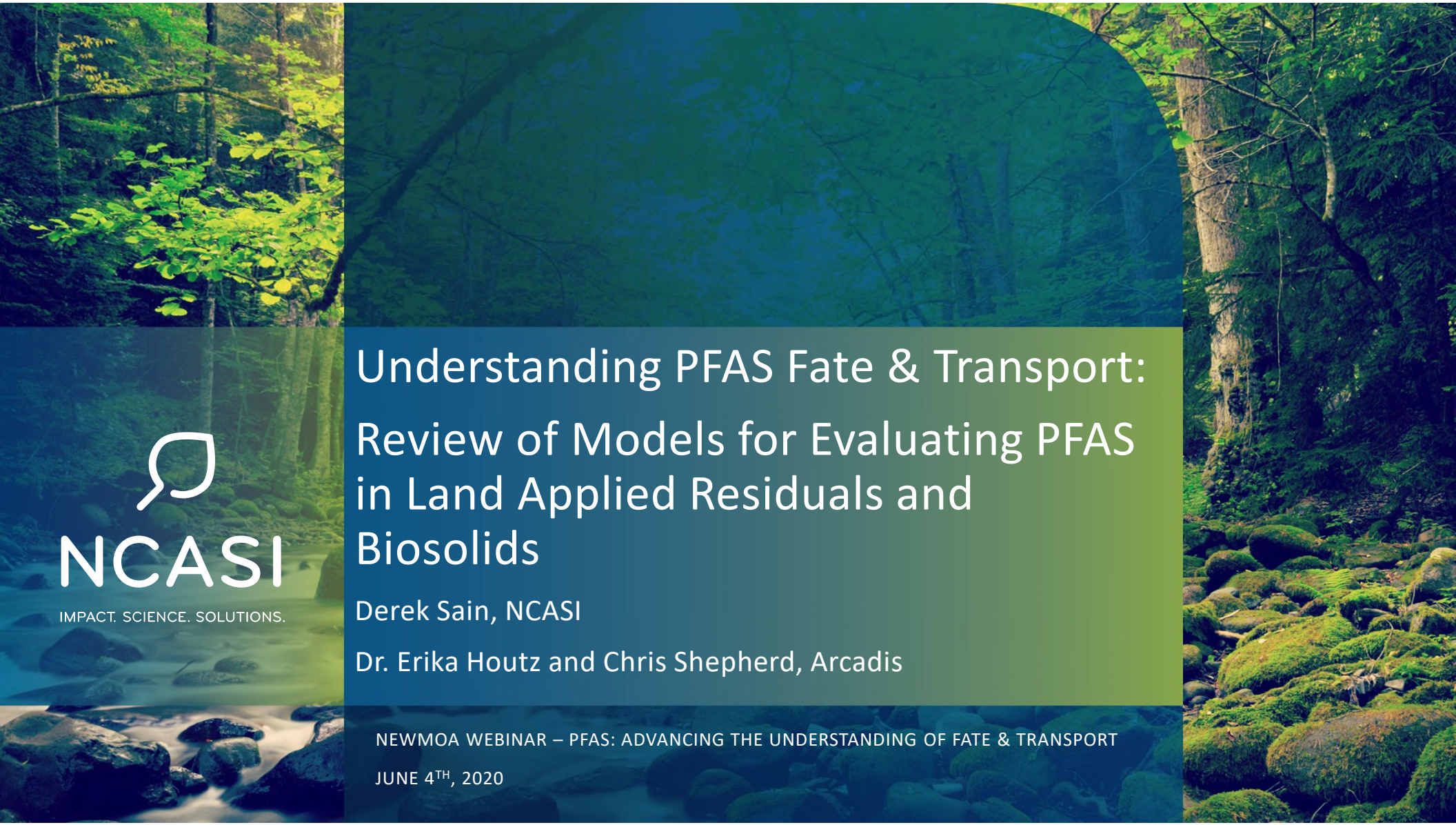

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Understanding PFAS Fate & Transport:

Review of Models for Evaluating PFAS in Land Applied Residuals and Biosolids

Derek Sain, NCASI

Dr. Erika Houtz and Chris Shepherd, Arcadis

NEWMOA WEBINAR – PFAS: ADVANCING THE UNDERSTANDING OF FATE & TRANSPORT

JUNE 4TH, 2020

Background

Benefits of land application

- Source of nutrients
- Improve soil properties
- Increase soil carbon content
- Attractive alternative to landfill disposal

