TU Delft

Grey box modeling of Municipal Solid Waste

A.G. van Turnhout, T.J. Heimovaara, R. Kleerebezem

This presentation

What is Municipal Solid Waste?
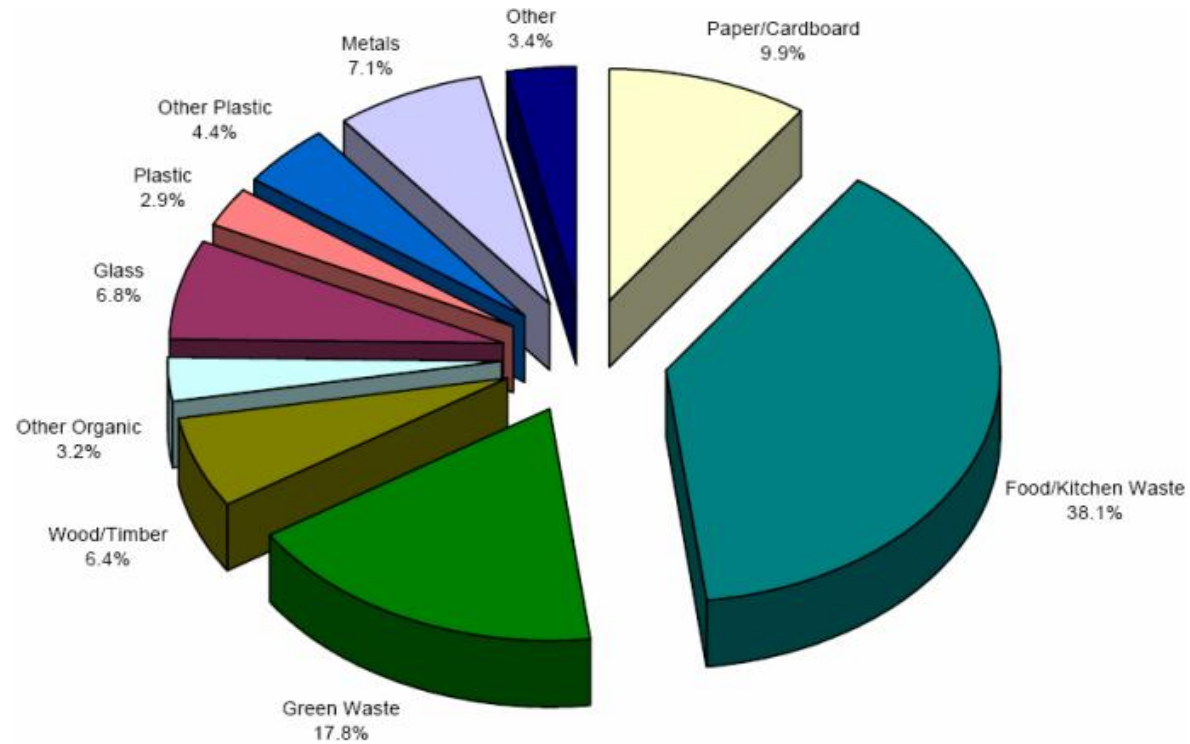
Why do we need to manage it?

How can we model Municipal Solid Waste?

What kind of reactions take place?

What kind of tools do we need?

What is Municipal Solid Waste

What is Municipal Solid Waste

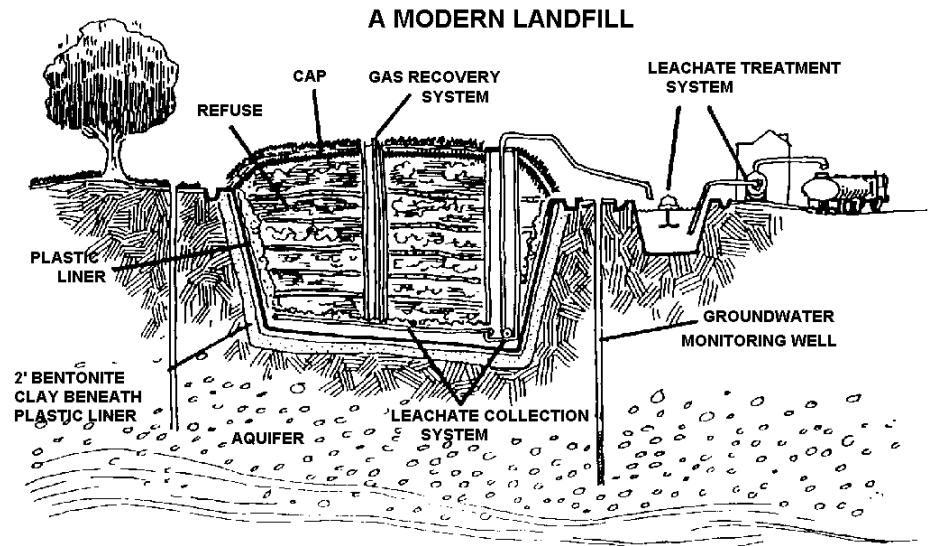## Why do we need to manage it?

What is Municipal Solid Waste

Why do we need to manage it?

