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Xenobiotic Mass Balances:
Residence Time Distributions as a
Guiding Principle for Sampling Strategies

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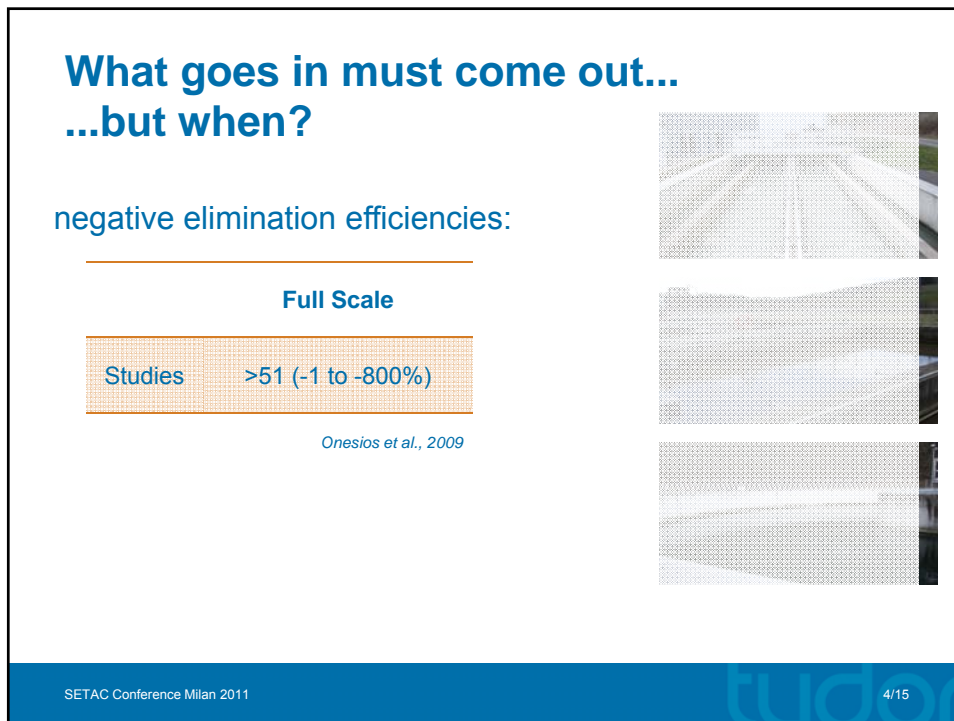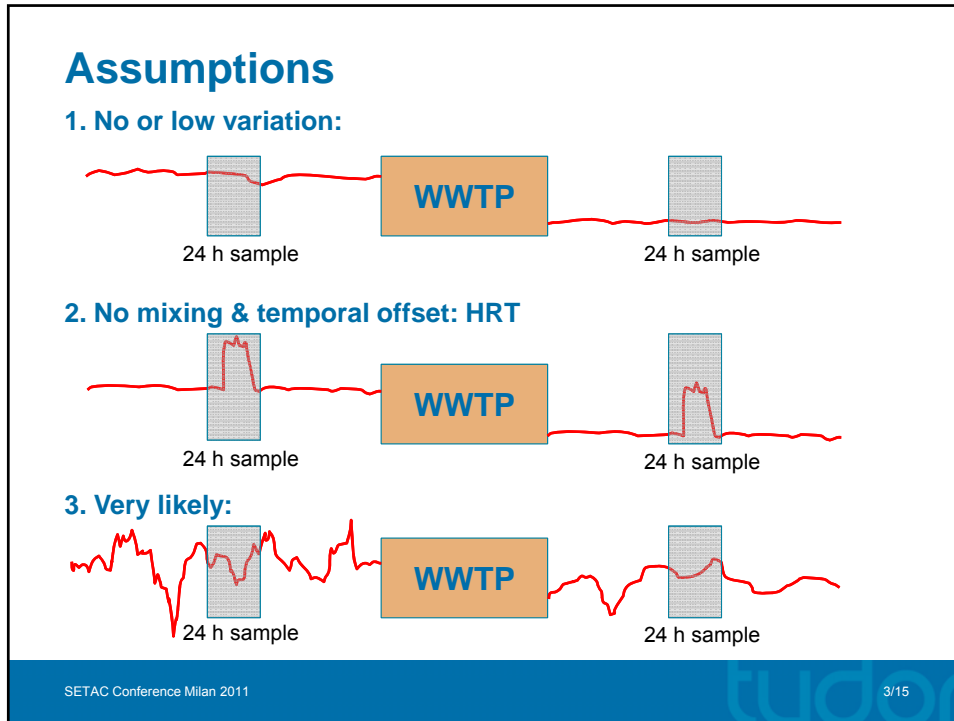*[d] modelEAU, Département de génie civil et de génie des eaux, Université Laval, Canada*

