# Modelling of the integrated urban river system in view of optimisation of river water quality.

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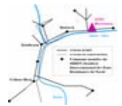
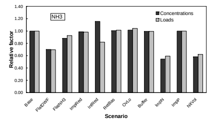
## Presentation Outline









## Introduction: Objectives

- Water Framework Directive
  - Holistic approach
  - « good » chemical and ecological status of natural waters: **Immission crititeria (combined to emission)**

River water quality evaluates the performance of the urban wastewater system

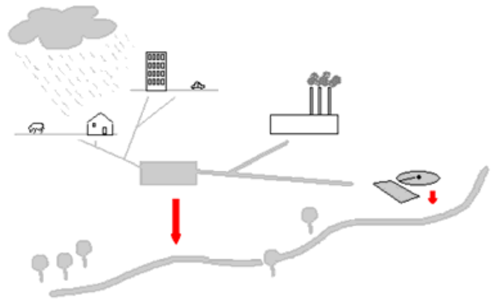
- CD4WC

Cost-effective optimisation of the integrated operation of the sewer and the WWTP for better river water quality



## Introduction: Challenges

- Complexity of the entire system
- Different problematics in subsystems:
  - different variables of interests
  - different modelling approaches
  - different softwares
- Choice of models
- Data availability



**Find appropriate models to fulfil objectives**

## Introduction: Approach

### Objectives: Scenario Analysis

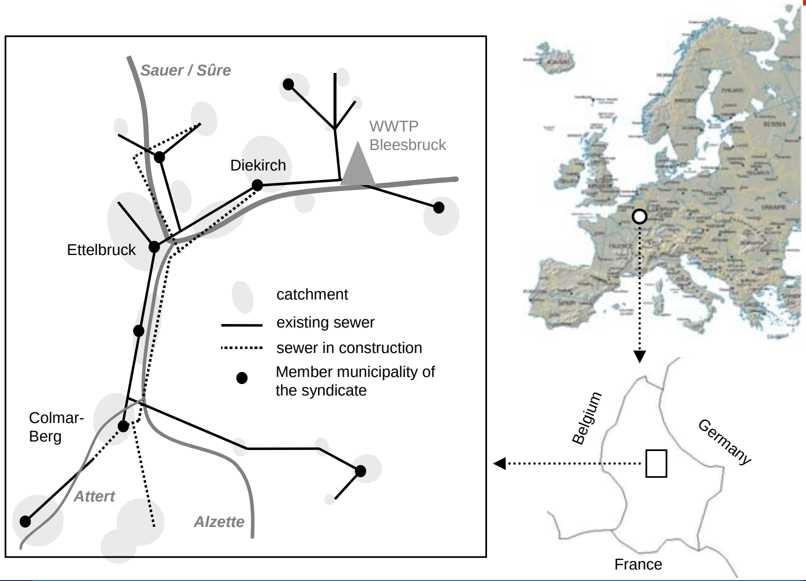
**Case Study**

**Data Collection** | **Model in WEST®**

**Simulations**

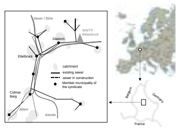


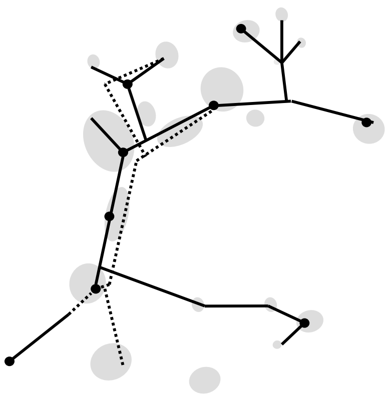
## Case Study: Luxembourg






## Case Study: Catchment





### catchment

~ 10 km²

~ 20 semi-rural subcatchments