Gas emissions

Leachate emissions

What is Municipal Solid Waste

Why do we need to manage it?
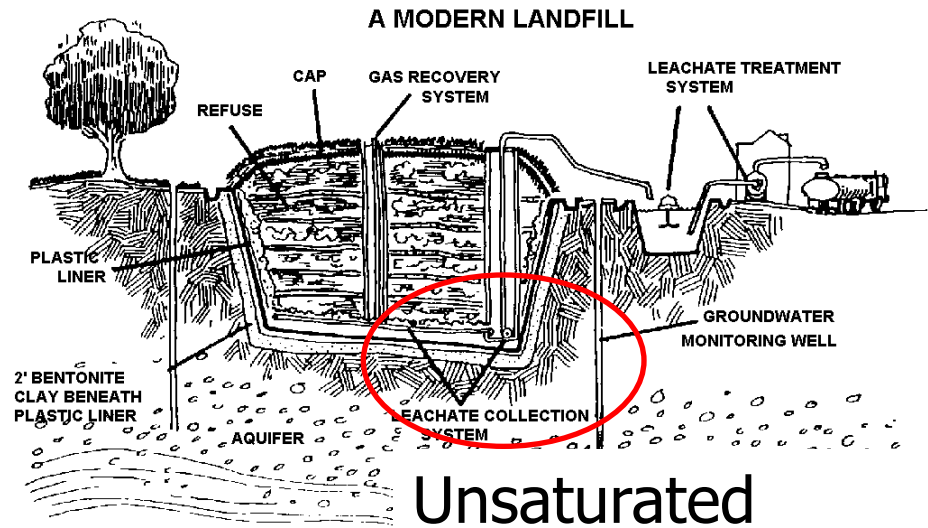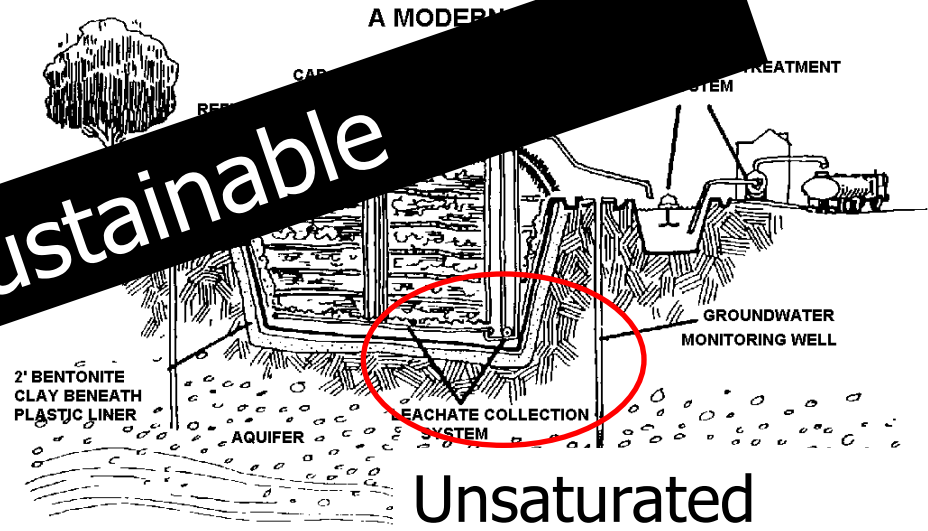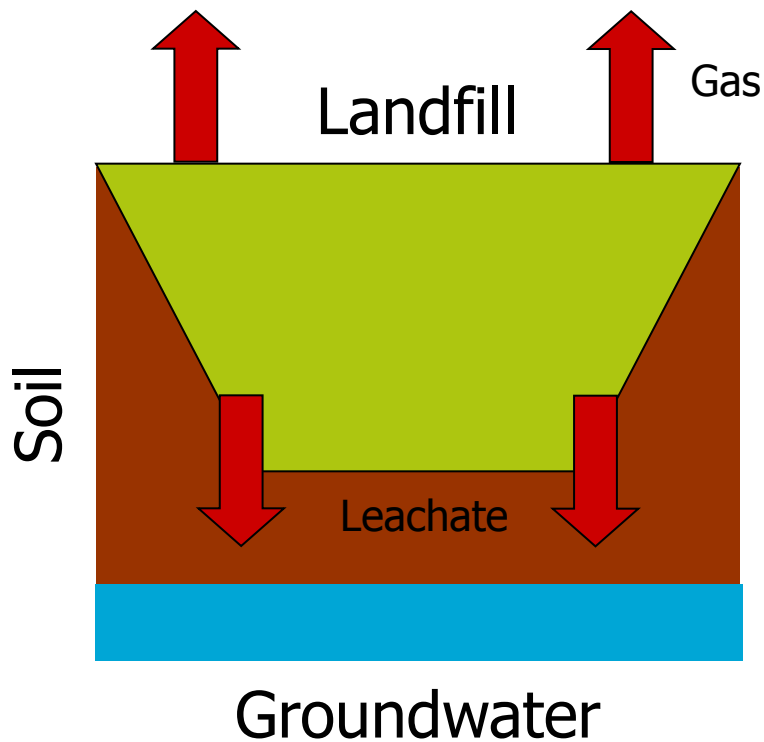
Gas emissions

