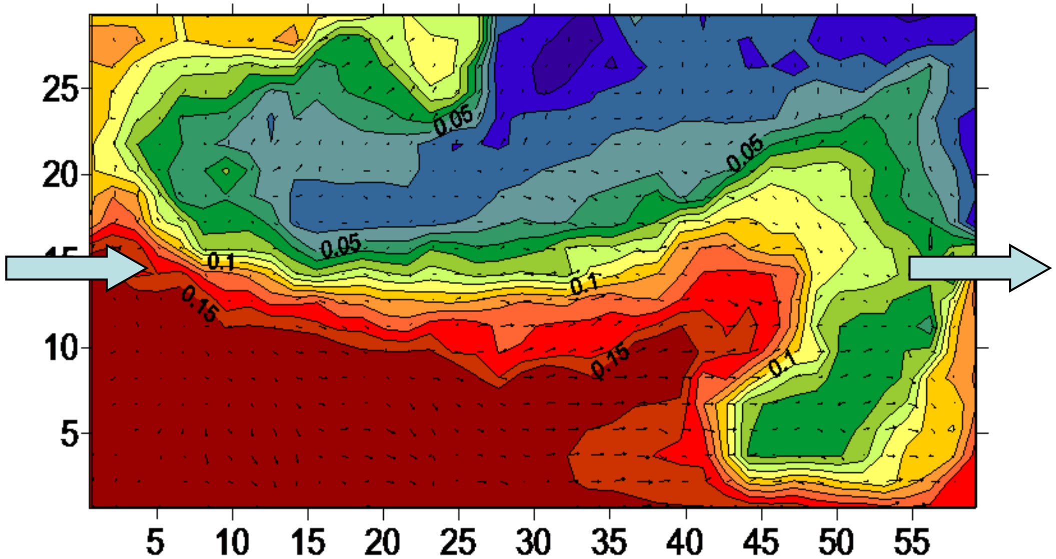
CFD modeling and Simulation

Round Table

bottom



Gerardo Aldana
Francoise Brissaud

8th IWA Specialist Group Conference on Waste Stabilisation Ponds

Principles

- **Expressing, through well established physical laws, all the processes involved in the hydrodynamic pattern.**

- **Solving the Navier-Stokes equation,**

  where water density depends on the temperature

Associated forcings

- Inlet flow rate
- Wind stress (surface boundary condition)

Other factors

- Temperature
- Inlet and outlet shear stress

The velocity field is required

Principles

Solving the temperature advection-dispersion equation

→ temperature field

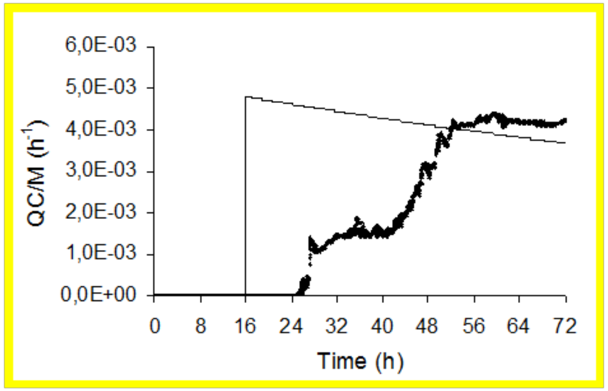
– Associated source terms
  - Solar radiation, latent heat flux, sensible heat flux, net long wave radiation

– Associated forcings
  - Meteorological conditions : solar radiation, wind speed, air humidity, air and water temperatures

The velocity field is required

- Hydrodynamic patterns result of the simultaneous computation of water velocity and temperature fields
  - whatever the pond geometry,
  - given unsteady forcings (meteorological conditions, inlet flow rate)

- Most frequently expected result :
  - water residence time distribution (RTD)
  - Velocities vectors
  - Water quality simulation



CFD modeling is a heavy task

A special grid has to be constructed for each pond geometry, which is time consumming