Domestic discharges: ~ 25000 PE

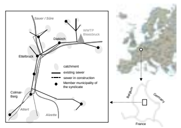
Industrial discharges: ~ 30000 PE

### sewer network

Length: ~ 60 km



## Case Study: WWTP



Hydraulic capacity:
100000 PE

2 bio-units in series,

chemical phosphate precipitation,

online $NH_3$, $NO_3$, $PO_4$ measurements

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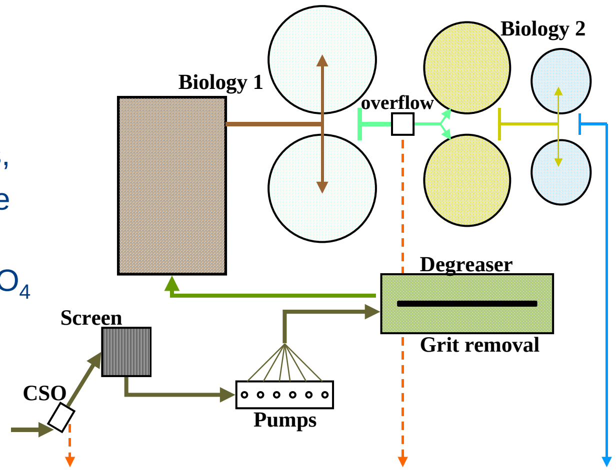


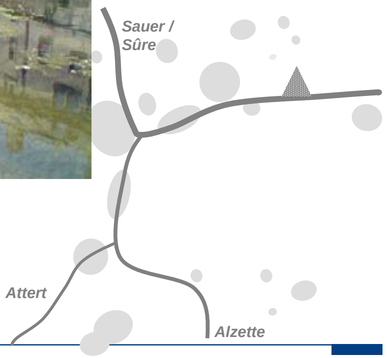
# Case Study: Receiving rivers



**3 river stretches**

Length: ± 20 km

Base Flows: 3-15 m3/s






# Case Study: Receiving rivers



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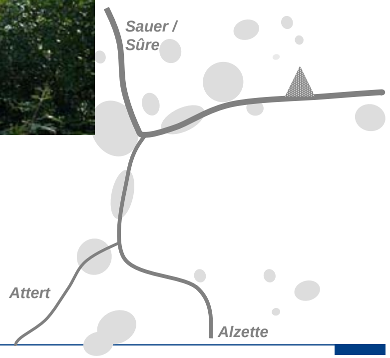
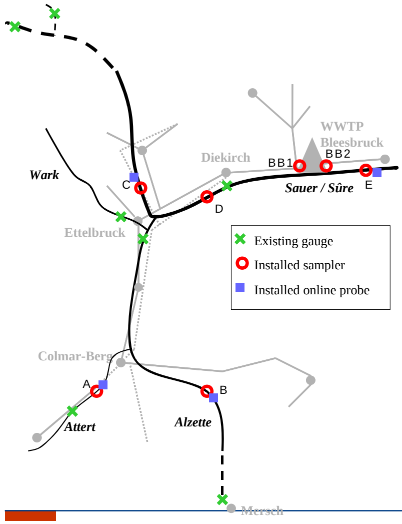





# Case Study: Measurement Campaign

Water Quality

www.cd4wc.org



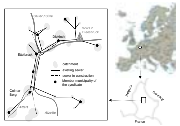

- ↗ DO, Temp
- ↗ BOD, COD particulate, COD soluble
- ↗ $NH_3$, $NO_3$, $PO_4$
- ↗ ChlA
- ↗ Suspended Solids



# Case Study: Measurement Campaign

Water Transport

## Case Study: Progress and Objectives



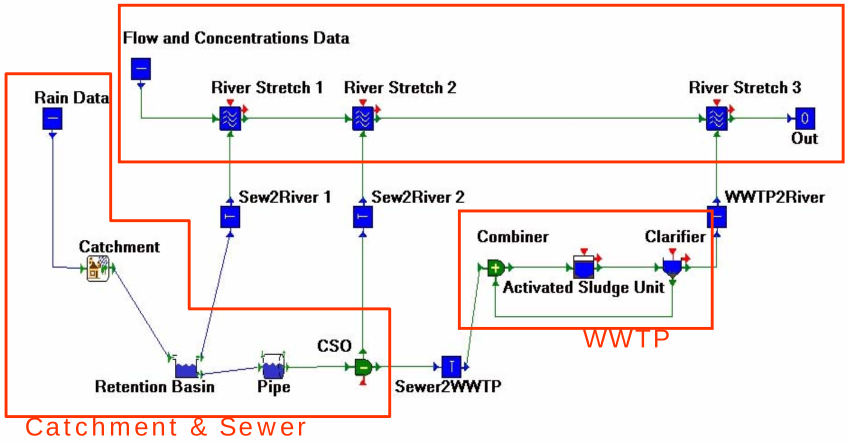
- **Measurement campaign** on the river and the WWTP (CD4WC).
- **Data collection** and **deficit analysis**
- **Model** building and calibration

**Develop scenarios** to improve quality of the eutrophied river and test them using simulatons of the integrated system.