PFAS in WWTP solids

- A percentage of PFAS entering into a WWTP can remain with the organic solids
- Land applied WWTP solids are a potential source of PFAS into the environment

Evaluating impact of PFAS in land applied residuals

- Use modeling to estimate the fate and transport of PFAS
- No standard modeling guidance for conducting this type of analysis
- States have to determine the most appropriate model and inputs to use

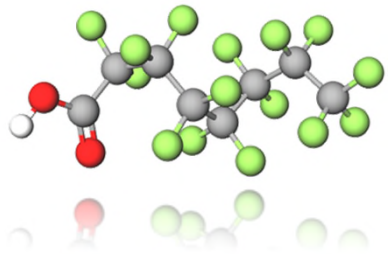
Activity in the Northeast

- Maine was first state to set screening levels
- North East Biosolids & Residuals Association (NEBRA) conducted separate modeling effort for Maine screening levels
  - Modeling conducted by Stone Environmental using US EPA's Pesticide Root Zone Model (PRZM) for a screening level estimate of PFAS concentrations in residuals/biosolids that would be protective of groundwater targets
  - This activity illustrates the importance of model selection and execution and was a factor in our decision to prepare a report
- Need for a resource to help states make informed and scientifically defensible choices when selecting modeling tools for this purpose
- NCASI (along with WEF, NACWA, and AF&PA) contracted with Arcadis to review fate and transport models for PFAS in land applied residuals

ARCADIS Design & Consultancy for natural and built assets

REVIEW OF MODELS FOR EVALUATING PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) IN LAND APPLIED RESIDUALS & BIOSOLIDS

An Assessment of Fate and Transport Models for Groundwater Leaching, Surface water Runoff, & Plant Uptake



June 4, 2020

ARCADIS Design & Consultancy for natural and built assets

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Water Environment Federation the water quality people

NACWA

American Forest & Paper Association

Study Objectives

Assess suitability of existing models for PFAS:

1) Leaching
2) Runoff
3) Plant uptake

What was not included:

Minor pathways

Surface water & groundwater models

Share findings

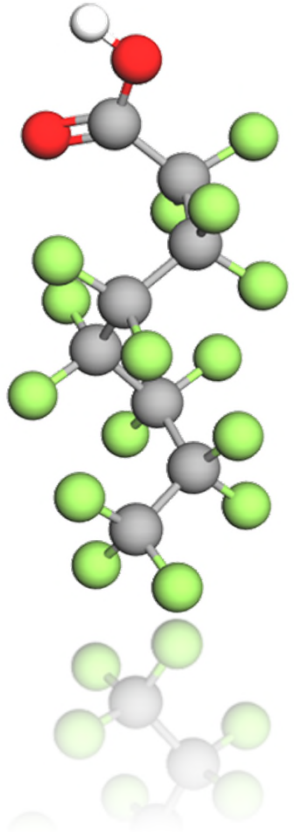
Challenges

Thousands of PFAS compounds

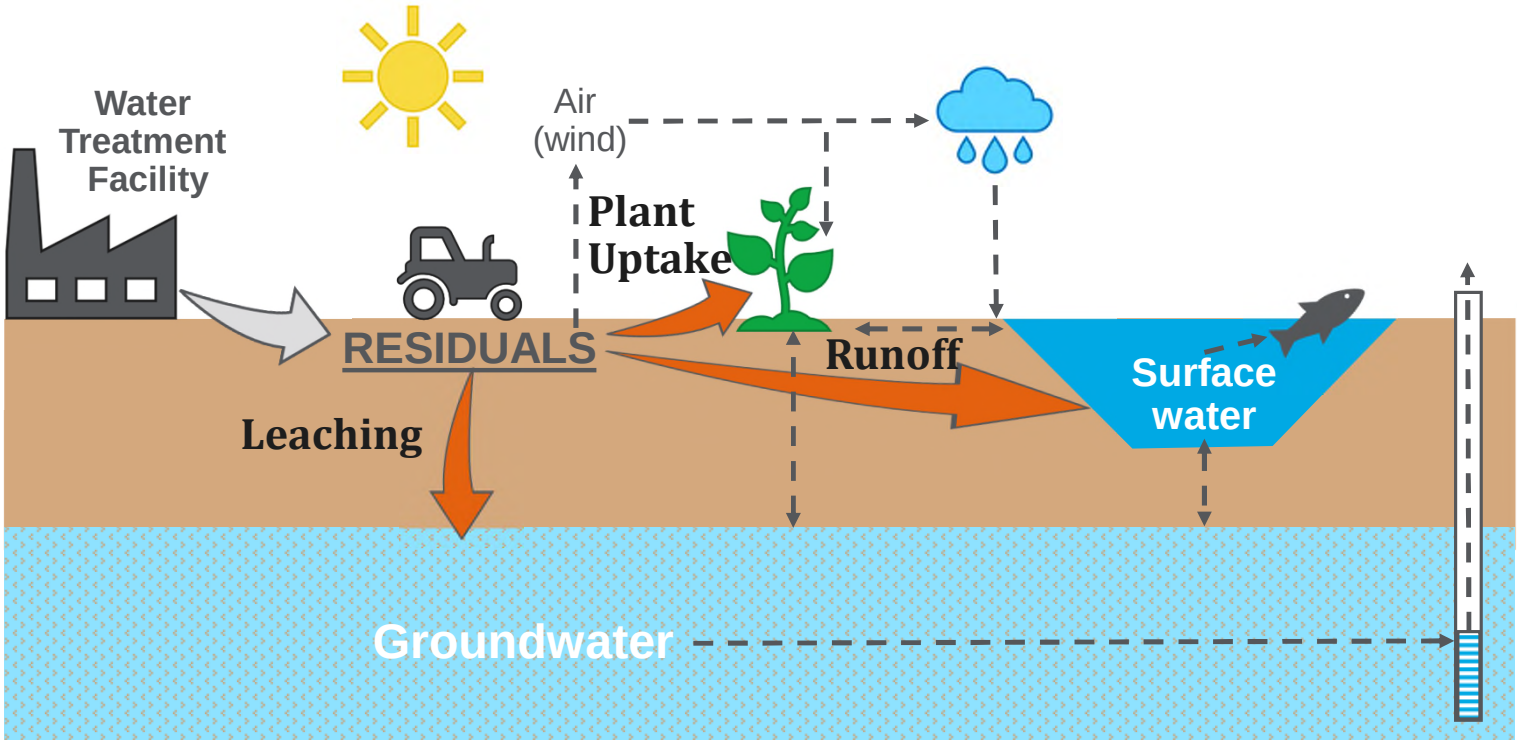
- Each compound has unique characteristics
  - Transport parameters
  - Toxicity
  - Chain length & functional groups are key

No models designed to model PFAS

Evolving regulations & lack of guidance



PFAS in Residual Pathways



Effect of Key PFAS Parameters on Modeling

Parameter	Leaching to Groundwater	Surface Water Runoff	Plant Uptake
Hydrophobic Sorption (k_{oc})	**High**	**High**	**High**
Soil-to-plant Transfer Factor (*TF*)	Low	None	**High**
Generation from Precursors	**Mod-High**	**Mod-High**	**Mod-High**
Air-Water Interface Partitioning (K_{ia})	**Mod-High**	**Low**	**Mod-High**
Electrostatic Adsorption (K_d)	**Mod-High**	**Mod-Low**	**Mod-High**

Mod = moderate

General Considerations

PFAS concentration (residuals, mixing depth)

Residual application (application rate & frequency, size of area, …)

Terrain & Climate

Plant/Crop (species, tissue type)

Distances (to groundwater, to stream, …)

Residual & soil properties (moisture, carbon content,…)

Precursor transformation & Background

Model Review Process

ID Models (>70)

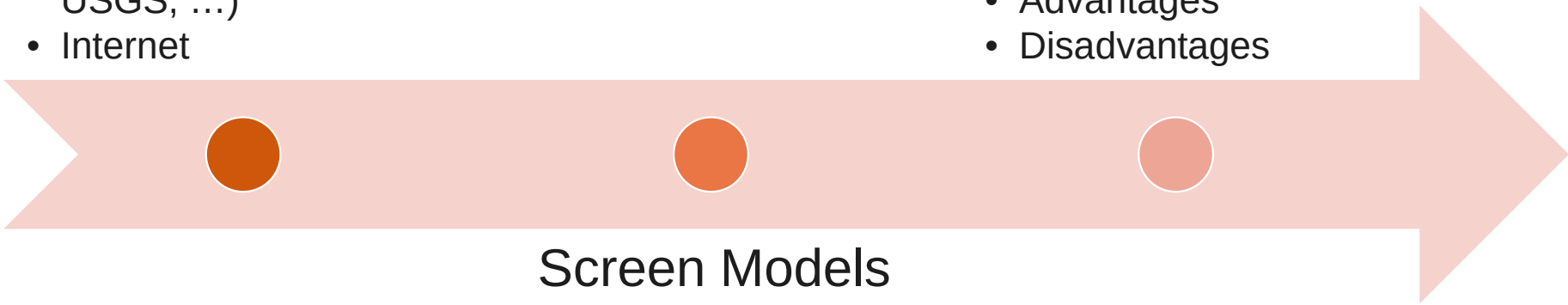
- Known resources (EPA, USGS, …)
- Internet

