University of Liège – Department ArGEnCo

2014 – 2015

Numerical modeling of the long term behavior of Municipal Solid Waste in a landfill

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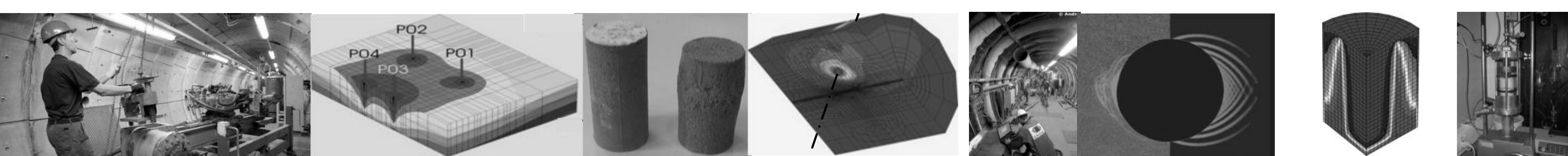
Promoteur : Frédéric Collin

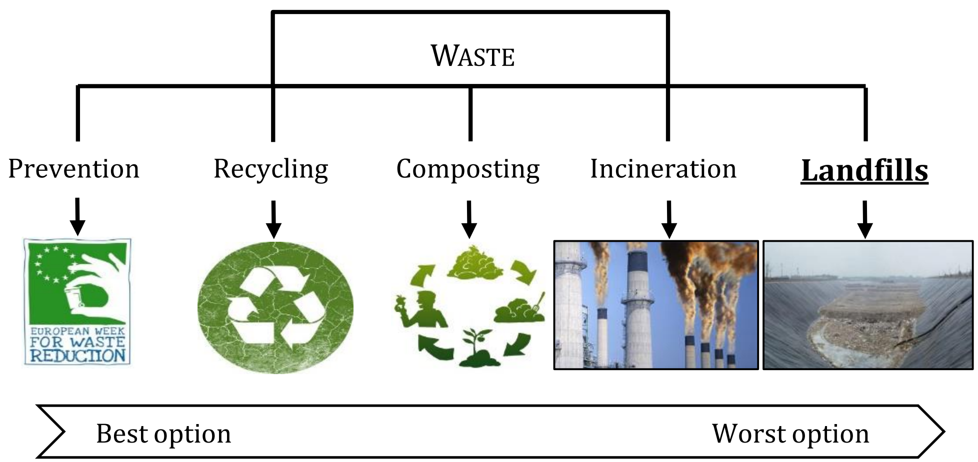


SUMMARY OF THE PRESENTATION

- Introduction to the waste management issue
- THBCM multi-physics model
  - Hydraulic model
  - Bio-chemo model
  - Thermal model
  - Mechanical model
- Test simulation and results
- Conclusion

Waste management issue

- Waste production $\nearrow \begin{cases} \text{Demographic explosion} \\ \text{Over} - \text{Consumption} \end{cases}$
- It has to be taken care of :



- One of the key point of the waste management issue
- Objective : optimal post closure management

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HYDRAULIC MODEL

- MSW behave like an unsaturated soil :

$$\frac{\partial\left(\rho_w n S_{r,w}\right)}{\partial t} + div\left(\rho_w \underline{f_w}\right) = Q$$

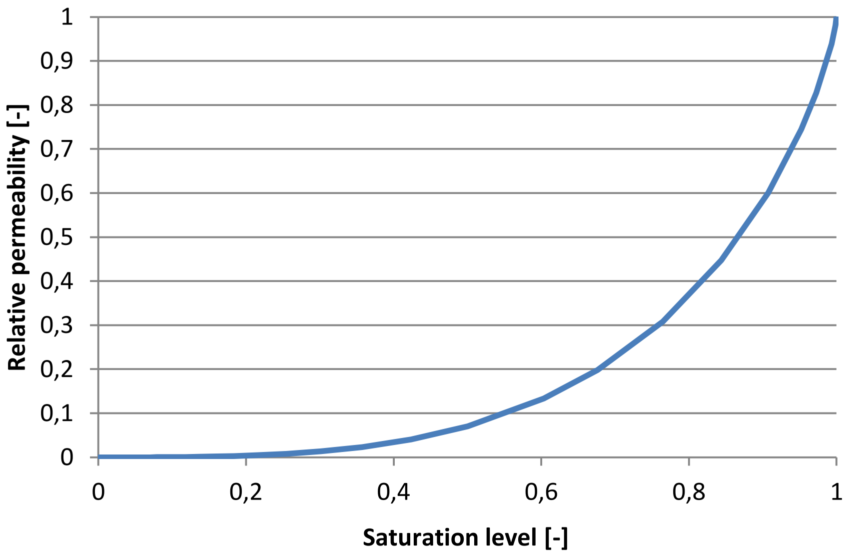
$\underline{f_w}$ is the Darcy's flow given by the following equation:

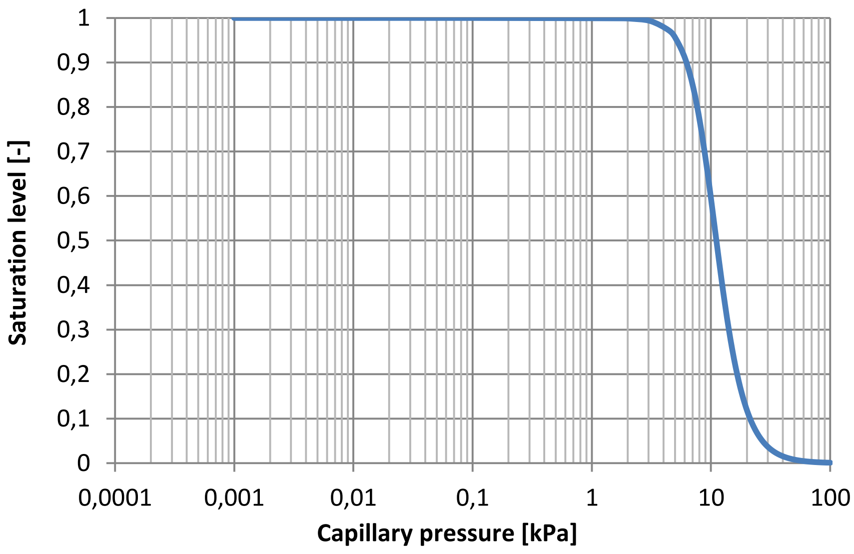
$$\underline{f_w} = -\frac{k_w\left(S_{r,w}\right)}{\mu_w}\left(grad(p_w) + \rho_w . g . grad(y)\right)$$

HYDRAULIC MODEL

Relative permeability and water retention curves (van Genuchten):

Relative permeability	Water retention
$k_{rel} = \sqrt{S_{r,w}}\left[1-\left(1-S_{r,w}{}^{\frac{1}{mvG}}\right)^{m_{vG}}\right]^2$	$S_{r,w} = S_{res} + (S_{sat} - S_{res})\left[\left(1+\frac{p_c}{\alpha}\right)^{n_{vG}}\right]^{-m_{vG}}$

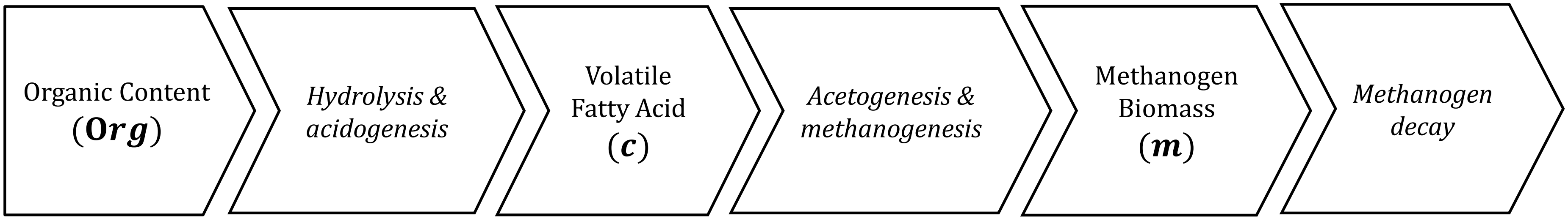




Bio-Chemical Model

- Can be split into two main stages :
  - Aerobic stage $\Longrightarrow$ neglected
  - Anaerobic stage

It is assumed it can be simplified :



Bio-Chemical Model

- McDougall's formulation:
  - Hydrolysis and acidogenesis

$$r_g = b\theta_e\phi P$$

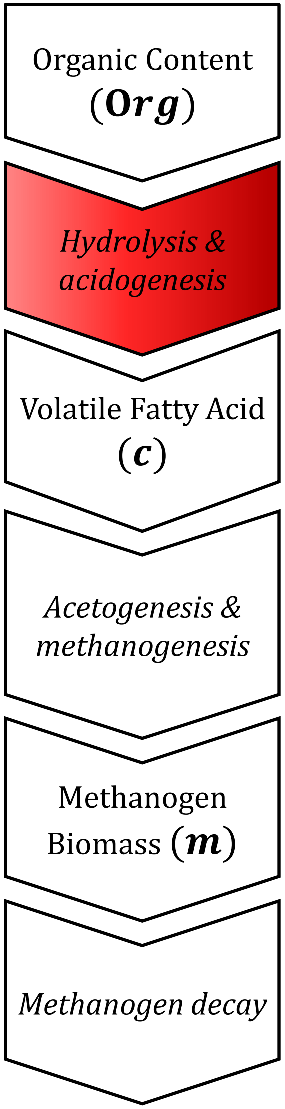
  - Acetogenesis and methanogenesis

$$r_j = \frac{k_0 c}{k_{MC} + c} m$$

$$r_h = \frac{r_j}{Y}$$

  - Methanogen decay

$$r_k = k_2 m$$



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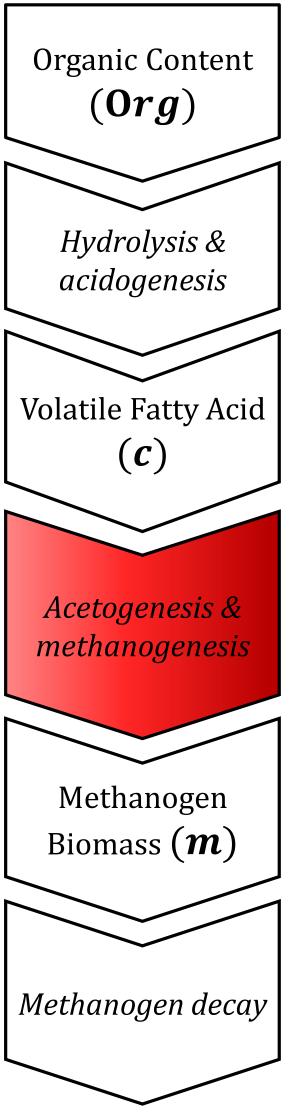