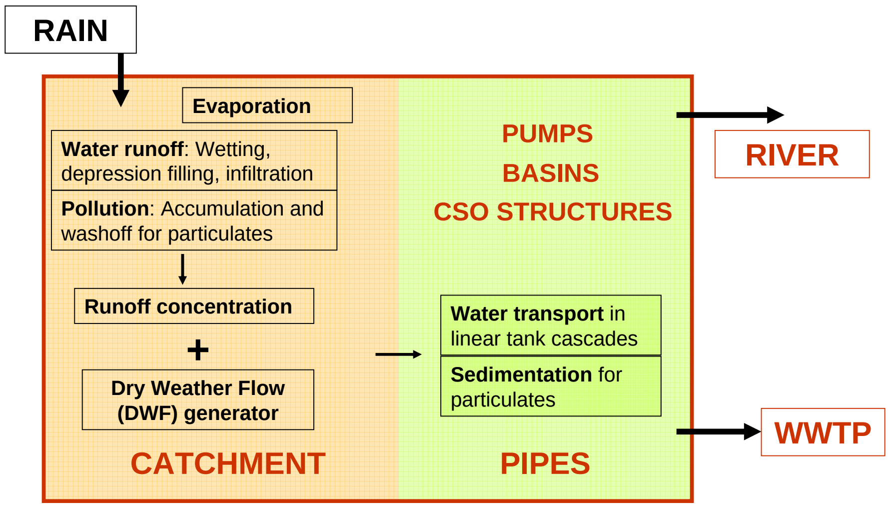
**How much pressure is this catchment/WWTP exerting?**