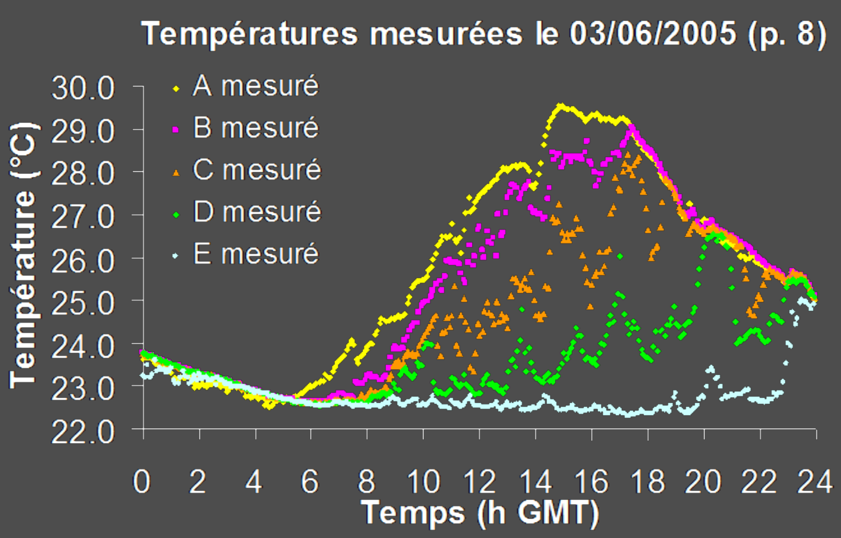
Calibration and validation are always required, which needs appropriate data :

- Tracer tests (monitoring in pond and/or outlet concentrations) ,
- Monitoring water temperature field,
- Physical model
- *Together with simultaneous on site meteorological conditions recording*