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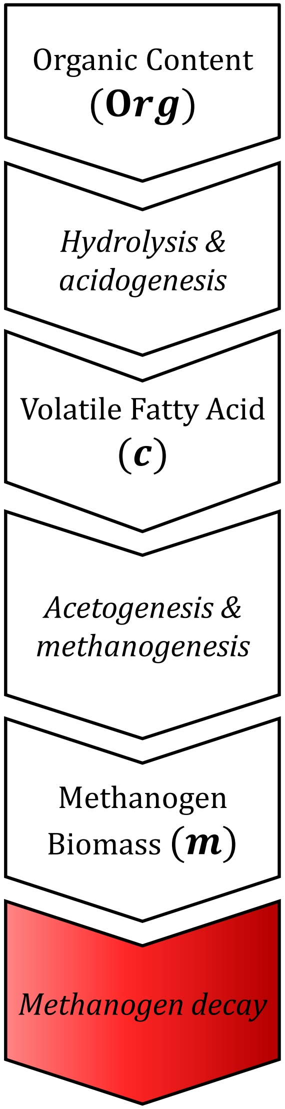


Bio-Chemical Model

- Governing balance equations taking into account transport phenomena :

Variable	Balance equation
Organic Matter (***Org***):	$-\theta Z r_g = \frac{\partial Org}{\partial t}$
VFA (***c***):	$div(u.c\ ) - div(D_h \nabla c) + [r_g - r_h] = \frac{\partial c}{\partial t}$
MB (***m***):	$div(u.m\ ) - div(D_h \nabla m) + [r_j - r_k] = \frac{\partial m}{\partial t}$

Thermal model

- The degradation of the organic matter is an exothermal reaction
- Classical heat storage and diffusion model :

$$\dot{S}_T + div(V_T) - Q = 0$$

$$V_T = -\Gamma \, \nabla T + c_{p,w} \rho_w \underline{f_w} (T - T_0)$$

- Heat generation term based on the variation of the organic content :

$$Q = \frac{\Delta Org(t)}{\Delta t} Q_m$$

Mechanical model

- The degradation of the organic matter is going to modify the mechanical properties of the MSW

- Chemo-Hydro-Mechanical model introduced by Liu *& al*

$$\dot{\varepsilon}_{ij} = \dot{\varepsilon}_{ij}^{e} + \dot{\varepsilon}_{ij}^{p}$$

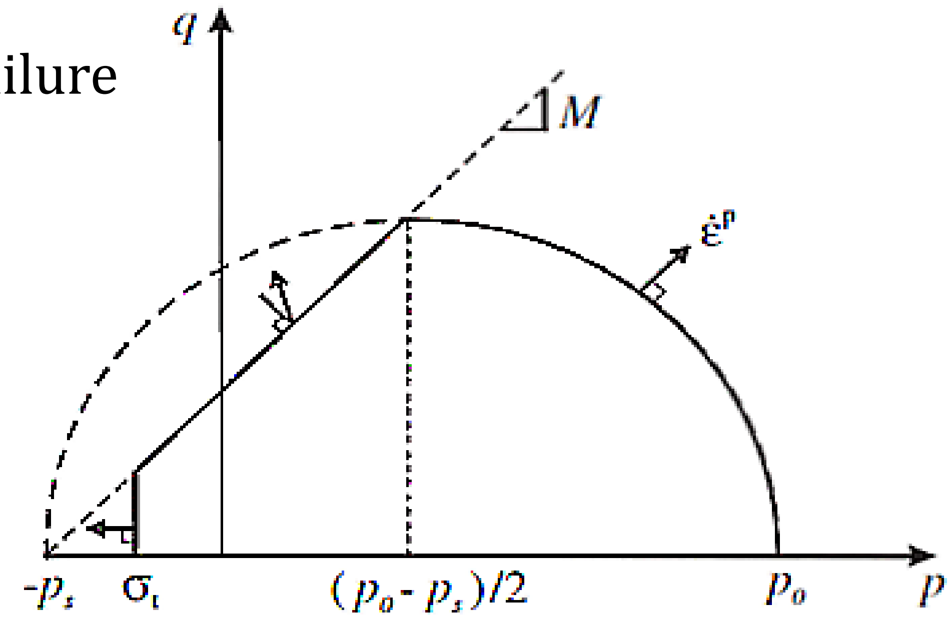
  - Classical elastic stress-strain relationship

  - The plastic strain rate is defined within the boundaries of the yield criterion:

$$f(\sigma_{ij}, \kappa) \leq 0$$

Mechanical model

- Three plastic yielding mechanisms are implemented into the CHM:
  - pore collapse
  - frictional-cohesive failure
  - tensile failure



