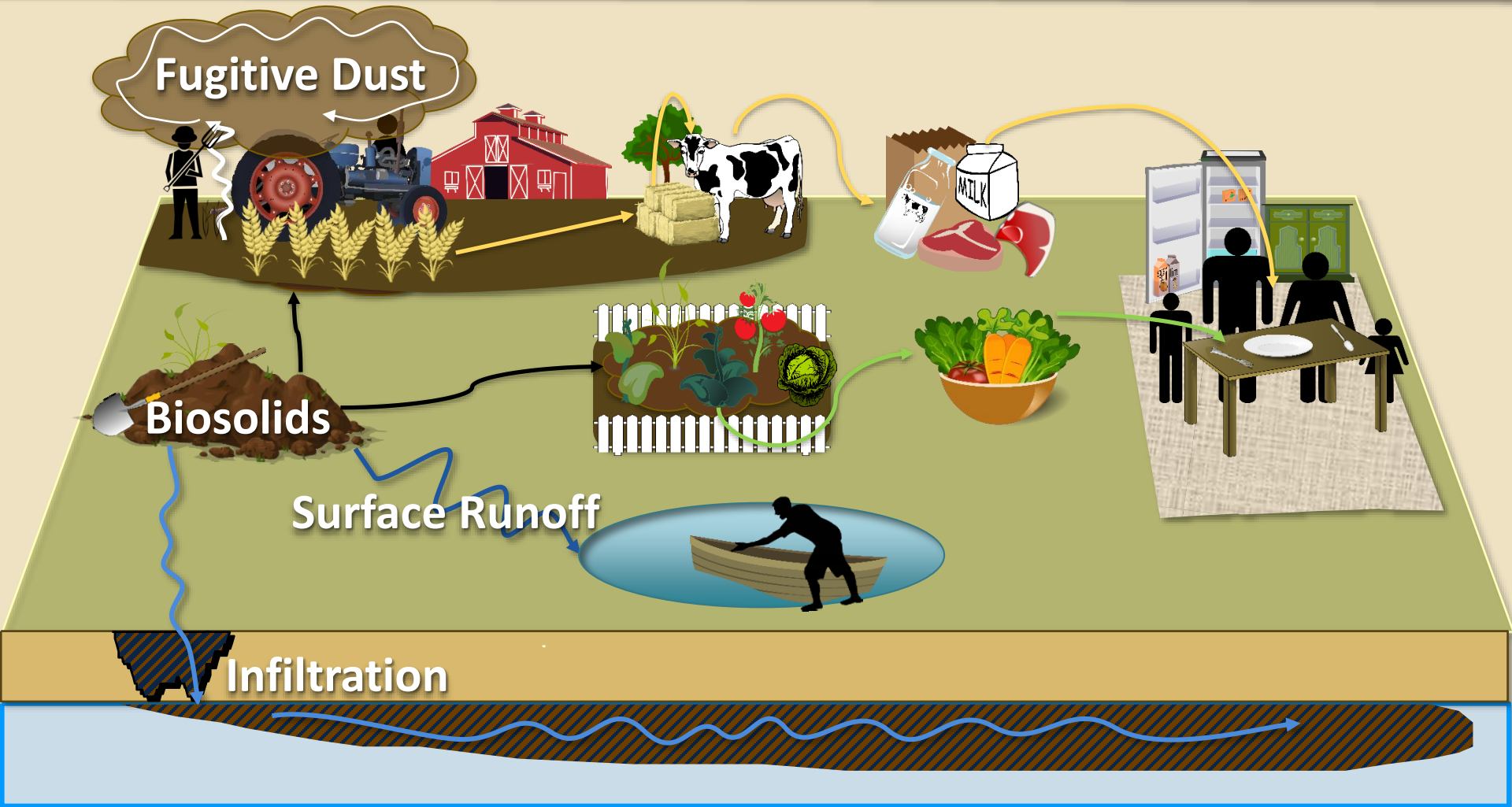
## *Ubiquitous*

- Doesn't degrade in conventional waste treatment
- Continued inputs; overseas manufacture, import of PFASs
- Transformation of long-chain PFASs in WWTPs 

