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Evaluation of the relative importance of microbial reactions on organic matter removal in horizontal subsurface flow constructed wetlands treating wastewater rich in nitrates: CWM1-RETRASO simulation results

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Treatment wetlands and modelling

- Large number of physical, chemical and biological processes in parallel + influence each other

- Understanding of CW is very difficult

- Experiments needed for CW understanding are complex and need hard work (and large amount of money!)

- Numerical modelling constitutes a tool that can help to bypass these problems

  - Allows predictions (and provides hypotheses that can be tested by direct experiments)
  - In the future design will be done based on these models

- Development of mechanistic models of SSF CWs relatively new (from approximately 2000)

OBJECTIVE OF THIS STUDY

Evaluation of the relative contribution of the microbial reactions considered in the CWM1-RETRASO model on organic matter removal in HSSF CWs treating high-nitrate wastewaters

- New knowledge in order to understand the performance of HSSF CWs function (in this case mainly in terms of biokinetic reactions)

- This study is a very first step, by which the theoretical performance of the model is checked

Simulation model

CWM1 + **RETRASO CodeBright** = **2D simulation CWM1-RETRASO**

RCB
(REactive TRAnsport of SOlutes)

Biochemical processes

Flow properties
Reactive transport

19 kinetic reactions
17 components

CWM1-RETRASO characteristics

- Based on mass balance equations

$$\frac{\partial C}{\partial t} = -q\nabla C + \nabla(D\nabla C) + r$$

Advective term

Diffussive-dispersive term

RCB

CWM1

Implementation of CWM1's biochemical processes

COUPLING

Kinetic reactions considered in CWM1

- Hydrolysis by heterotrophic and fermenting bacteria
- Growth and lysis of:
  - heterotrophic bacteria (aerobic/anoxic conditions)
  - autotrophic nitrifying bacteria
  - fermenting bacteria
  - acetotrophic, methanogenic bacteria
  - acetotrophic, sulphate reducing bacteria
  - sulphide oxidizing bacteria (aerobic/anoxic conditions)

Modelling considerations

- Considered: - physical oxygen transfer from the atmosphere to the water
- Not considered: - oxygen leaking from macrophytes
  - suspended solids accumulation (clogging)

Data from

- An HSSF CW located in a pilot plant in Les Franqueses del Vallès (province of Barcelona)