Mechanical model

- The degradation of the organic matter induces hardening/softening :
  - "Concentration" parameter :

$$\alpha = 1 - \frac{Org}{Org_0}$$

  - Effect of the concentration on the yield surface:

$$p_0(\alpha) = p_0^* S(\alpha)$$

$$p_s = p_s^* + k_{OC}\alpha$$

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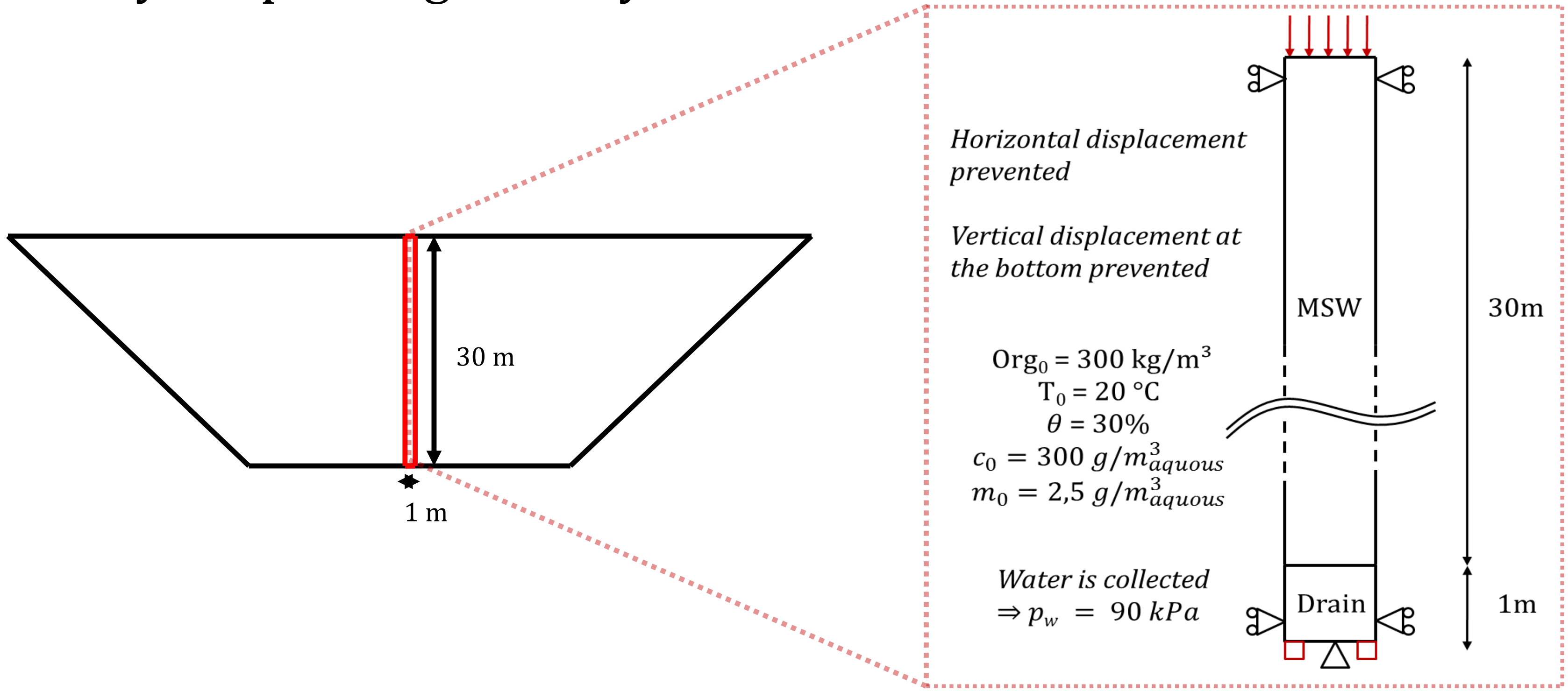
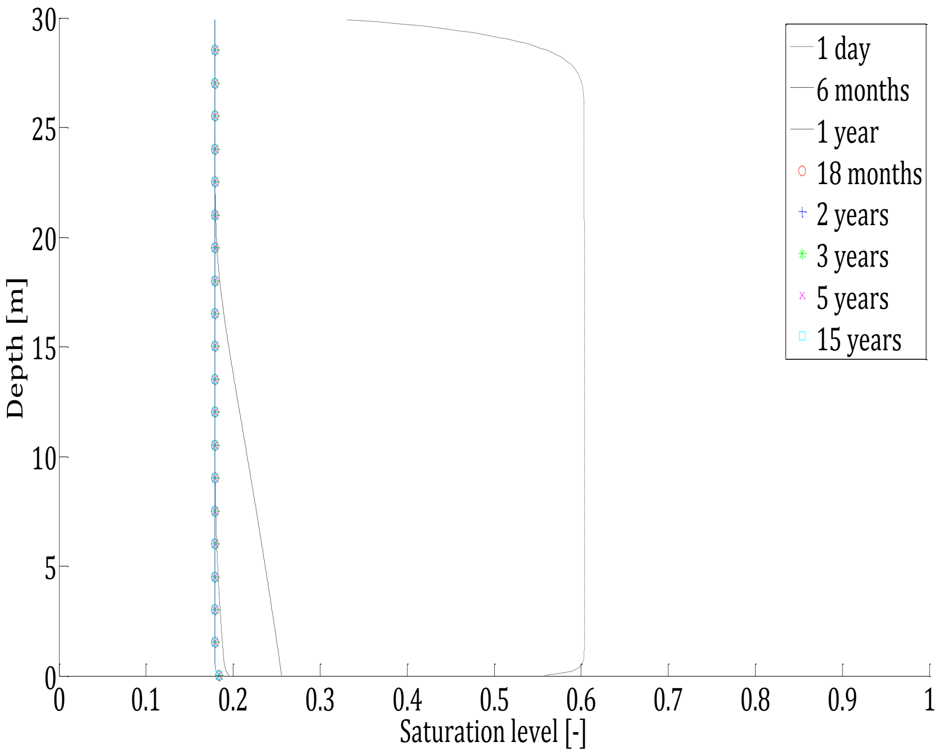
Geometry and initial/boundaries conditions