## The Integrated Model: Modelling Approach

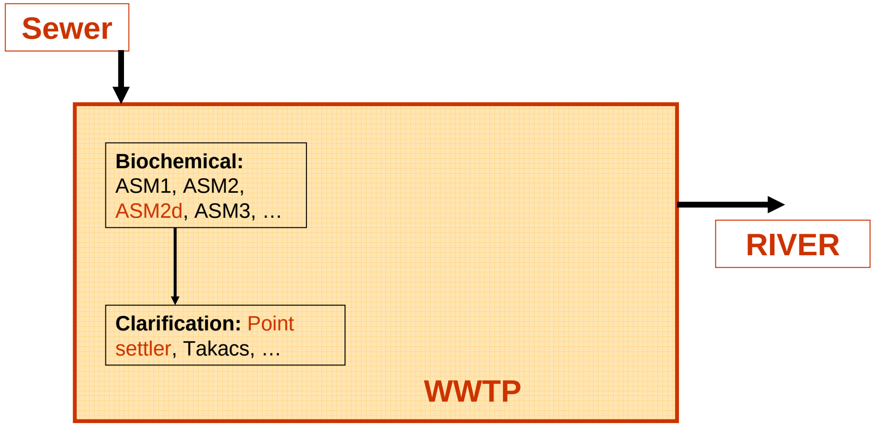



## Modelling & Simulation: Catchment & Sewer

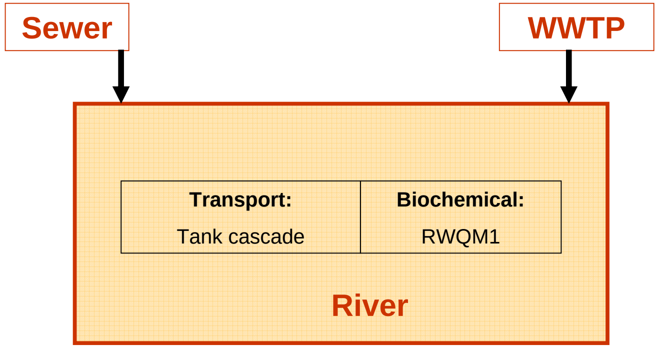





## Modelling & Simulation: WWTP

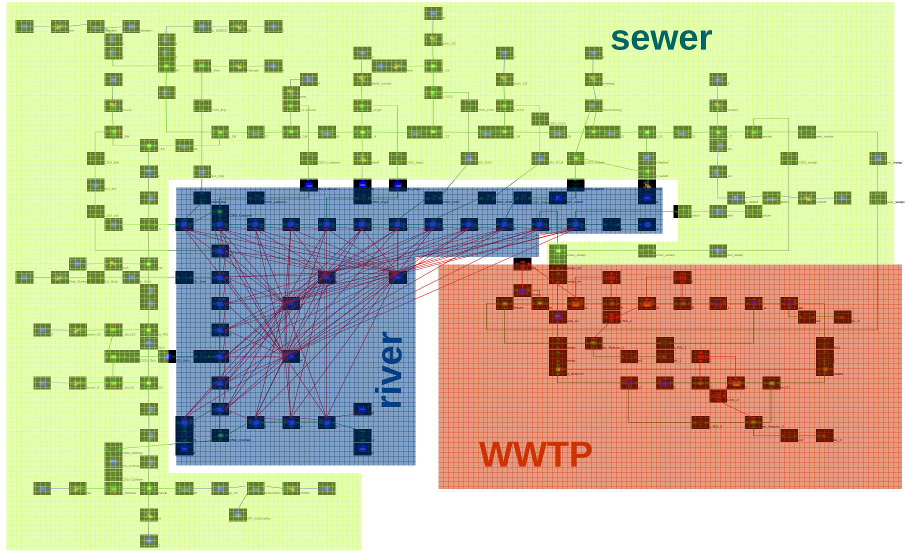


## Modelling & Simulation: River






## The Integrated Model






## The Integrated Model

**Catchment & Sewer (1): Construction**

- ↗ 20 catchments
- ↗ 4 basins / storage pipes
- ↗ 6 pumps
- ↗ 16 km main collector
- ↗ Reduction of CSOs down to 16

**DATA USED:**

Population and industry

Surface characterisation

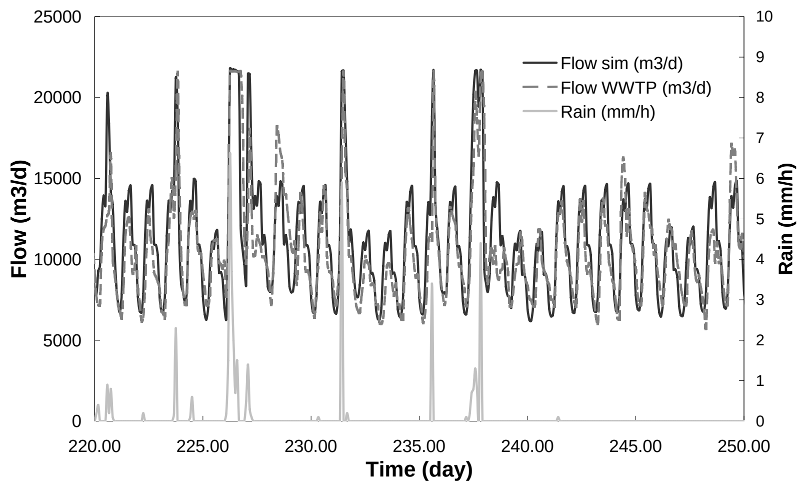
Geometric data for sewer

evaporation & infiltration



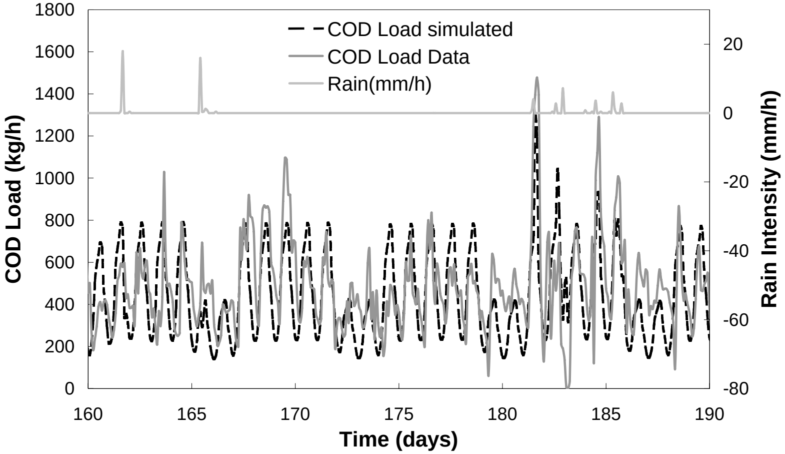
## The Integrated Model

**Catchment & Sewer (2): Calibration**



# The Integrated Model

**Catchment & Sewer (3): Calibration**






# The Integrated Model

**WWTP (1): Construction**

- 2 activated sludge units in series (removal of COD, nitrification): ASM2d model
- Chemical phosporous removal by precipitation
- Clarification with ideal settlers