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„Traditional" Approach
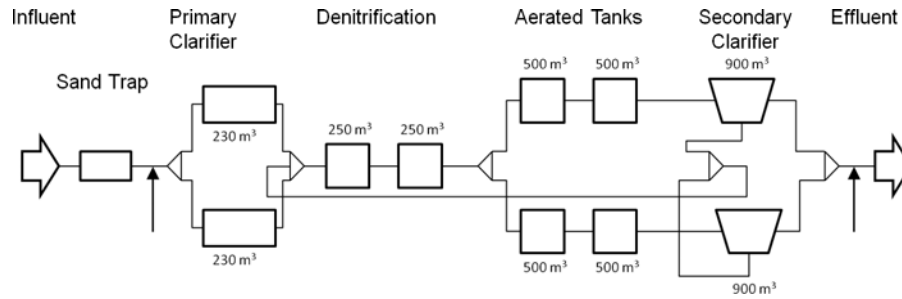
24 h composite samples

WWTP

$$\text{Removal in } [\%] = \frac{Load_{in} - Load_{out}}{Load_{in}} \cdot 100$$

Assumptions

1. No or low variation:

24 h sample   **WWTP**   24 h sample

2. No mixing & temporal offset: HRT

24 h sample   **WWTP**   24 h sample

3. Very likely:

24 h sample   **WWTP**   24 h sample

What goes in must come out...
...but when?

negative elimination efficiencies:

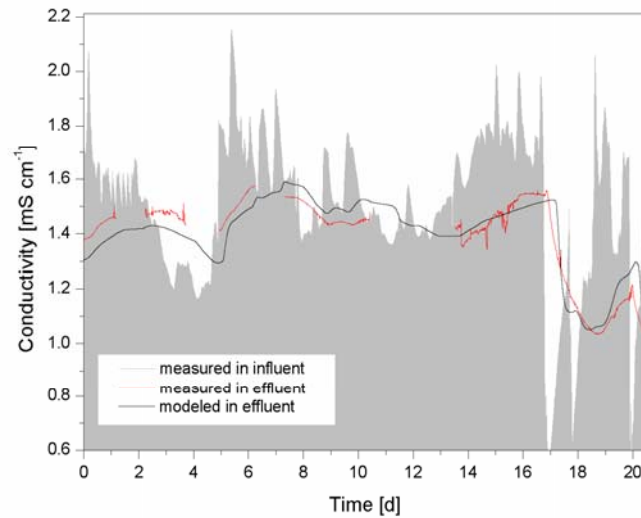| Full Scale	
Studies	>51 (-1 to -800%)

Onesios et al., 2009

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Plant Layout
WWTP Mamer 20'300 PE, 100% capacity utilization
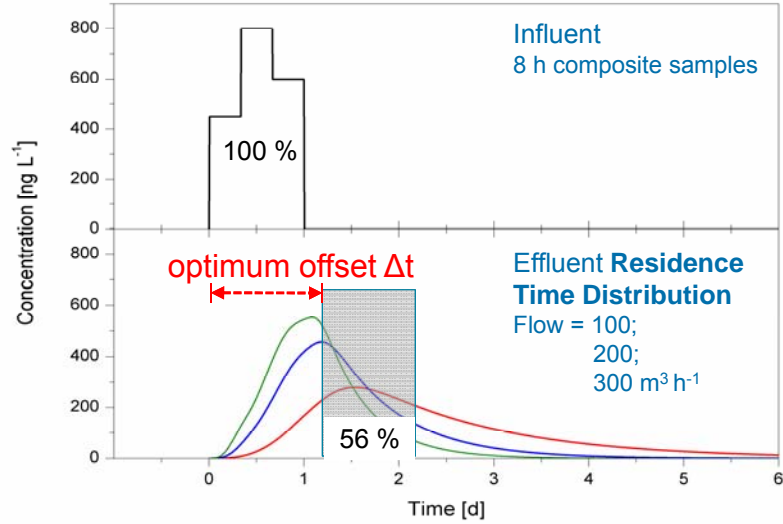

• Hydraulic model within GPS-X
• Completely mixed tanks-in-series

Tracer – Wastewater Conductivity

Residence Time Distributions (RTD)

Influent
8 h composite samples

100 %

optimum offset Δt

Effluent **Residence Time Distribution**
Flow = 100;
        200;
        300 $m^3 h^{-1}$

56 %

# Sampling Scenario:
flow = const.

Influent

Xenobiotic Concentration [ng L^{-1}]

0 1 2 3

Influent, sampled on 3 days

Effluent
RTD in effluent
24h Sampling interval
with optimal offset

0 1 2 3

Xenobiotic Concentration [ng L^{-1}]

Time [d]

Fractions on the effluent sampling interval:

Day 0:   8 %
Day 1:   24 %
Day 2:   56 %
Day 3:   11 %
Non-covered: 1 %

sum: 100%

5/22/2011
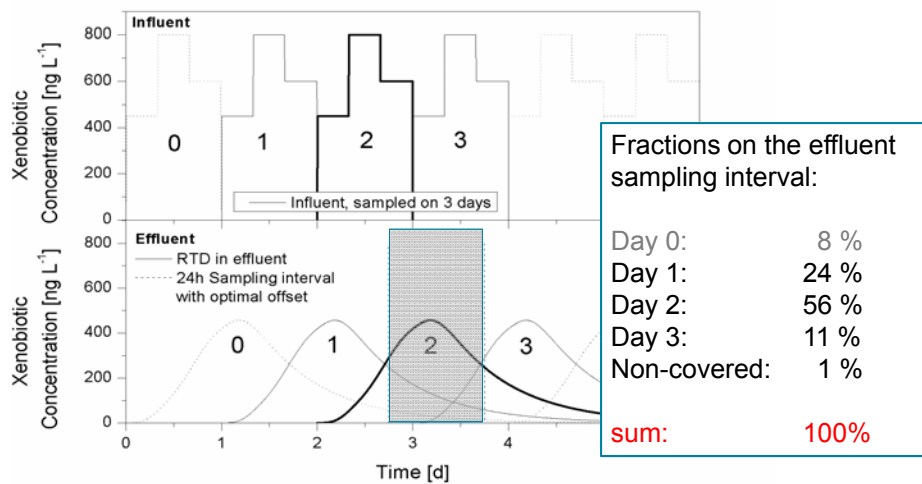
Sampling Scenario: Realistic Data

Fractions on the effluent sampling interval:

Day 0:   14 %
Day 1:   22 %
Day 2:   31 %
Day 3:   16 %
Non-covered: 17 %

sum: 100%
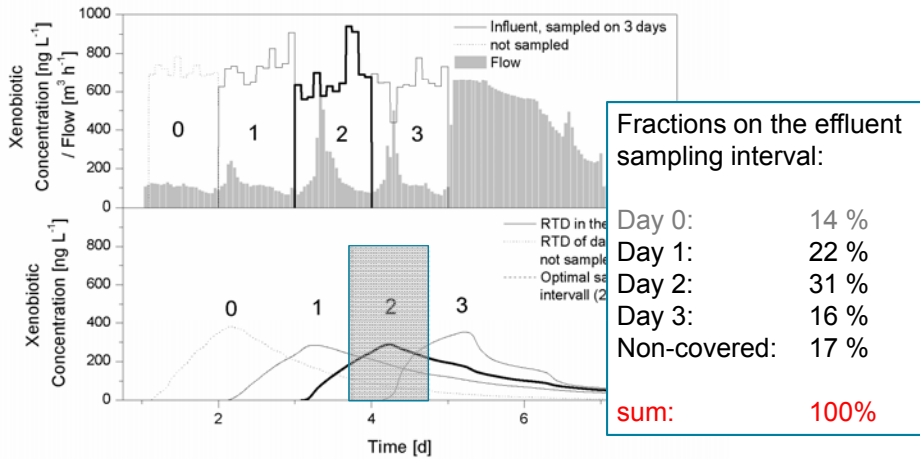
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Estimating the Actual Elimination Efficiency

$$\text{Reference Load} = \sum f_n \cdot Load_{in,n}$$

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Estimating the Actual Elimination Efficiency

Measurement day	Contribution to effluent load	Cumulative contribution	Elimination efficiency by **fractionation**	Elimination efficiency by **single day average** loads
	[%]	[%]	[%]	[%]
day 0	14.4	14.4	-	-0.80
day1	22.4	36.8	-	-23.19
day 2 (optimum offset)	30.7	67.5	-	-5.60
day 3	16.0	83.5	-	14.71
non covered period	16.5	100.0	0 ± 2	-

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„You cannot step

twice into the same river."

Confucius 551 – 479 b.c.

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Conclusions

- **very likely:** a 1/1 day influent-effluent campaign compares two largely different water volumes (loads)

- **in this study:** a 4/1 day influent-effluent campaign would be necessary to explain more than 80 % of the effluent load

- **total error:** uncertainty of non covered period PLUS errors of discrete sampling (*Ort et al.*) lead to total errors of > 15-20 %

- **implication:** RTD instead of HRT for xenobiotic modeling

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Acknowledgements

National Research Fund Luxembourg
within AFR 17/07

Fonds National de la Recherche Luxembourg

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Centre de Ressources des Technologies pour l'Environnement

Universität Trier

UNIVERSITÉ LAVAL

Hydromantis
Environmental Software Solutions, Inc.

Majewsky, M., Gallé, T., Bayerle, M., Goel, R., Fischer, K., Vanrolleghem, P.A. (2011): **Xenobiotic Mass Balances: Residence Time Distribution as a Guiding Principle for Sampling Strategies**. Water Research, *submitted*.

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