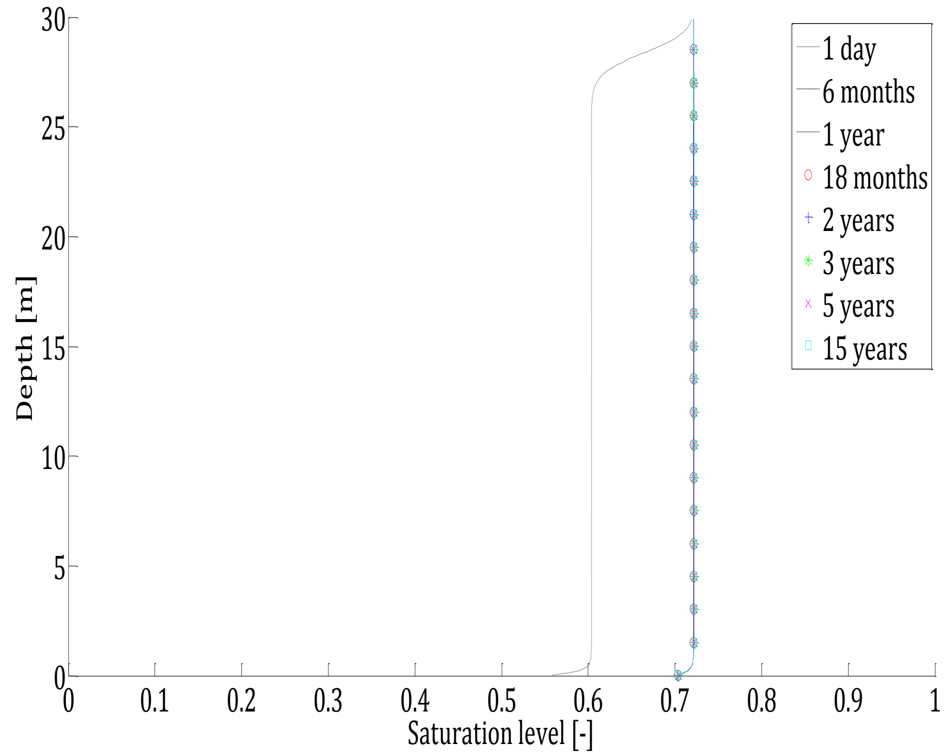
- Goal : Assess the performance and validity of the model
- Very simple 1D geometry



Hydraulic results

$Q = 2{,}5 * 10^{-8} m^3/s$ Injected water flux $Q = 2{,}5 * 10^{-6} m^3/s$





Hydraulic parameters based on *Manassero & al (1996)* ; *Olivier & al (2007)* ; *Staub & al (2009)* and *Feng & al (2014)*

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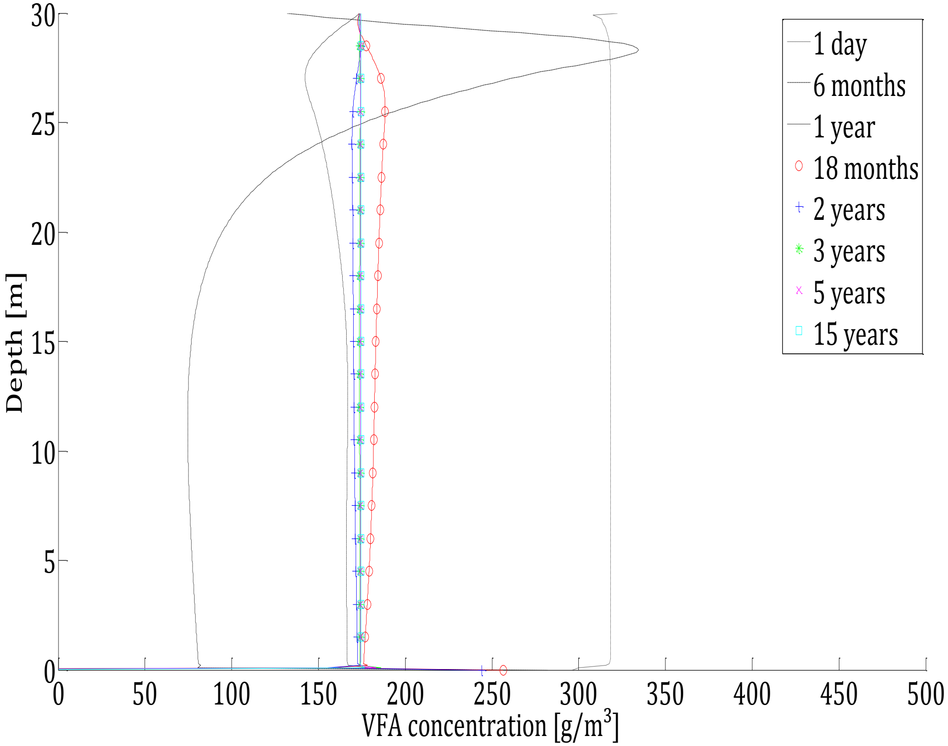