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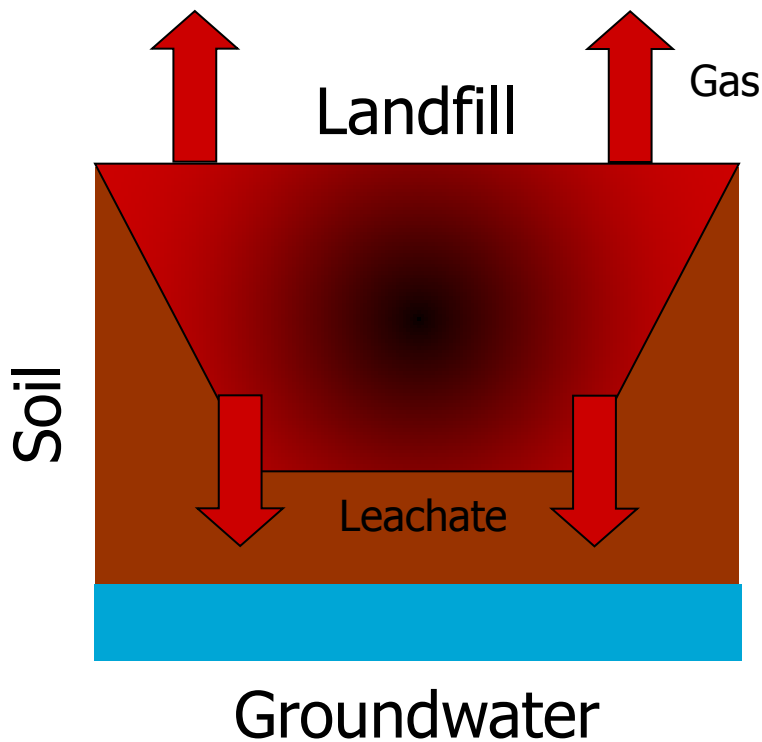A MODERN LANDFILL

CAP

GAS RECOVERY SYSTEM

LEACHATE TREATMENT SYSTEM

REFUSE

PLASTIC LINER

2' BENTONITE CLAY BENEATH PLASTIC LINER

AQUIFER

LEACHATE COLLECTION SYSTEM

GROUNDWATER MONITORING WELL

Why do we need to manage it?

Gas emissions

Leachate emissions

A MODERN LANDFILL

CAP · GAS RECOVERY SYSTEM · LEACHATE TREATMENT SYSTEM · REFUSE · PLASTIC LINER · 2' BENTONITE CLAY BENEATH PLASTIC LINER · AQUIFER · LEACHATE COLLECTION SYSTEM · GROUNDWATER MONITORING WELL

Unsaturated

What is Municipal Solid Waste

Why do we need to manage it?

Gas emissions

Not Sustainable

Leachate emissions

A MODERN ... TREATMENT

GROUNDWATER MONITORING WELL

2' BENTONITE CLAY BENEATH PLASTIC LINER

AQUIFER

LEACHATE COLLECTION SYSTEM

Unsaturated

ONCE UPON A TIME PEOPLE USED TO DUMP HERE ALL THEIR WASTE!

How do we model MSW

What do we need to know?

Gas

Landfill

Soil

Leachate

Groundwater

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How do we model MSW

What do we need to know?

Landfill

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Groundwater

1. The remaining emission potential

How do we model MSW
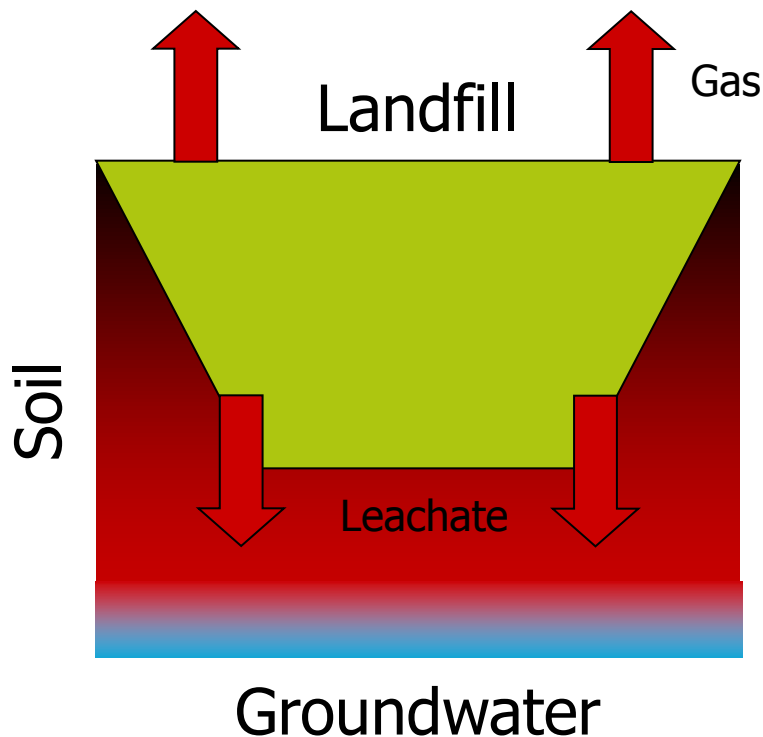
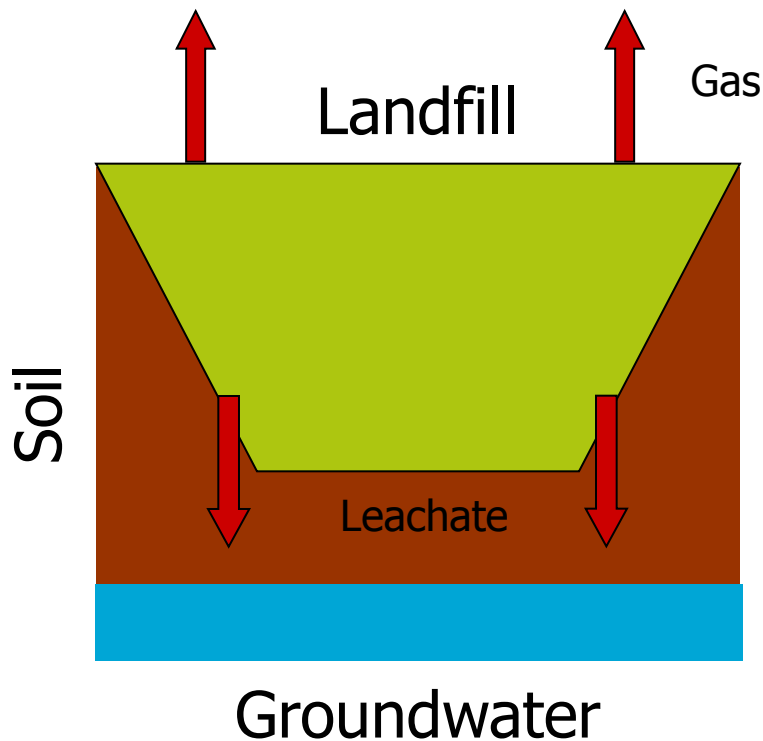## What do we need to know?