**DATA USED:**

WWTP dimensions

Water quality measurements

Influent characteristics

Operation schemes

Existing model

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# The Integrated Model

**WWTP (2): Calibration**

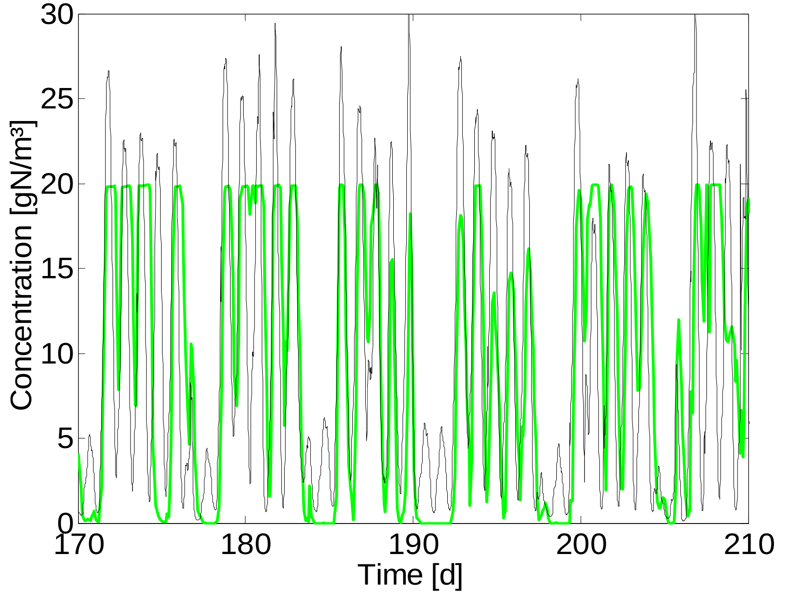
- Life project: kinetic parameter **calibration**
- CD4WC project:
  - one week **validation**
- One year **calibration**

| 1st BioUnit | | NEW | |
|---|---|---|---|
| $\mu_H$ | 6.0 | 3.0 | $d^{-1}$ |
| $b_H$ | 0.6 | 1.2 | $d^{-1}$ |
| $\mu_{AUT}$ | 1.0 | 1.5 | $d^{-1}$ |
| $\eta_{NO3}$ | 0.8 | 1.0 | - |



# The Integrated Model

**WWTP ASU 2 Out - Ammonium**



# The Integrated Model
## River

- River: Tanks-in-series (transport)
  Simplified RWQM1
  - Dissolved Oxygen
  - Nitrogen
  - Phosphorus
  - Algae
  - Heterotrophs, autotrophs, nitrifiers
- Connectors:
  - Conserving elemental mass balances

**DATA USED:**

Water Level, Solar Radiation, Temperature, Humidity…

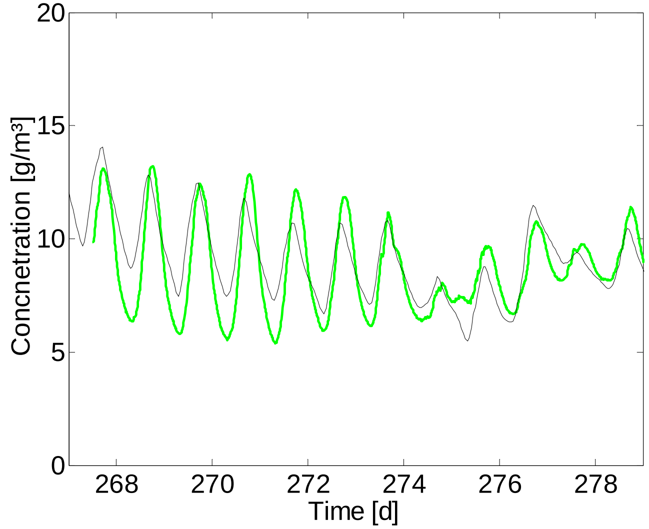
Water quality measurements

Tracer tests



# The Integrated Model
## River

**Dissolved Oxygen Bettendorf, Autumn 2005**






# Scenario Analysis

- **Source control:**
  - Ammonia decoupling — FlatNH3
  - DWF flattening through basins at housing level — FlatDWF
  - Impervious surface reduction — RedImp
- **System rehabilitation**
  - Sewer infiltration reduction — RedInf
  - Retention basins — RetBas
  - Buffer tank for incoming sludges — SluBu
  - Nitrification volume increase — NitVol
  - Sludgewater Treatment — SluWT
- **Operation Strategies**
  - Increase in WWTP loading — OvLo
  - Improved nitrogen control — ImprN
  - Improved phosphorus control — ImprP
- **River measures**
  - Shading — Sha
  - Reaeration — Reae