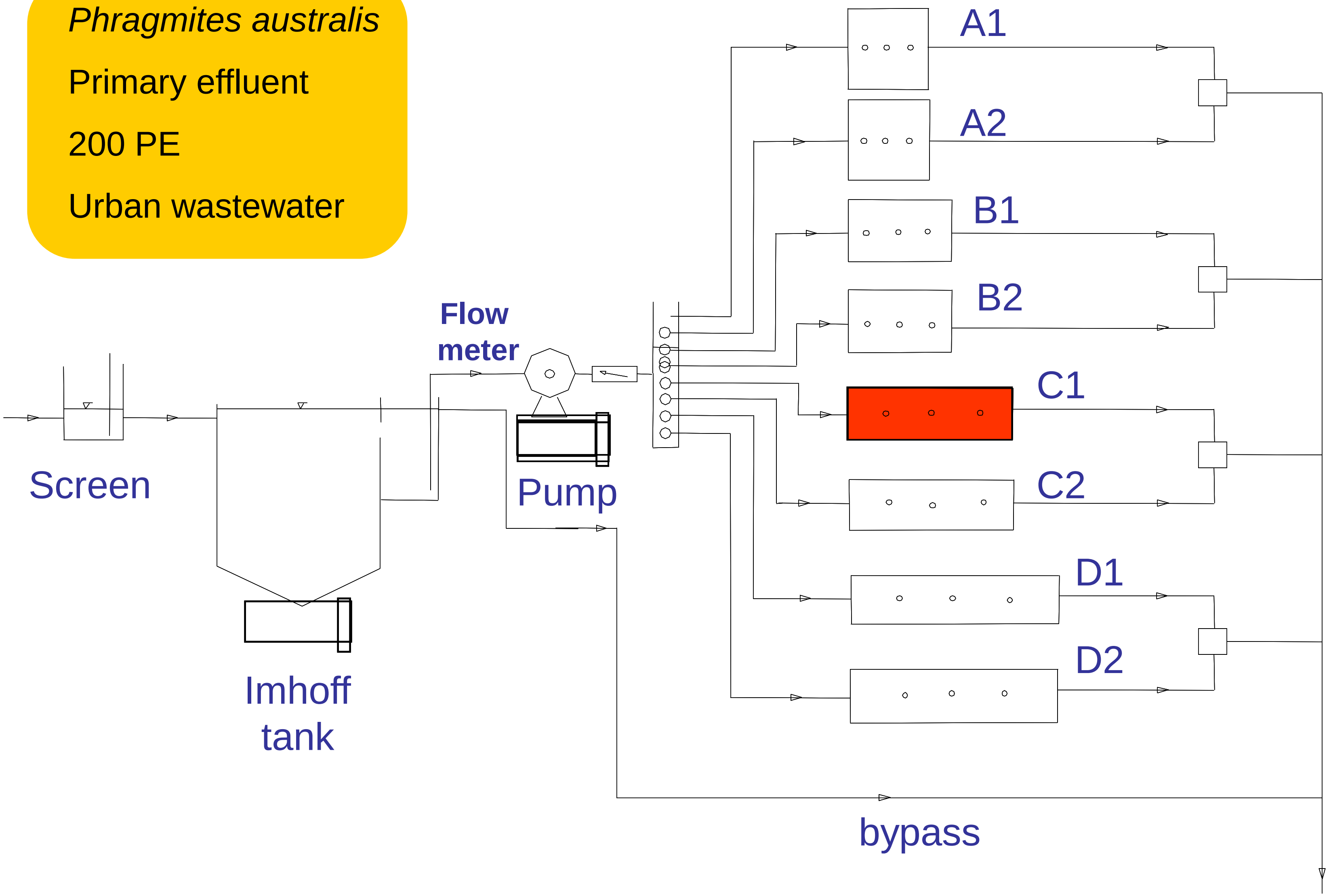
Technical characteristics of the wetland

Phragmites australis

Primary effluent

200 PE

Urban wastewater



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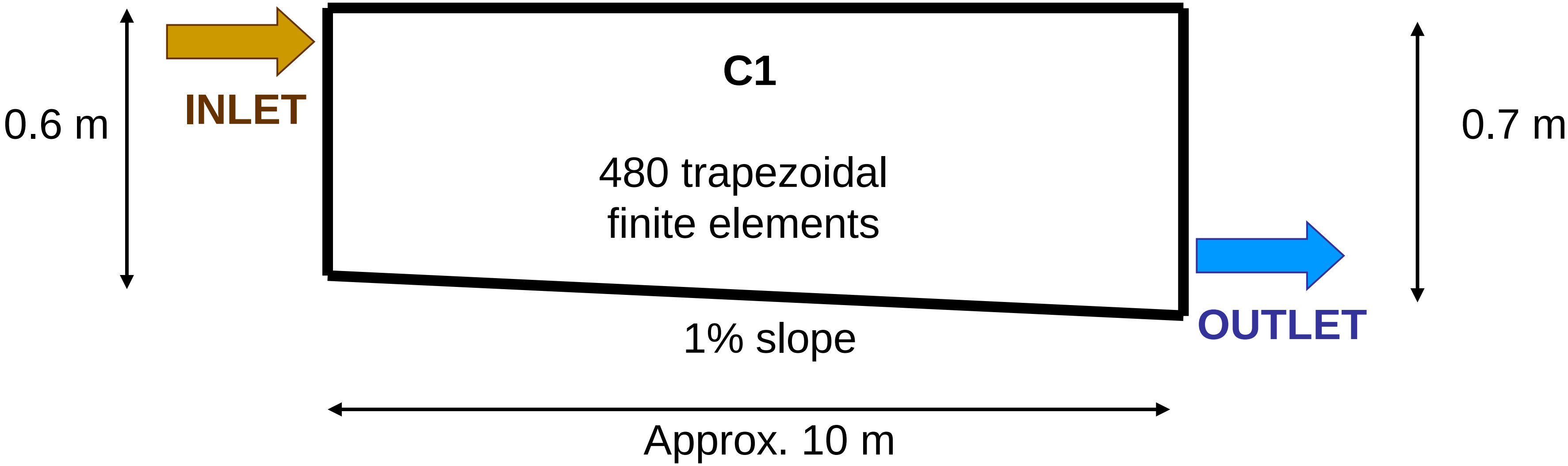
Mesh dimensions