Landfill

Gas

Soil

Leachate

Groundwater

1. The remaining emission potential

2. The environmental impact
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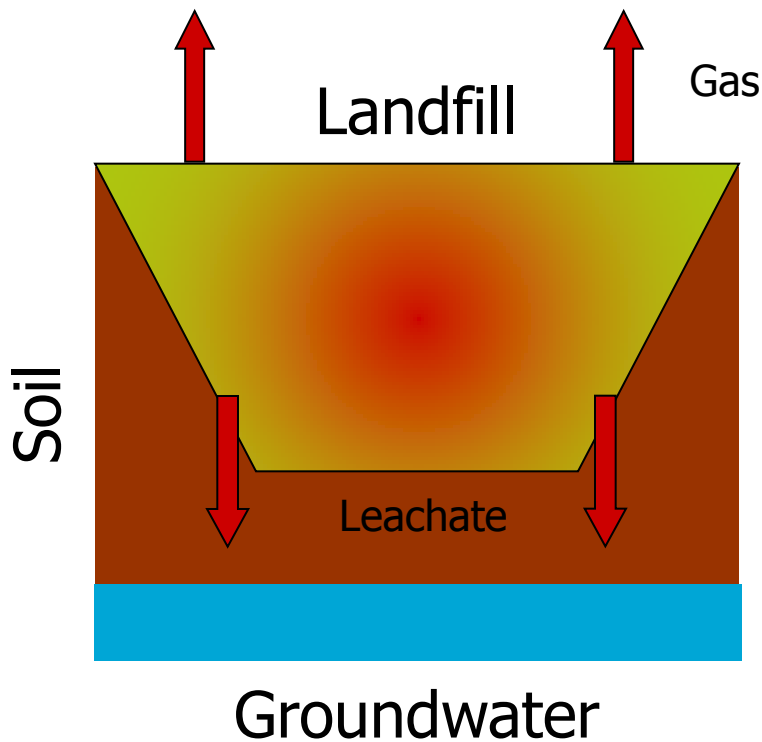
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How do we model MSW

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3. Optimization of leachate treatment

4. Optimization of biogas extraction

How do we model MSW

What do we need to know?

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1. The remaining emission potential

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3. Optimization of leachate treatment

4. Optimization of biogas extraction

5. Stimulation of potential reduction

How do we model MSW

What do we know?

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How do we model MSW

What do we know?

Very heterogeneous system!!
Large scale!!

Measurements alone are not sufficient
to quantify landfill behavior

How do we model MSW

Our modelling approach

Previous research indicates two fields dominating emissions

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How do we model MSW

Our modelling approach

Previous research indicates two fields dominating emissions

Transport: Water flow in porous media, unsaturated, Richards equation, preferential flow, convection, dispersion, diffusion, multiphase system, reactive (kinetics & equilibrium)

How do we model MSW

Our modelling approach

Previous research indicates two fields dominating emissions

Transport: Water flow in porous media, unsaturated, Richards equation, preferential flow, convection, dispersion, diffusion, multiphase system, reactive (kinetics & equilibrium)

Bio(geo)chemistry: (An)aerobic degradation of organics, redox reactions, dissolution/precipitation of minerals, metal/salt leaching, gas production, multicomponent system, reactive (kinetics & equilibrium)
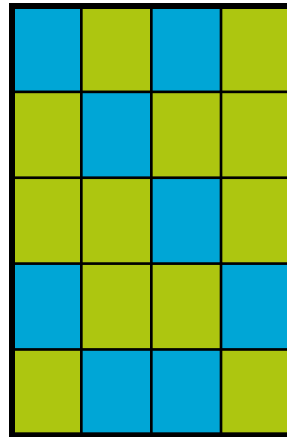
How do we model MSW

Our approach

Immobile water (Biochemistry)
A.G. van Turnhout

Mobile water (Transport)
S. Baviskar

Coupled model (by Diffusion)
A. Bun

Parameter information (Geophysics)
L. Konstantaki

How do we model MSW

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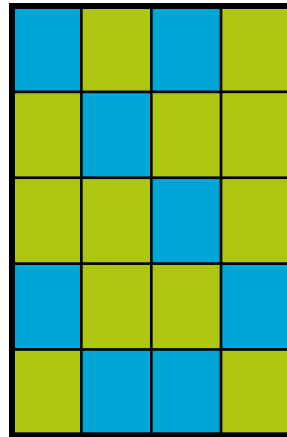
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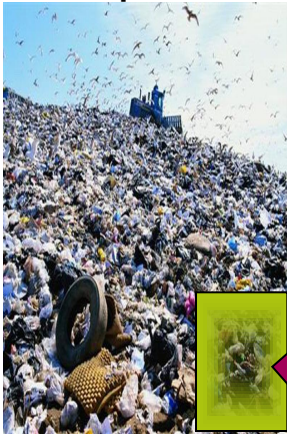# How do we model MSW