# Scenario Analysis

**Evaluation criteria**

**Immission and Emission**

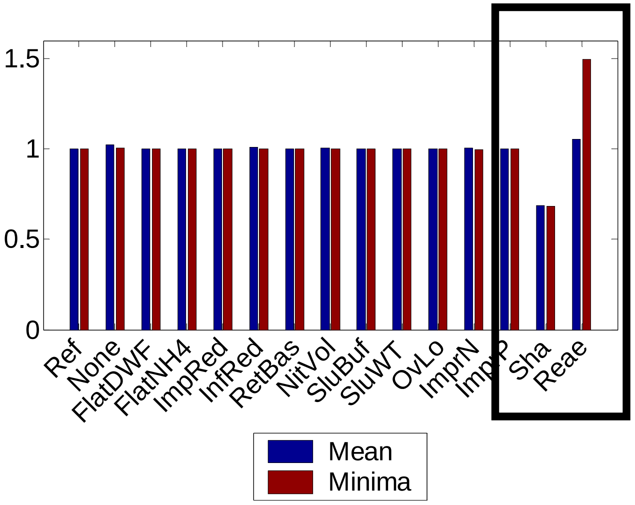
- Exceedance lengths
- Number of exceedances
- Means
- Maxima
- Minima
- Total loads

**Long-term analysis /**

**Event-based analysis**

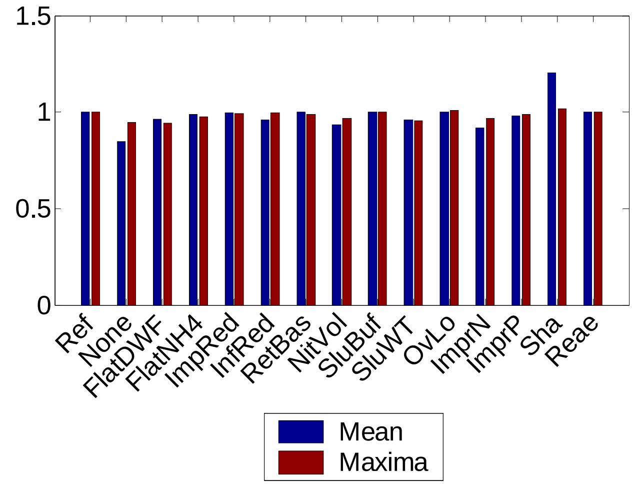
## Scenario Analysis

### Immission: Dissolved Oxygen after WWTP



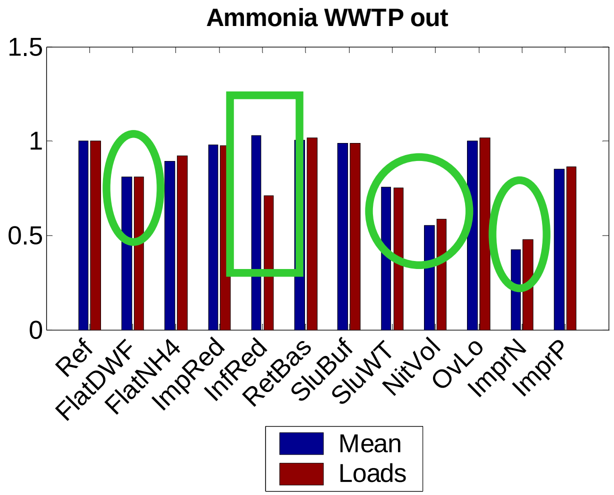

## Scenario Analysis

### Immission: Ammonium after WWTP




## Scenario Analysis

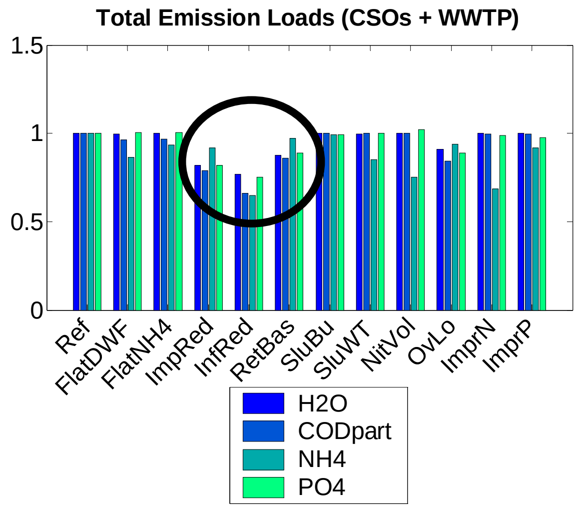
### Emissions: WWTP





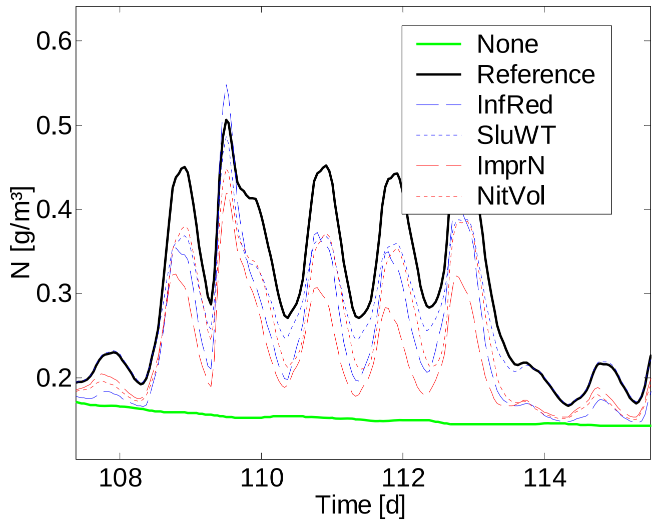

## Scenario Analysis

### Total Emission Loads from CSOs and WWTP



## Scenario Analysis

**Immissions: Low base concentrations: after WWTP**




## Scenario Analysis: Costs

| Measure | Investments (€) | Operation (€) |
|---|---|---|
| FlatDWF | ++++ | |
| ImpRed | +++ | 0 |
| InfRed | +++ | 0 |
| RetBas | +++ | + |
| NitVol | ++ | 0 |
| SluWT | ++ | ++ |
| ImprN | + | |
| ImprP | 0 | 0 |
| OvLo | 0 | 0 |
| Reae | ++ | ++ |



## Conclusions (1)

**Immissions: Existing**

- **Hydraulic contributuion** of catchment small compared to river flow
- **Background pollution** large, therefore measures within the catchment seem to have little impact (Careful: within this modelling context, ≠hydromorphological, ≠ecological…)
- **Shading** not an option here
- **Reaeration** helps to improve DO concentrations (needs good planning, operation costs, should be combined with measures at source)