Screen Models

- General suitability
- Maintained

Review Retained Models

- Capabilities
- Advantages
- Disadvantages



Leaching Models

Identified 31 models

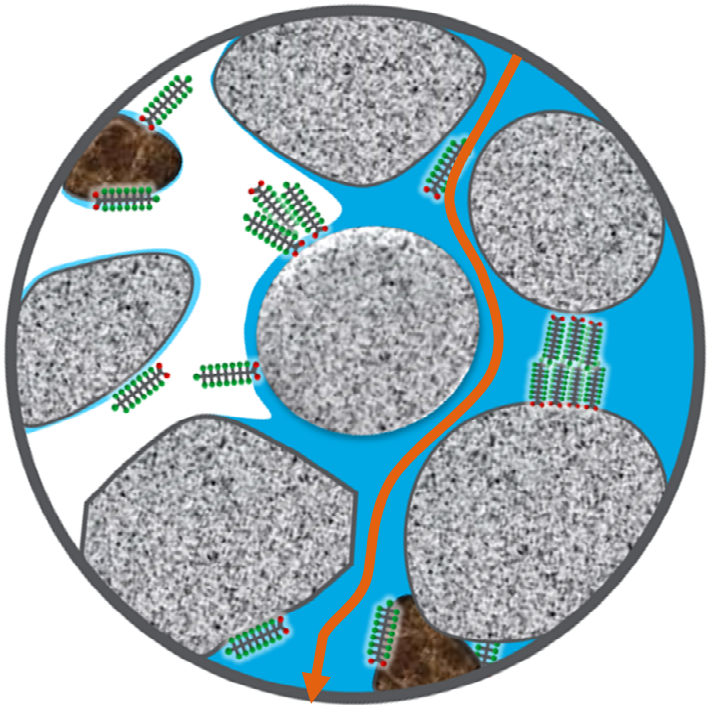
18 models retained for review

3 models more suitable

- **HydroGeochem**
- **Hydrus**
- **SVEnviro**

More Suitable Leaching Models

- Maintained & peer reviewed/accepted
- Rely on Darcian flow & standard advection/dispersion equations
- Account for:
  - *Koc &/or Kd*
  - Probability to include *Kia* &/or surfactant effects in future
  - Soil heterogeneity & dual domain
  - Variable recharge rates (transient)
  - Time dependent loading (sources & sinks)



Runoff Models

Identified 30 models

3 models retained for review

1 model more suitable

- **Pesticide Water Calculator (PWC)**

More Suitable Runoff Model

Maintained & peer reviewed/accepted

Accounts for:

- Chemical-specific inputs (*Koc, Kd*, etc.)
- Nonlinear partitioning/reactions
- Water balance as it interacts with soil (not just sheet flow like other models)
- Range of landcover scenarios
- Crop application(s)
- Time dependent loading (sources & sinks)

Meaningful model outputs

PFAS transport in runoff similar to other common contaminants

Plant Uptake Models

Identified 12 models

All models reviewed, however

Focus on plant transfer factors (TFs)

Key Plant Uptake Findings

Most plant uptake models designed for:

- Hydrophilic & lipophilic (fat) compounds
- Partition to carbon & fats

However, PFAS are generally ionized, partitioning more complex, & governed by additional physicochemical properties

Mechanistic models for ionized chemicals could be applicable to PFAS

- Require substantial data/inputs
- More complex
- Rely on PFAS- & plant-specific TFs (limited)
- For these reasons, detailed mechanistic models not practical at this time