The biochemical sub-model

Immobile
water pocket

How do we model MSW

The biochemical sub-model

Immobile water pocket

Column experiment

Shredded Municipal Solid Waste
(R. Valencia 2009)

How do we model MSW

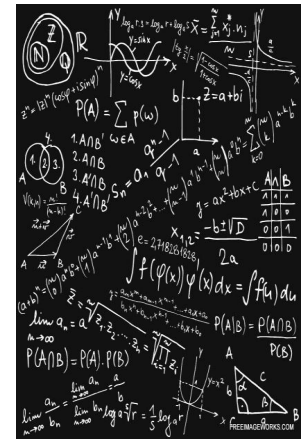## The biochemical sub-model

Immobile
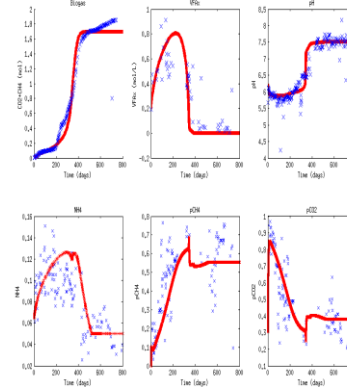water pocket

Column
experiment

Numerical
model

Shredded Municipal Solid Waste
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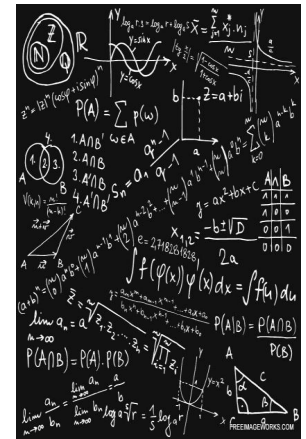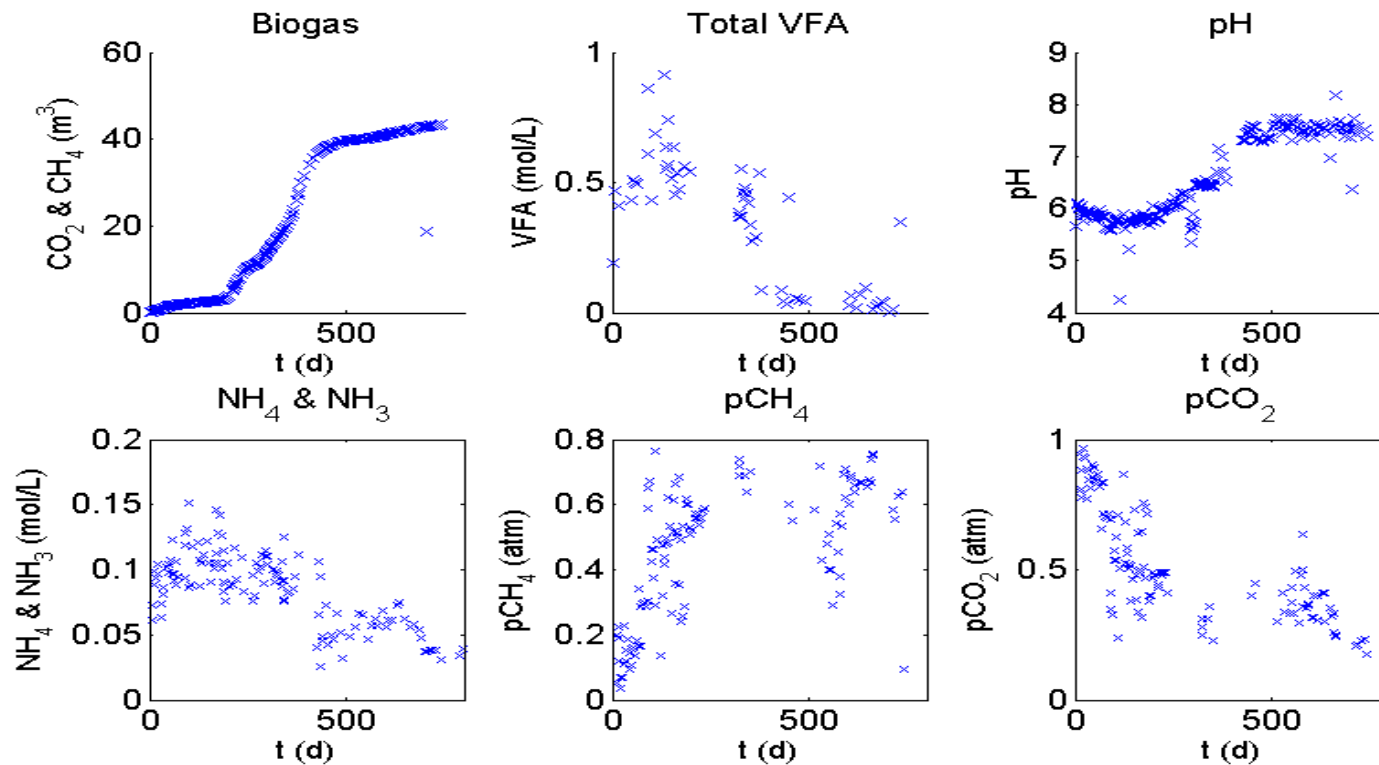
The biochemical sub-model