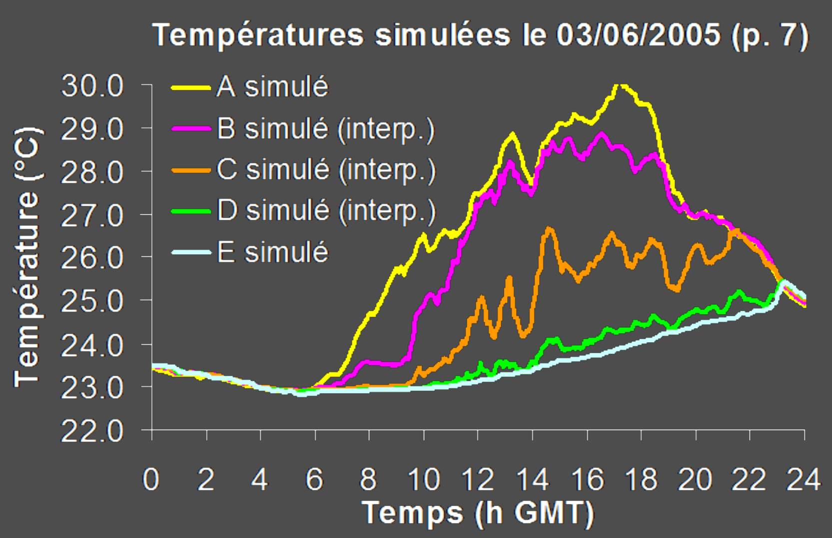
Validation: temperature

June 3rd 2005

Measures

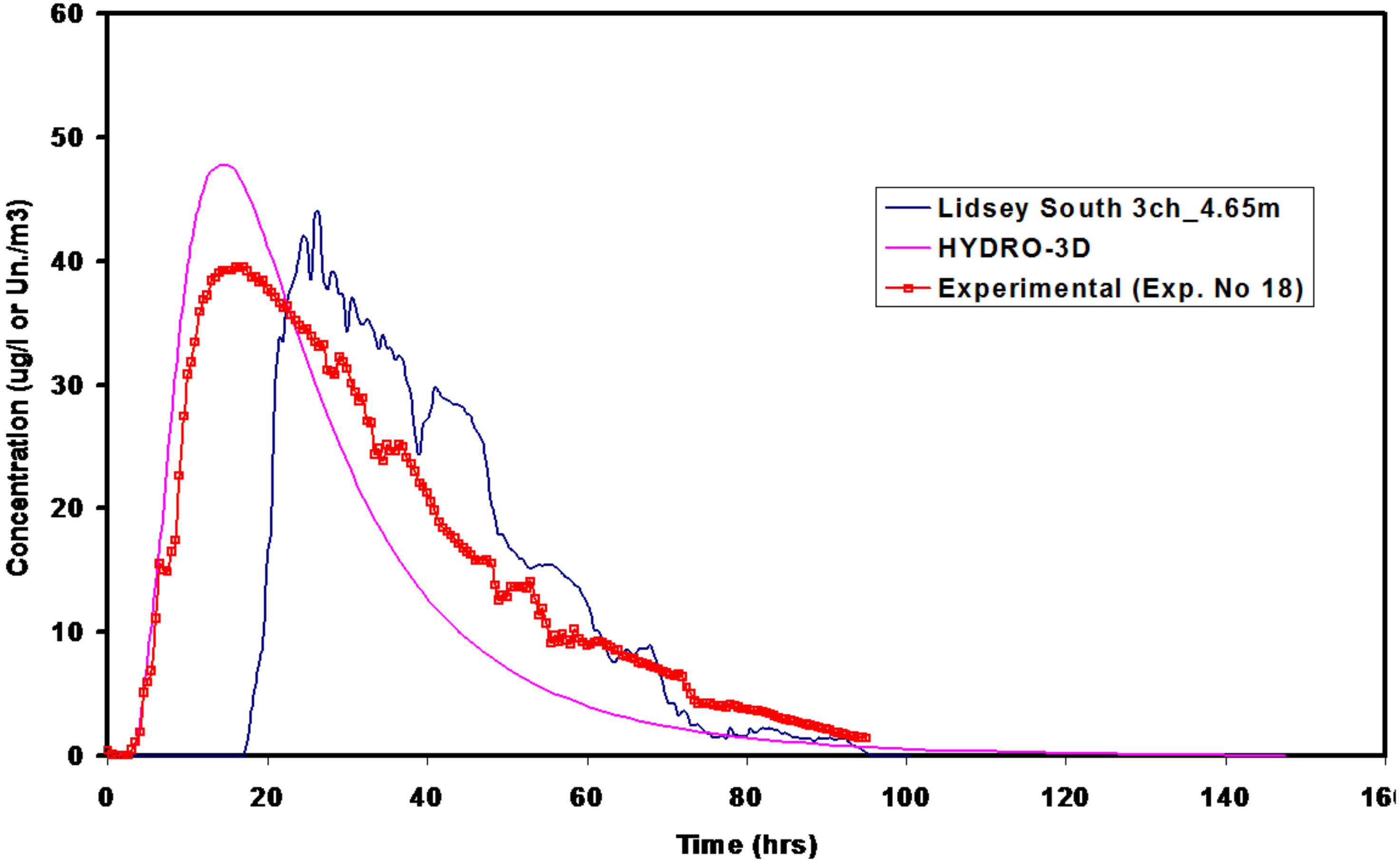


Simulation



A = water surface; B = 0.225 m; C=0.450 m; D =0.675 m; E = 0.9 m.

Agreement between full-scale, experimental and computational methods



CFD modeling is a heavy task

Simulation needs meteorological data records

Simulation is time-consumming

(about 1 day computation for 1 week simulation on a PC)

The result (Residence time distribution) depends on the meteorological conditions and calibration: eddy viscosity

as many meteorological, data series, physic, chemical and bacteriologic data as many outputs.

Description of common systems, processes and parameters studied in hydraulic modelling

Systems	Processes	Model parameters	Simulation parameters
Shallow water	Turbulance flows, tidal currents	Wind drag, density, bed friction, mean water level	Mean ebb and peak tide velocity
Waste stabilisation ponds	Laminar to transition flows, biological, aerobic and anaerobic transformations	Temperature, density, kinematic viscosity, die-off, coefficient dispersion	Concentration level vs hydraulic nominal retention time, current velocities

After Aldana, 2004

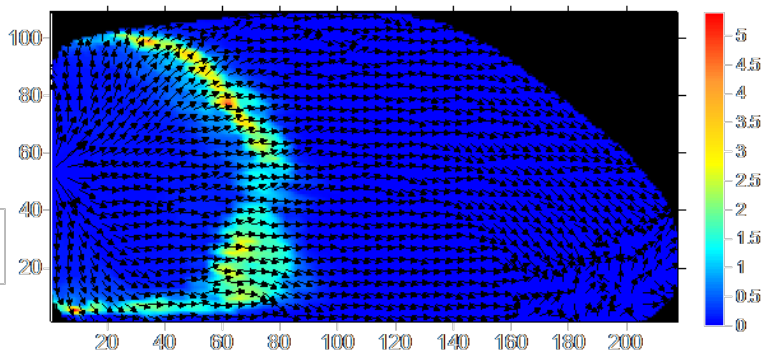
Mixing and transfer processes (2/2)