WETLAND C1

Aspect ratio 2:1

Water depth = 0.5m

Coarse gravel (D60 = 3.5mm; Cu=1.6)

Initial porosity = 41%

Influent composition of the scenarios

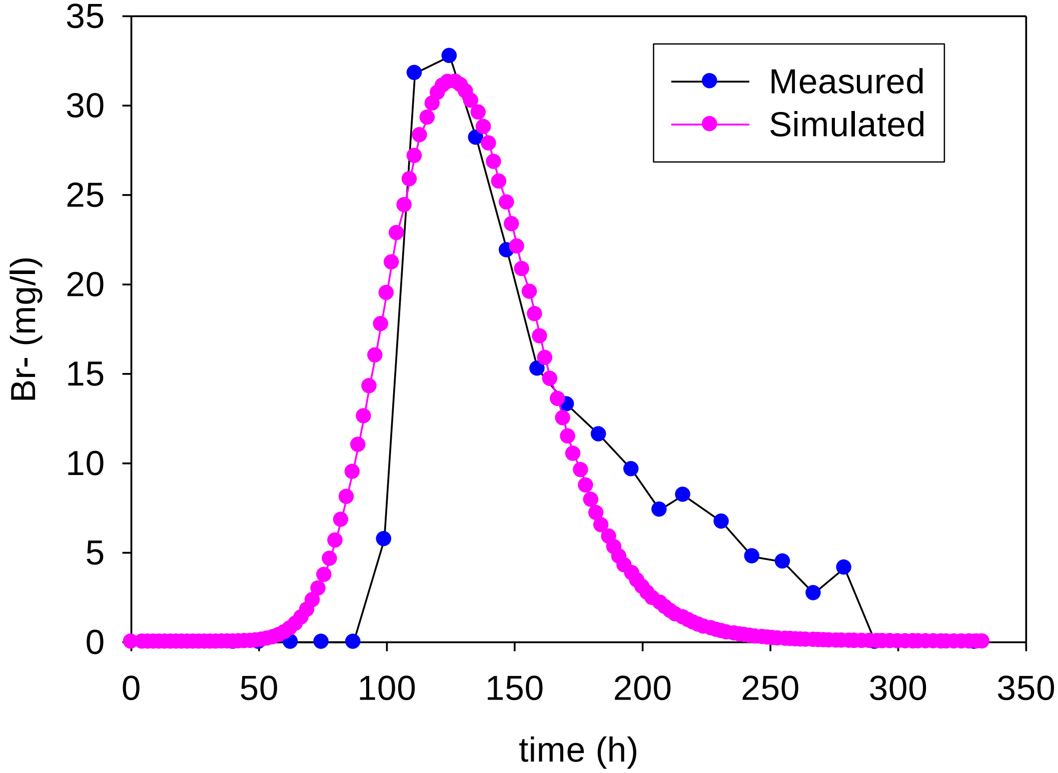
Theory-based cases (6, 7)

Real cases: urban / plant nursery irrigation (8, 9)

Scenarios / Components [units]	1	2	3	4	5	6	7	8	9
S_O [mg O_2/ L]	0.86	0.86	0.86	0.86	0.86	0	0	0	0
S_F [mg O_2/ L]	115	227	0	0	170	195	0	23	3
S_A [mg O_2/ L]	0	0	0	115	27	0	195	6	3
S_I [mg O_2/ L]	0	0	0	0	13	0	0	3	1
S_{NH} [mg N/ L]	0	14	0	0	57	0	0	9	1
S_{NO} [mg N/ L]	0	0	0	0	0	12	12	12	4
S_{SO4} [mg S/ L]	0	0	0	5	35	0	0	47	0
S_{H2S} [mg S/ L]	0	0	0	0	0	0	0	0	0
X_S [mg O_2/ L]	0	0	115	0	33	0	0	26	13
HLR [mm/d]	20	20	20	20	36	20	20	20	20