Immobile
water pocket

Column
experiment

Data & model
results

Numerical
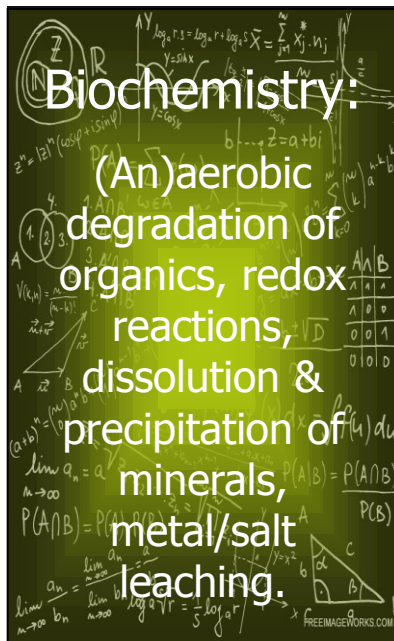model

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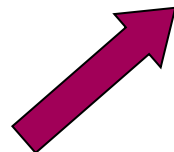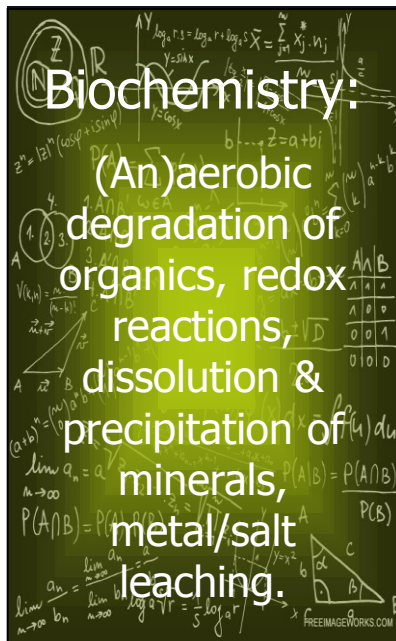
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(An)aerobic degradation of organics, redox reactions, dissolution & precipitation of minerals, metal/salt leaching.

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How do we model MSW

The biochemical sub-model

Biochemistry:

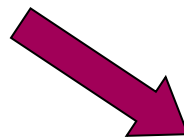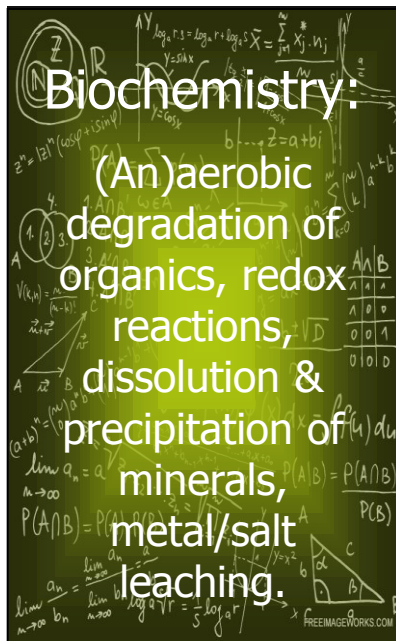(An)aerobic degradation of organics, redox reactions, dissolution & precipitation of minerals, metal/salt leaching.

White box:

Too many processes & parameters to consider. System becomes redundant, too uncertain.

How do we model MSW

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Black box:

Too little information to model complete set of emission parameters accurate.

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How do we model MSW

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White box:

Too many processes & parameters to consider. System becomes redundant, too uncertain.

Black box:

Too little information to model complete set of emission parameters accurate.

Grey box:

Reduces number of processes while keeping enough complexity

Utilizes 'bottleneck' processes

How do we model MSW

The biochemical grey model

Where to simplify the model?

Model only the slow dominant reactions

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How do we model MSW

The biochemical grey model

Where to simplify the model?
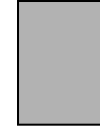
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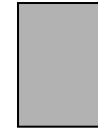1. Hydrolysis and Methanogenesis kinetics
2. Mass transport kinetics neglected

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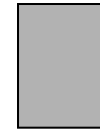
How do we model MSW

The biochemical grey model

Where to simplify the model?
Model only the slow dominant reactions

➡ 1. Hydrolysis and Methanogenesis kinetics
2. Mass transport kinetics neglected

INCLUDING

Accurate calculation of chemical and physical equilibrium

How do we model MSW

The biochemical grey model

1. **Lumped hydrolysis**
   (pH and VFA inhibition)

   $CxHyOzNi + H2O \rightarrow VFA + NH3 + X + CO2$

Kinetics

How do we model MSW

The biochemical grey model

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3. Chemical speciation/precipitation/dissolution

Compound speciations $\rightarrow$ pH $Ca + CO3 \leftrightarrow CaCO3$

Equilibrium

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Equilibrium

4. **Phase equilibrium**
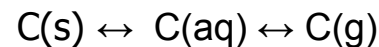
$$C(s) \leftrightarrow C(aq) \leftrightarrow C(g)$$

Equilibrium

How do we model MSW

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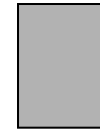
Implementation