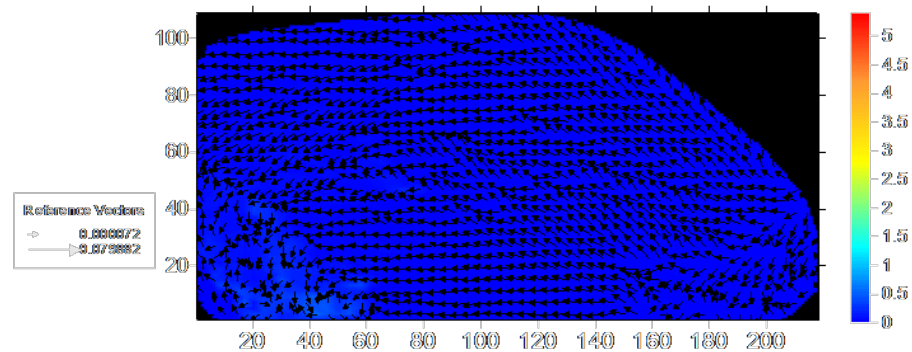
Simulating the transfer of a tracer injected at 16h

bottom, 18/03/2005

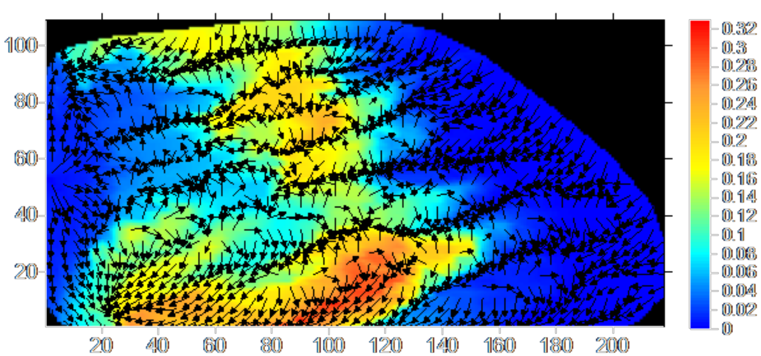
surface, 18/03/2005

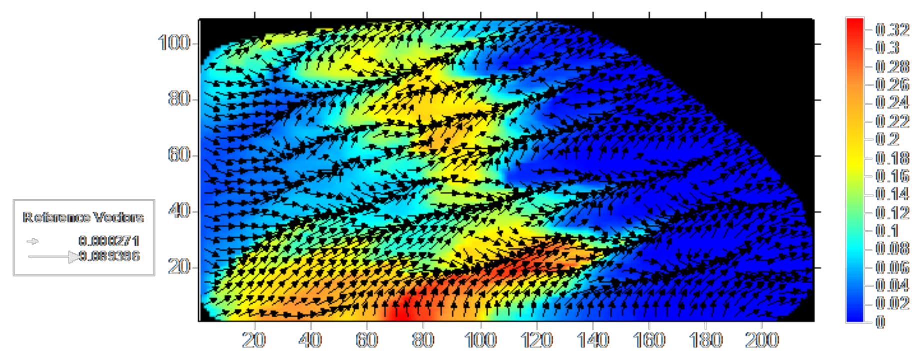
20h





24h





Microbial removal derived from RTD, assuming a die-off constant of 0.6 d^{-1}

	CSTR	DF	Run 1	Run 2	Run 3	Run 4
Injection time			03/18/2005 08:00 am	03/18/2005 04:00 pm	03/31/2005 08:00 am	03/31/2005 04:00 pm
Removal (log)	0.79	1.2	1.09	1.27	0.87	1.13

High wind speed

Lower wind speed

For this pond and the recorded meteorologocial conditions,

-when wind speed exceeds 6 ms^{-1}, → CSTR is an appropriate approximation

- for lower wind velocities, → a Dispersed Flow hydrodynamic regime provides acceptable approximations

Models limitations

The difference between a calibrated and uncalibrated model is that the former at least has an agreement with the full-scale lagoon by using field data to test the computational model.

uncalibrated model: Most of the CFD research to date has been carried out with uncalibrated models (FLUENT 5.5) because it is difficult to get adequate controlled data from full-scale lagoon experiments. The data used for the model validation must be collected during intensive diagnostic field studies.

calibrated model:

A CFD model, HYDRO-3D, has been calibrated with field data collected over two years. Another two years were necessary for further refinement of the computational model and to gain an in-depth understanding of the system.

HYDRO-3D challenges that we had proposed such as delay of the first peak, shape of the profile and MHRT.

What is needed in research with models

Study needs to be carry out to search:

1. Impact of side wind
2. Influence of the bed and wall friction
3. CFD calibration by agreement between full-scale, experimental and computational methods
4. Effect of losses mass on non-conservative tracer

   Exponential adjustment which should be for a decay rate k to correct the discrepancy by using equation throughout the whole experiment at the physical model.

$$F(t) = \frac{f(t)}{e^{-kt}}$$