E. Llorens, M. W. Saaltink, M. Poch, J. García. 2011. *Bioresource Technology* 102, pp. 928-936.

Simulation of hydraulic behaviour: tracer response curve



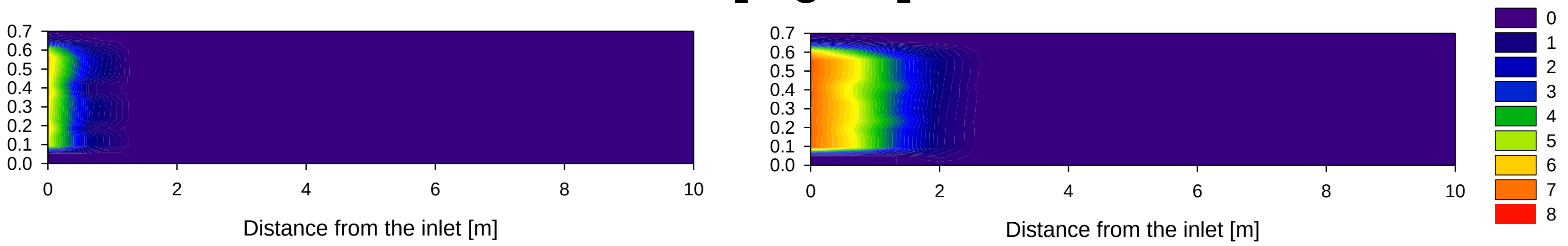
Q= 2 m^3/d
HLR= 36 mm/d

Simulated changes along the length of the wetland

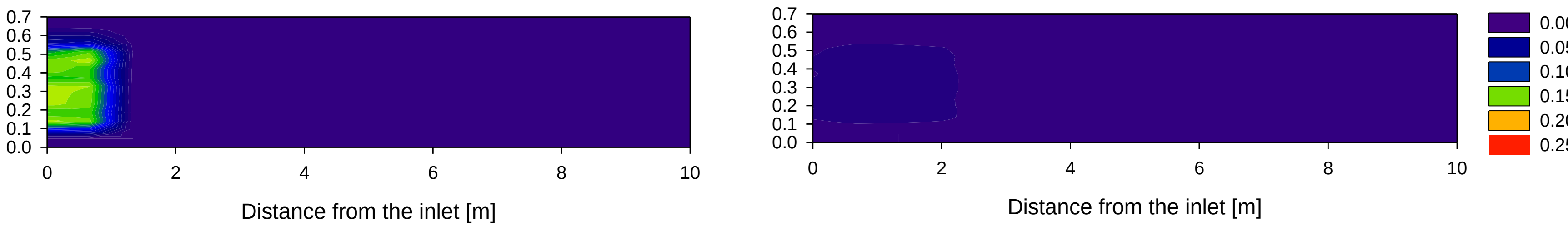
(process rate units= mol substrate/ 8.4 E5 s · kg water)

Scenario 6, COD= S_F | **Scenario 7, COD= S_A**

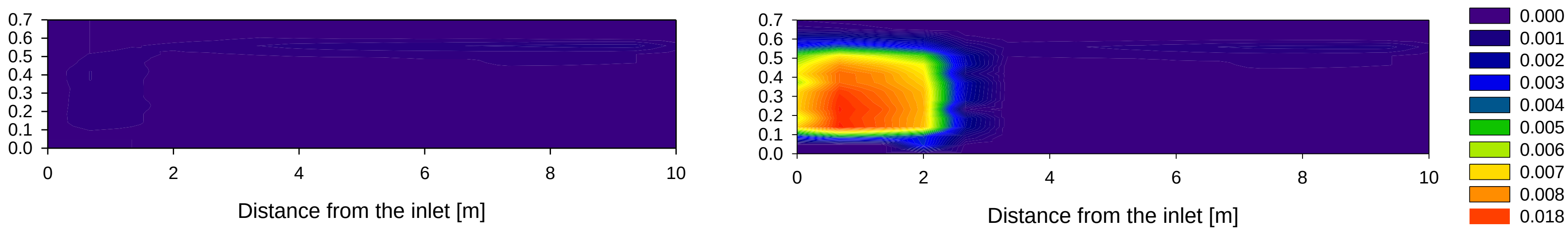
NO3-N [mg N/l]