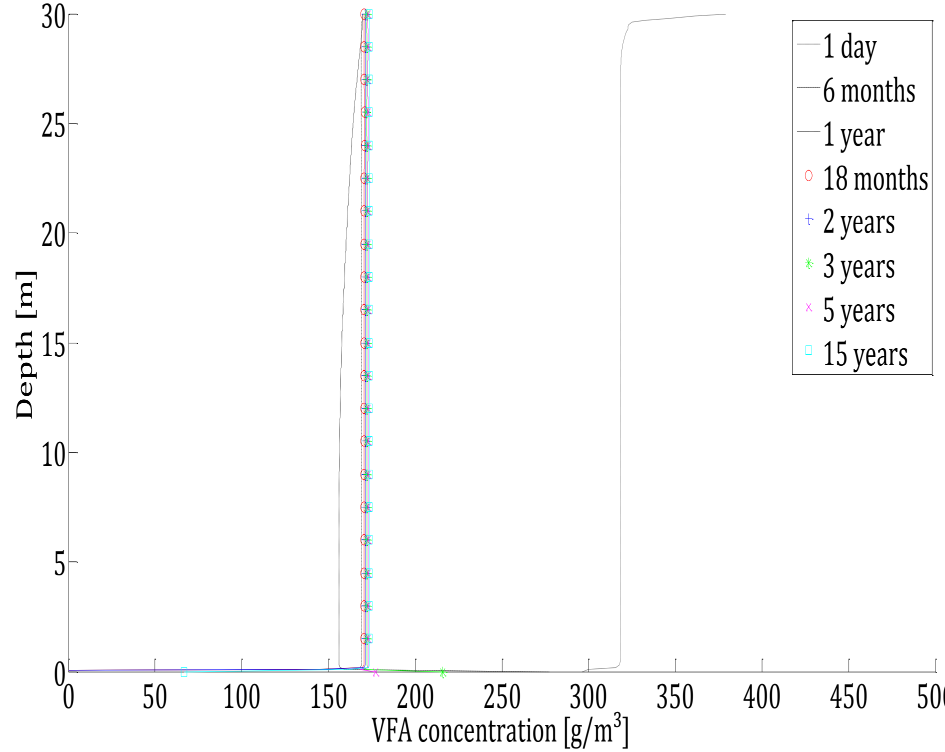

Transport parameters based on *Domenico & al* (1998) *and Cooke & al* (2008). Biodegradation parameters based on *McDougall* (2007)

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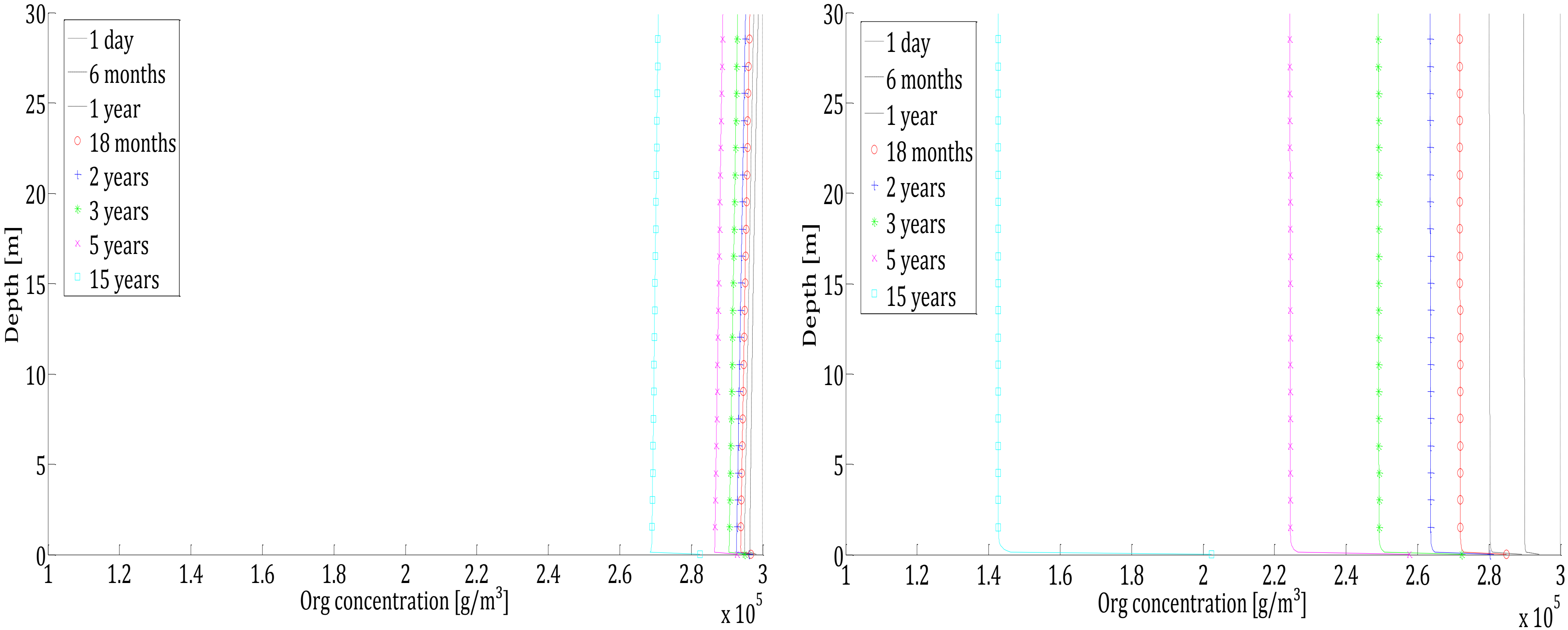