## Conclusions (2)

**Emissions: Existing**

- Measures are often expensive, **ImprN** and **ImprP** cheap to implement bringing about good changes
- **SluWT** onsite is a good option
- **InfRed** reduces loads significantly
- **ImpRed** shows beneficial impact (keep impervious surface to a minimum during planning processes)
- General: measures in sewer are expensive but effective → **Source control**

## Conclusions (3)

**Immissions: Low base concentrations**

- **Impact** of catchment is significantly higher
- WWTP **ammonia** peaks found in river concentrations
- **Sewer system** has an impact at CSO level, especially COD peaks reduced by **RetBas** and **ImpRed** (planning)



## Conclusions (4)

- Creation of an integrated model: Same model **approach** for the 3 subsystem (use of one software)
- **Complexity** of scenarios analysis evaluation:
  - Multiple criteria (costs, quality limits,…)
  - Interactions between subsystems
  - Evaluation criteria
- Tool for local, more detailed analysis in the implementation process of the EU **Water Framework Directive**
- Integrated model useful for illustrating interaction (**education**) in urban wastewater engineering



## Outlook (1)

- Further investigations of the model (e.g. test **control strategies**, model uncertainty,…)
- **Data** quantity and quality (measurement campaigns)
- How can such results be linked to **ecological** tools in evaluations of systems
- …



## Merci.

www.cd4wc.org

The presented results have been elaborated in the framework of the European Project CD4WC of the CityNet cluster (FP5).