Anoxic growth X_{HF} on S_F



Anoxic growth X_{HA} on S_A



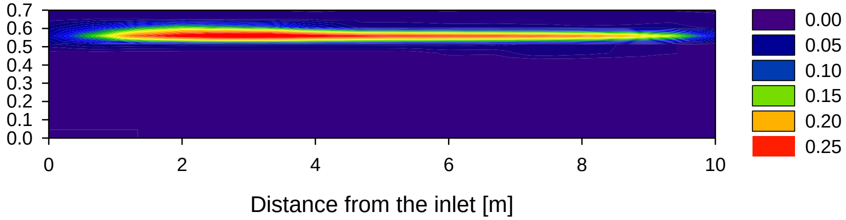
Simulated changes along the length of the wetland

(process rate units= mol substrate/ 8.4 E5 s · kg water)

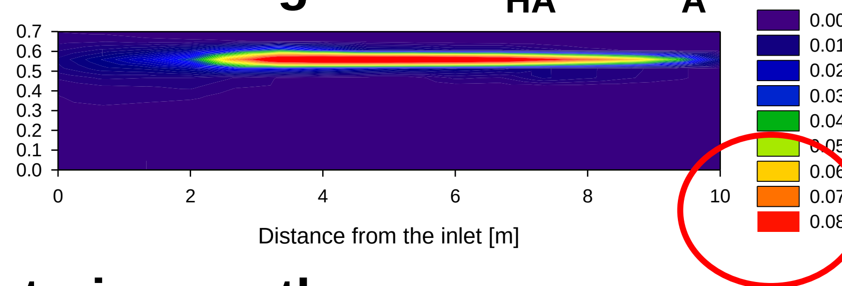
Scenario 6, COD= S_F

Scenario 7, COD= S_A

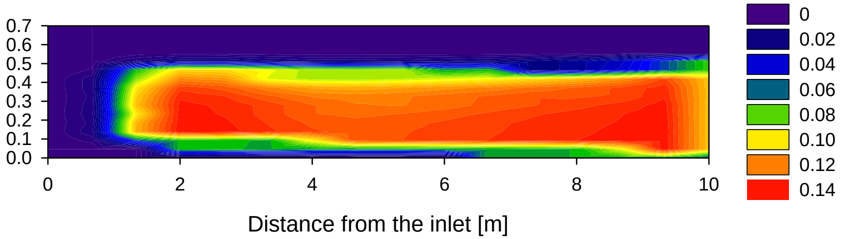
Aerobic growth X_{HF} on S_F

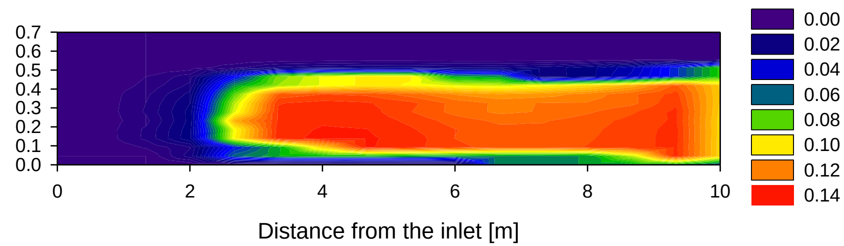


Aerobic growth X_{HA} on S_A