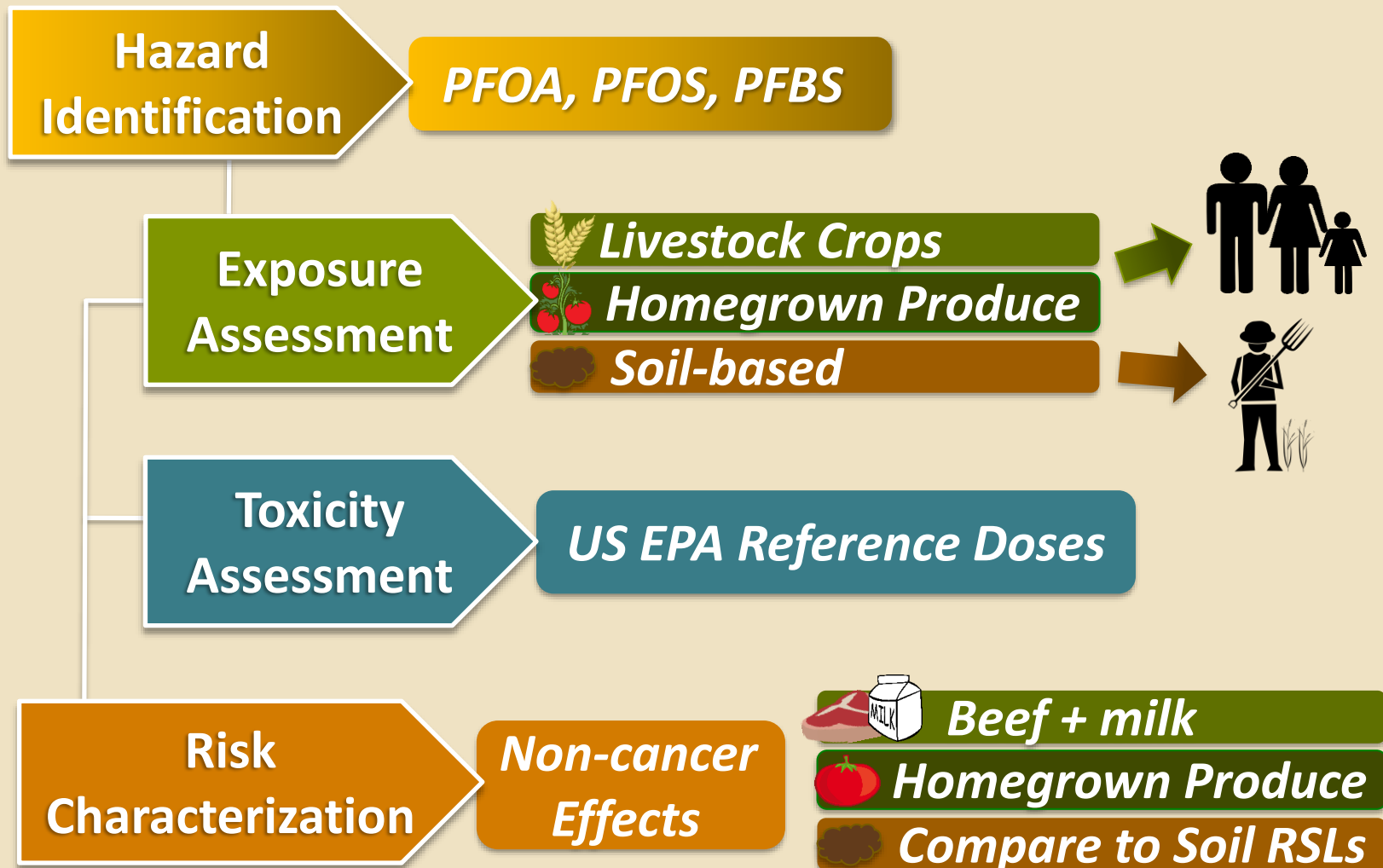
## *Soluble*

- Perfluorocarboxylic acids, perfluorosulfonic acids (ex. PFOA, PFOS)
  - Anions at environmental pH
  - Highly soluble
  - Can be taken up by plants

# CONCEPTUAL SITE MODEL



# HUMAN HEALTH RISK ASSESSMENT OF LAND-APPLIED BIOSOLIDS



# PFAS FOOD CHAIN TRANSFER CALCULATIONS

**PFAS** *Soil Concentrations*

*Transfer Factors:*



*Plant Bioaccumulation Factors*



*Animal Biotransfer Factors*

*PFAS Concentrations in:*



*Crops* →  *Meat, Milk*

*Homegrown Produce*



*Intake*

# EXPOSURE ASSUMPTIONS: MEAT, MILK, PRODUCE<sup>1</sup>

## *Beef, Milk*



- Consumed once/day
  - Beef: 7.7E-04 kg/kg
  - Milk (fluid): 0.24 kg/d
- Cattle fed crops grown on biosolids-amended soil

## *Homegrown Produce*



- Consumed once/day: 6.6E-4 kg/kg-d
- Adjusted for preparation and post-cooking losses
- All vegetables grown on biosolids-amended soil






## *Other Parameters*





- 80 kg body weight
- 13 year residence period
- 350 meals/year from meat, milk, or produce
- 4745-day Averaging Time

<sup>1</sup>USEPA Exposure Factors Handbook, 2011






# RESULTS – CONCENTRATION AND INTAKE

Analyte	 Plant and Animal Tissue Concentration (mg/kg)			
	 Crops	 Beef	 Milk	 Produce
PFBS	1.3E-4	8.0E-5	5.9E-5	3.8E-4
PFOS	1.5E-2	9.6E-3	7.1E-3	7.4E-2
PFOA	4.8E-3	5.2E-4	1.2E-3	5.5E-3