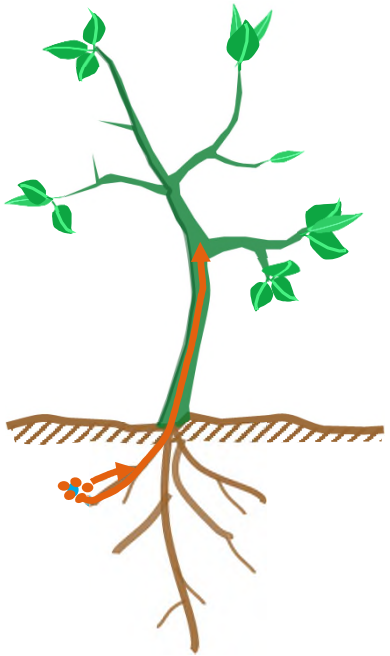
Key Plant Uptake Findings

Compiled plant TFs

Some general TF observations:

- Soil-to-plant TFs:
  - Decrease with increasing PFAS carbon chain length
  - PFSA TFs < PFCA TFs

- Solution-to-plant TFs:
  - Fruits TFs decrease with increasing carbon chain length
  - Root TFs increase with increasing carbon chain length
  - Fruit TFs < Roots TFs



Model Selection

Other models may be used to model PFAS, assuming their respective limitations are accounted for

Model selection should be based on:

1. Purpose / goals
2. Type of assessment
    1. Screening level (more conservative [e.g., PWC])
    2. Detailed/site-specific (more accurate [e.g., PWC + TFs + Hydrus])
3. Complexity of the site
4. Time, budget, etc.

Project objectives & site-specific factors should guide model selection

Conclusions

PFAS have characteristics that uniquely affect their F&T

Existing models not developed specifically for PFAS

- No models account for all key PFAS parameters

Some models more suitable for PFAS, but need to consider:

- Combined Kd effects (retardation)
- Precursor transformation
- Plant & PFAS-specific TFs
- Mass balance / conservation

Future Research Needs

General Model Application

- Predictive ability of existing models
- Mass balance & losses via the three pathways

Leaching

- Refine models to include K_{ia} & surface tension
- Evaluate non-linear & concentration dependent variables

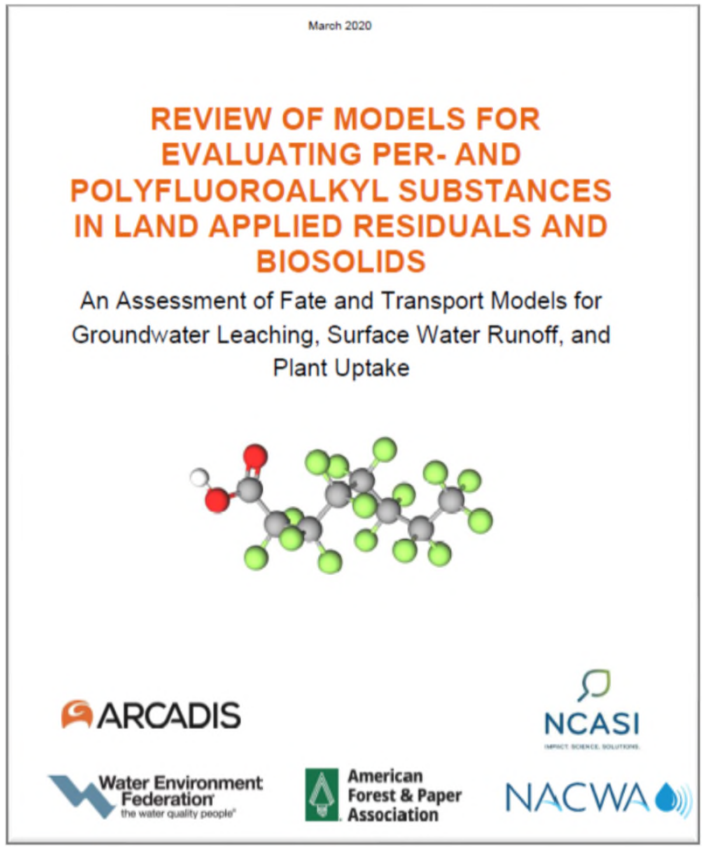
Runoff

- Desorption mechanisms from soils during runoff

Plant uptake

- Develop more robust TFs based on regression analysis & more complete compilation of TFs
- Development of better models

Report



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Available on NCASI's website:

https://www.ncasi.org/resource/review-of-models-for-evaluating-per-and-polyfluoroalkyl-substances-in-land-applied-residuals-and-biosolids/

Complete references in report

Thank you!

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