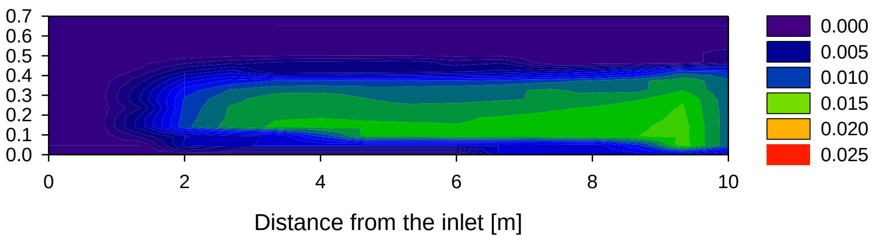


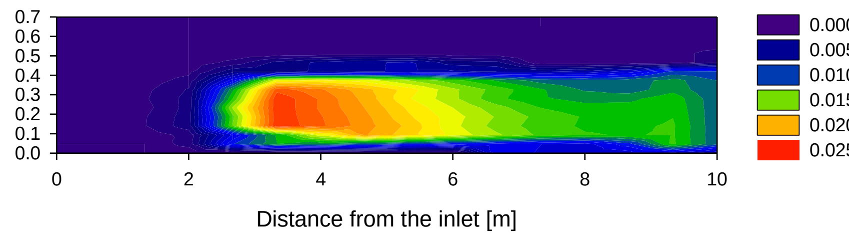
Fermenting bacteria growth





Methanogenic bacteria growth



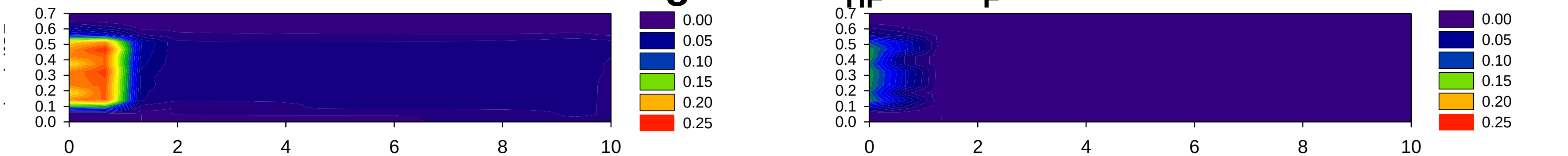


Simulated changes along the length of the wetland

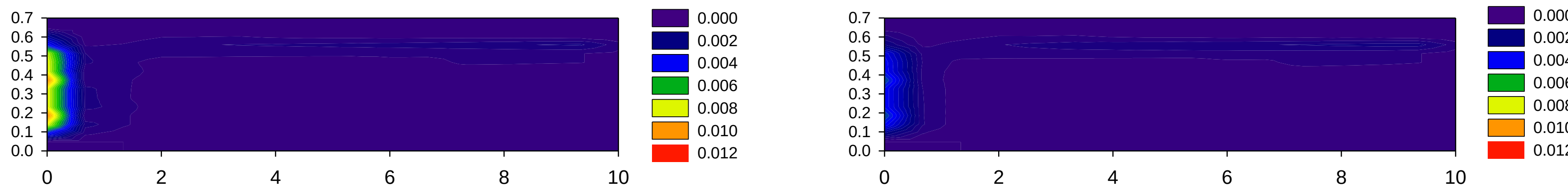
(process rate units= mol substrate/ 8.4 E5 s · kg water)

Scenario 8, VSSF CW effluent | **Scenario 9, plant nursery irrigation** (more diluted)