Estimate and collect all parameters in a matrix in Spreadsheet

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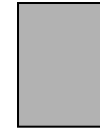
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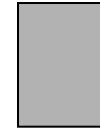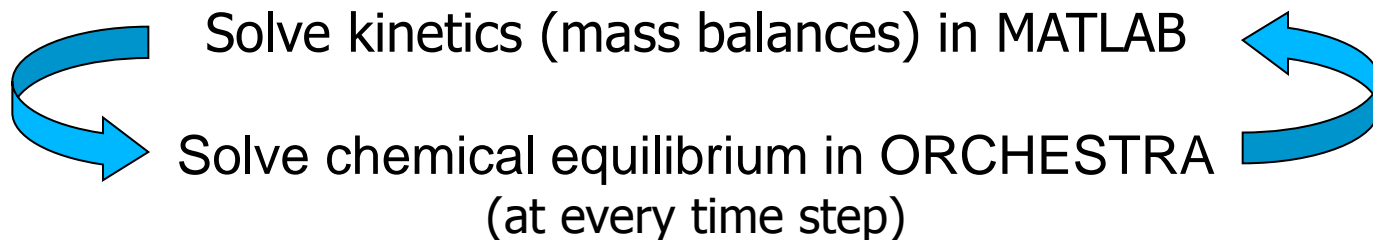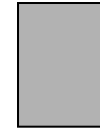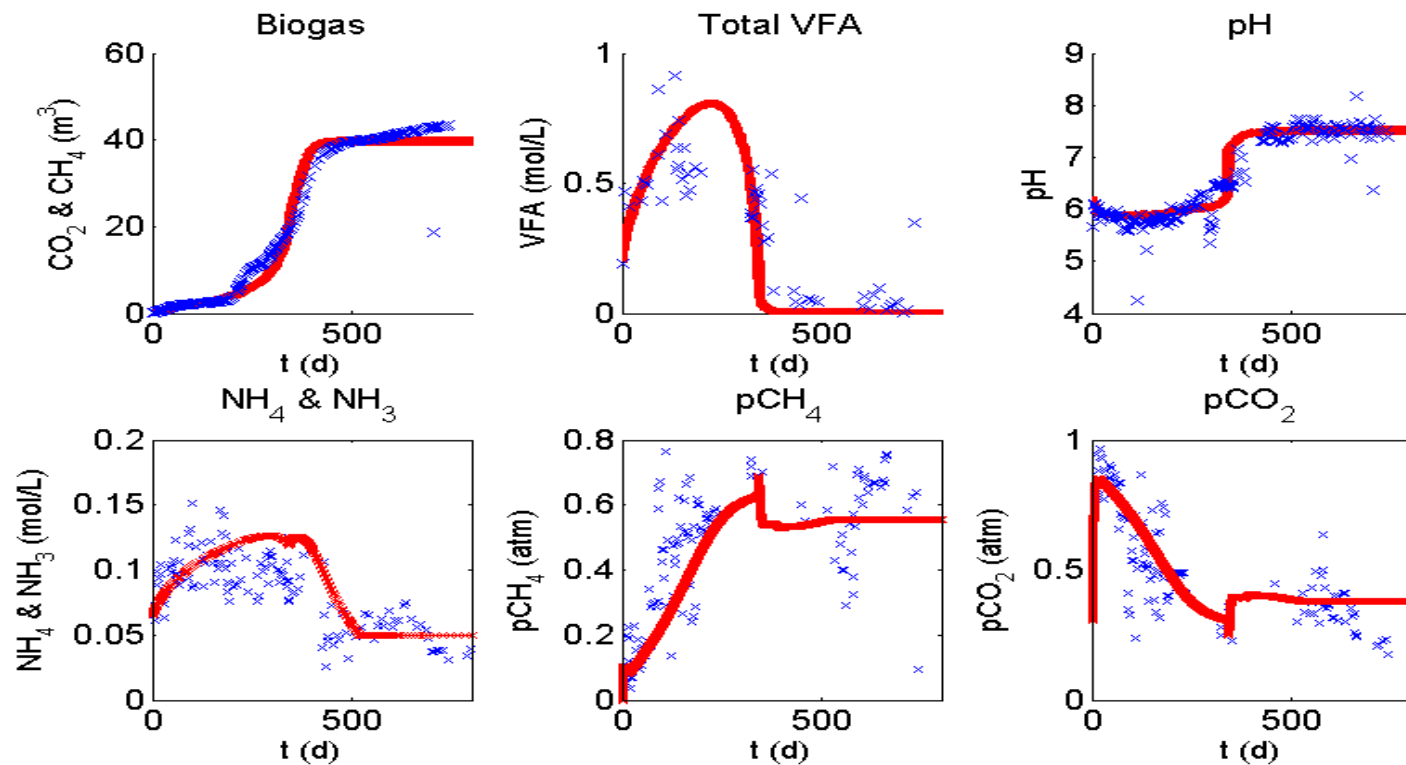
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How do we model MSW

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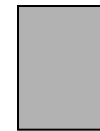
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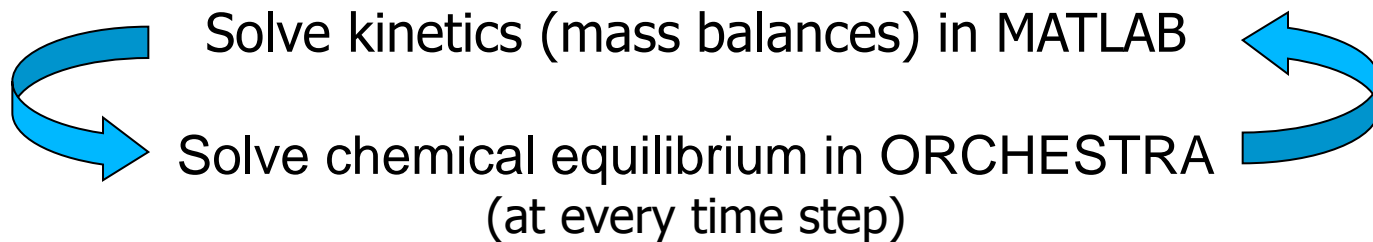
Output   Output   Output