Analyte	 Estimated Human Intake (mg/kg)		
	 Beef	 Milk	 Produce
PFBS	6.8E-9	1.7E-7	2.4E-7
PFOS	8.1E-7	2.0E-5	4.7E-5
PFOA	4.4E-8	3.3E-6	3.5E-6

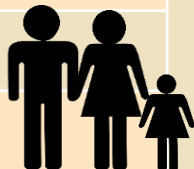
# RESULTS: NON-CANCER EFFECTS

Analyte	RfD <sup>1</sup> (mg/kg-d)	Pathway-Specific Hazard Quotient (unitless)		
		 Beef	 Milk	 Produce
PFBS	2.0E-2	3.4E-7	8.3E-6	1.2E-5
PFOS	2.0E-5	4.1E-2	1.0	2.3
PFOA	2.0E-5	2.2E-3	0.17	0.17

<sup>1</sup> US EPA 2014; 2016 a, b

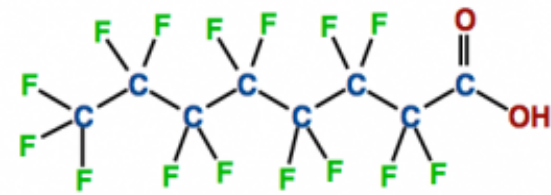
## Soil Concentrations vs Regional Screening Levels (RSL)

Analyte	Soil (mg/kg) <sup>1</sup>	RSL Agricultural Worker (mg/kg) <sup>2</sup>	RSL Resident (mg/kg) <sup>2</sup>
PFBS	1.0E-4	1.82 x 10 <sup>4</sup>	1.26 x 10 <sup>3</sup>
PFOS	1.5E-1	18.2	1.26
PFOA	9.0E-3	18.2	1.26



<sup>1</sup> Average estimated from Sepulvado et al. 2011; <sup>2</sup> U.S. EPA Regional Screening Level Calculator (US EPA, 2017)

# PFAS CARCINOGENICITY



## *PFOA*

- Suggestive Evidence of carcinogenicity (US EPA)
- Cancer slope factor, 0.07 (mg/kg-d)<sup>-1</sup>
- Non-cancer effects protective of cancer endpoint

## *PFOS*

- Suggestive Evidence of carcinogenicity (US EPA)
- Data too limited to support quantitative assessment

## *PFBS*

- Inadequate Information to Assess Carcinogenic Potential (US EPA)

# PFAS BIOSOLIDS RISKS IN PERSPECTIVE

- **Published PFAS Biosolids Soil Concentrations Variable <sup>1</sup>**
  - **Industrial vs Municipal Sources**
  - **Application Rate, Duration**
- **Plant Uptake Varies <sup>2</sup>**
  - **Plant part (root, shoot, fruit)**
  - **PFAS carbon chain length**
    - **>C8 not characterized**
- **Site-specific vegetation measurements can resolve key uncertainties**



<sup>1</sup> Sepulvado et al. 2011; Blaine et al., 2013; Wen et al., 2014

<sup>2</sup> Stahl et al., 2008; Blaine et al., 2013; Wen et al., 2014; Yoo et al., 2014

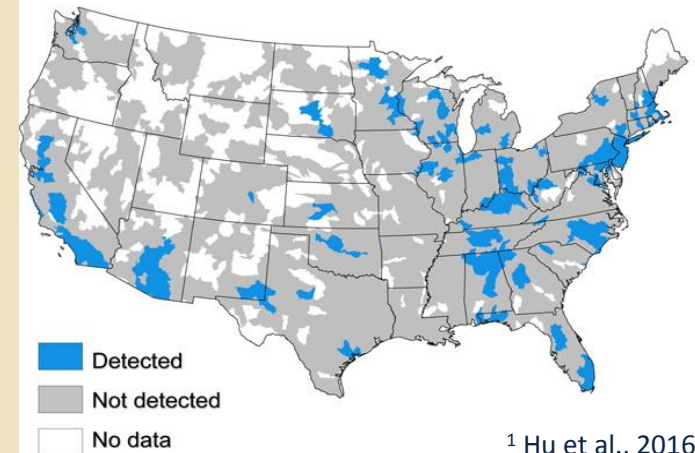
# PFAS BIOSOLIDS RISKS IN PERSPECTIVE, con't

Source attribution key  
to realistic risk assessment

- Widely detected in U.S. drinking water (UCMR3)
- Present in treated municipal water, irrigation water, soils, consumer and industrial products
- Distinguish biosolids contribution from irrigation water
- Distinguish background from site levels



Hydrological units with  
detectable PFASs



# Questions?

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