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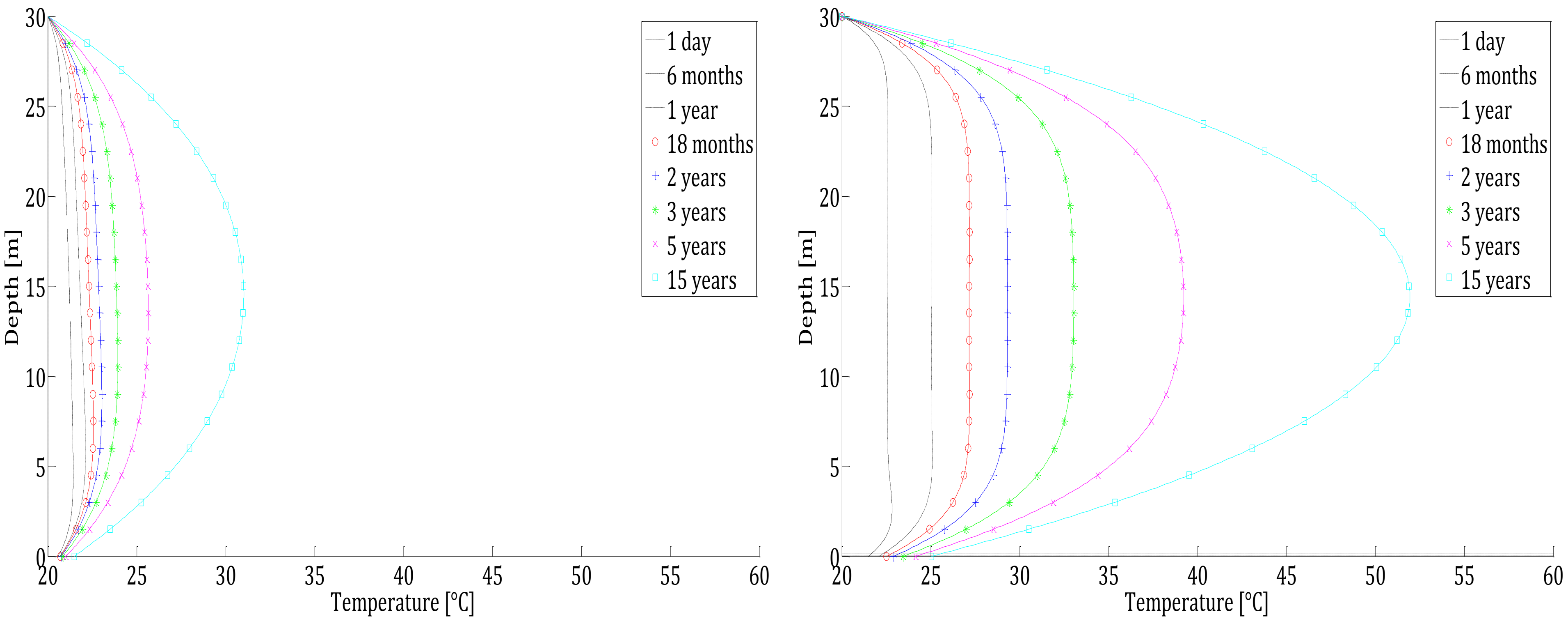

Heat transfert parameters based on *Yoshida & al* (1999) and heat production parameters based on *Boukpeti & al* (2004)