How do we model MSW

The biochemical grey model

How do we model MSW

The biochemical grey model

Parameter/process check with DREAM

Model parameters

1. Initial conditions (experiment)

2. Parameters (literature)

k(hyd)	pHi(hyd)
VFAi	µmax
Ks	pHi(hyd)
NH3i	Cxi

How do we model MSW

The biochemical grey model

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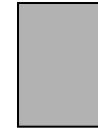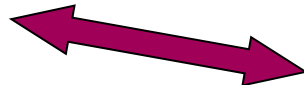|	
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DREAM

1. Optimizes parameters according to information in data by SLS

2. Calculates density distributions and correlation with Bayesian statistics

3. Parameters (optimized)

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How do we model MSW

The biochemical grey model

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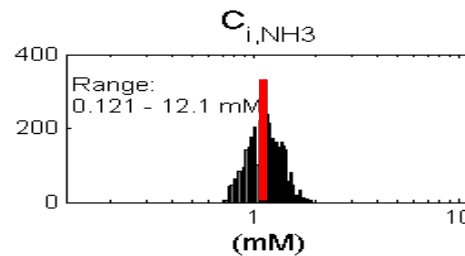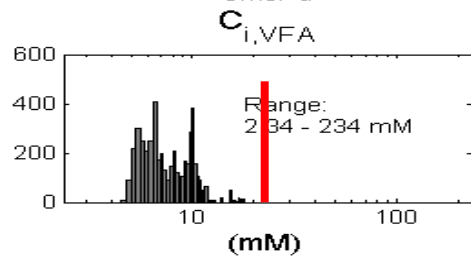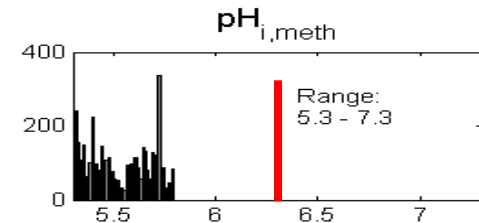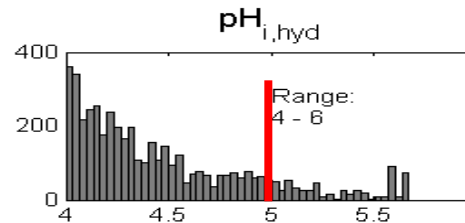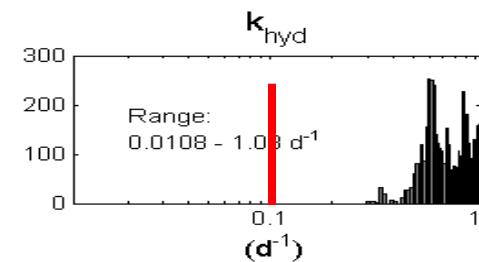
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The biochemical grey model
(logarithmic scales)
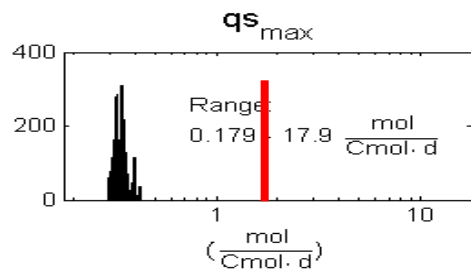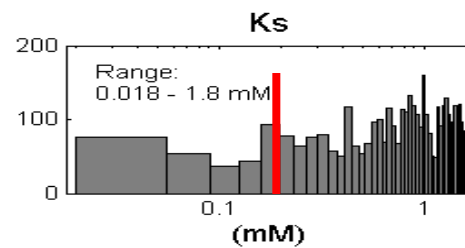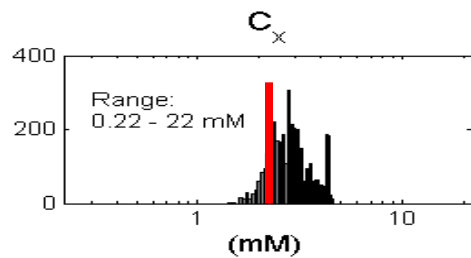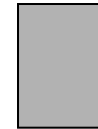
How do we model MSW

Conclusion & Outlook

Lab, Column & Pilot scale experiments

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Lab, Column & Pilot scale experiments

Extend model for other cases like;

SO4 oxidation, recirculation, aeration, Anammox, humic acids, mass transfer limitation, slow hydrolyzing substrates….

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Use modelled pH to predict metal/salt complexation

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Couple models to hydrological model
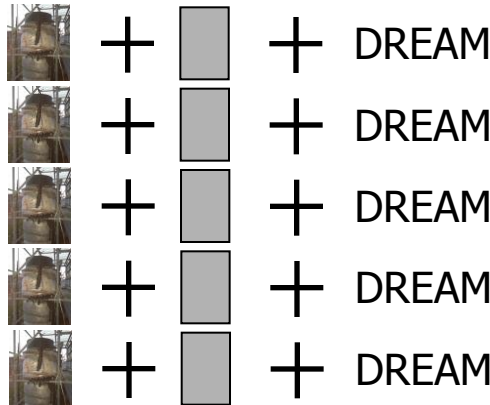
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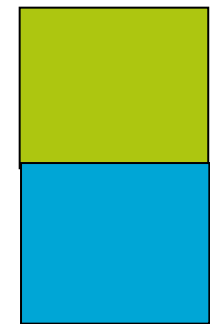TUDelft

How do we model MSW

Conclusion & Outlook

Test different scenarios

Create grey model per case

Combine

1. Irrigation/Recirculation
2. Aeration
3. 1 & 2 intermittent
4. 1 & 2 continuous
5. Nothing

+ ☐ + DREAM
+ ☐ + DREAM
+ ☐ + DREAM
+ ☐ + DREAM
+ ☐ + DREAM

Combined Bio-Transport model

Questions