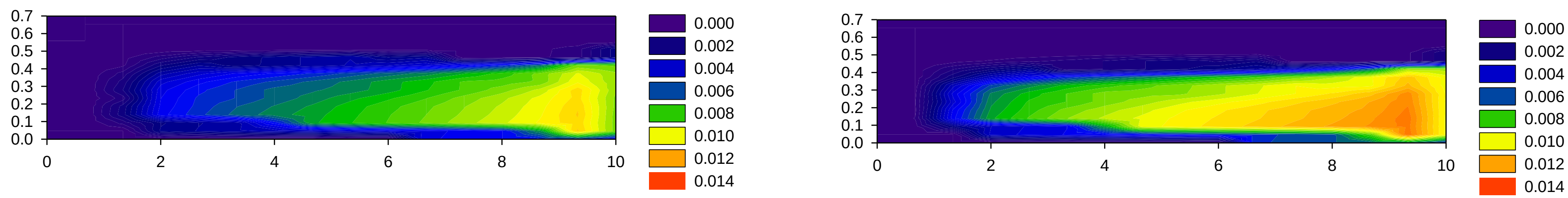
Anoxic growth X_{HF} on S_F



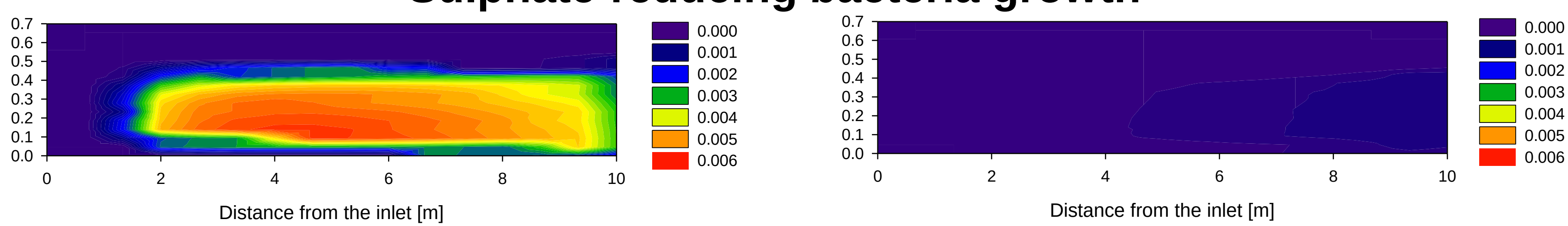
Anoxic growth X_{HA} on S_A



Methanogenic bacteria growth



Sulphate-reducing bacteria growth



Relative importance of the different microbial reactions on COD removal

Theory-based cases (6, 7)

Real cases: urban / plant nursery irrigation (8, 9)

Scenarios / Percentage [%]	1	2	3	4	5	6	7	8	9
Aerobic growth X_{HF}	22.59	20.47	20.93	13.70	15.99	20.36	13.08	18.78	20.75
Anoxic growth X_{HF}	0	0.90	0.98	0.62	0.71	6.87	1.75	18.42	4.45
Aerobic growth X_{HA}	6.26	6.28	6.11	6.69	6.60	5.38	7.27	3.51	5.60
Anoxic growth X_{HA}	0.13	0.13	0.13	0.11	0.12	0.12	1.43	0.29	0.25
Growth of X_{AMB}	72.15	71.43	70.97	73.32	58.17	66.49	75.72	46.10	68.04
Growth of X_{ASRB}	0.87	0.79	0.88	5.56	18.41	0.77	0.75	**12.89**	0.91
Aerobic processes	26.85	26.75	27.04	20.39	22.59	25.74	20.35	22.30	26.35
Anoxic processes	0.13	1.03	1.11	0.73	0.83	**7.00**	**3.18**	**18.71**	4.7
Anaerobic processes	73.02	72.22	71.85	78.88	76.58	**67.26**	**76.47**	58.99	68.95

CONCLUSIONS

1. CWM1-RETRASO demonstrated to be the first model to simulate successfully the processes described in CWM1 when high-nitrate concentrations.

2. Different simulations have proved the importance of anaerobic reactions in horizontal wetlands, which match well with experience from field experiments.

3. There are some problems with RETRASO: 1) bacteria travel through the wetland with the water flow (biofilm development is not possible to be simulated) and 2) lack of guide for users. We are now moving to another more easy reactive transport softwares.

4. CWM1-RETRASO (as other models) does not include solids entrapment, biofilm development, plant uptake, evapotranspiration, how hydraulic conditions change in time and space, etc. All these things represent a huge work and people working in modelling is very low. We need more researchers in this field. This will allow us to make great advances in CW knowledge.

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THANKS
FOR YOUR ATTENTION

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