Mechanical results

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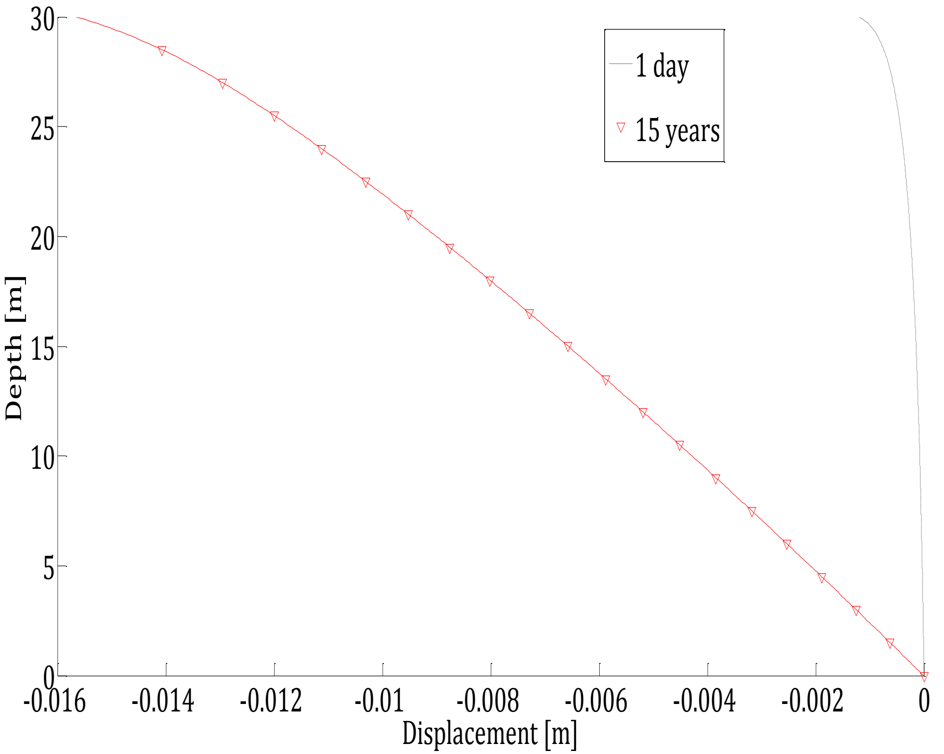
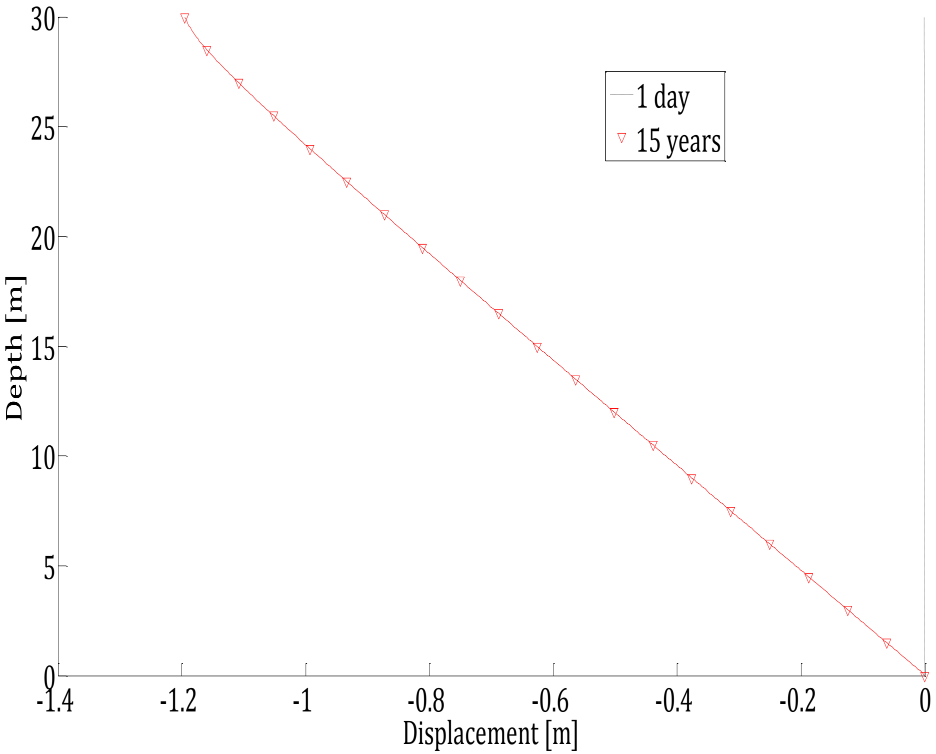
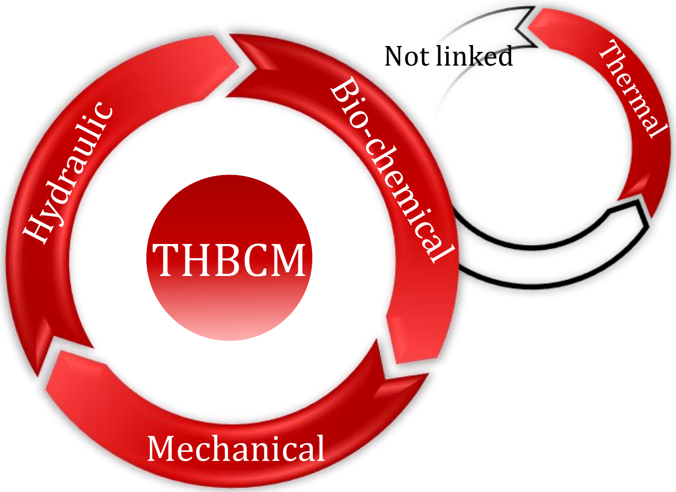




Conclusion

- Results linked to the hydraulic equilibrium reached
- Can work on any given geometry
- Thermal model not fully linked



- Effective to assess settlements
- Effective tool for pollution potential evaluation

Questions