# Flow measurements and sampling : Key information for environmental surveys

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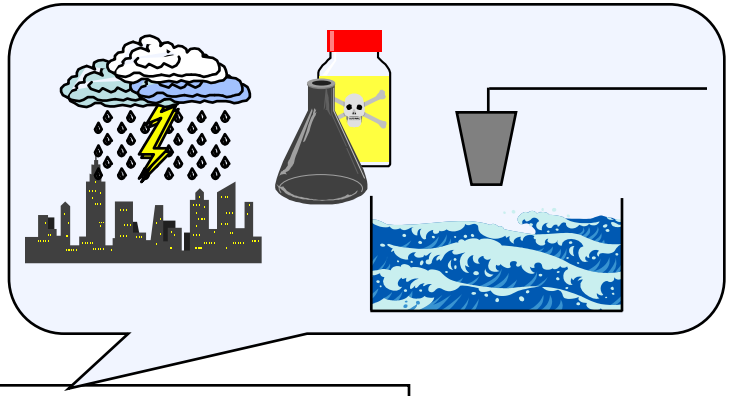
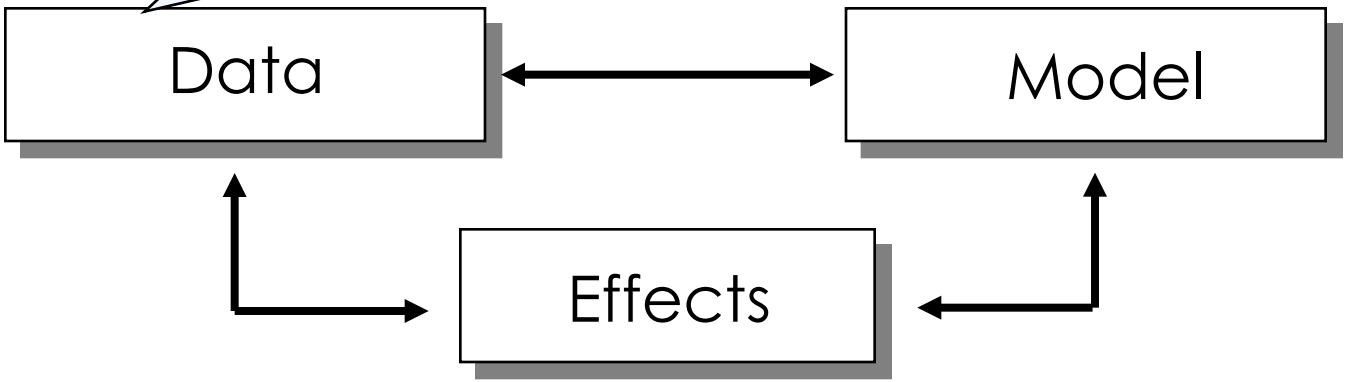
- Introduction
- Analytical procedure
- Flow measurements
- Scientific approach of sampling:
  - How and where should I take samples?
  - How many samples do I need?
  - What are the sources of uncertainties?
- New trends in sampling and flow measurements

# Goals of environmental survey



**Flowrate/samples: preliminary indispensable step for all surveys**



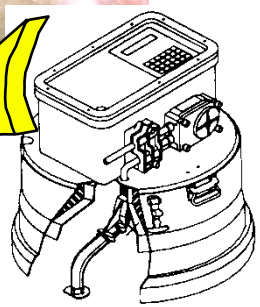

$$\frac{PEC}{PNEC} > 1\ ?$$

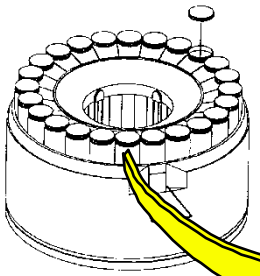
# Introduction

**Sampling = only a volume reduction ?**

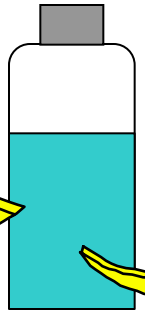
**Reduction factor: 1‘000‘000‘000 ($10^9$)**

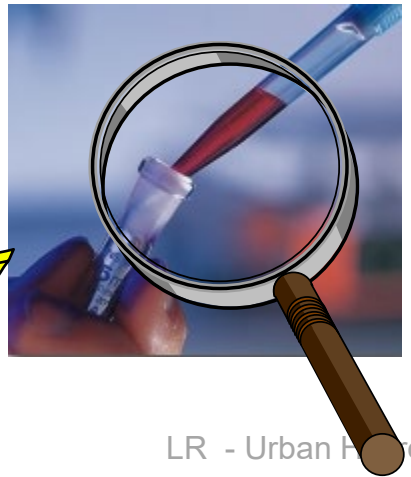
2000 $m^3$





3 liters

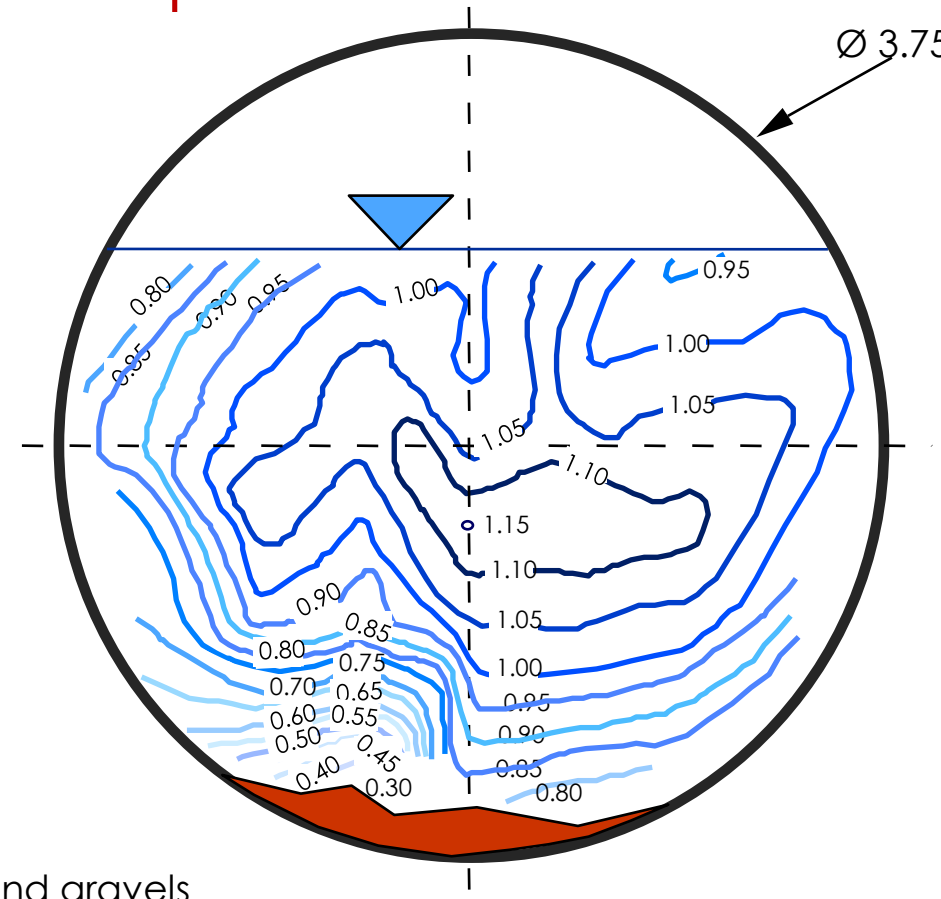




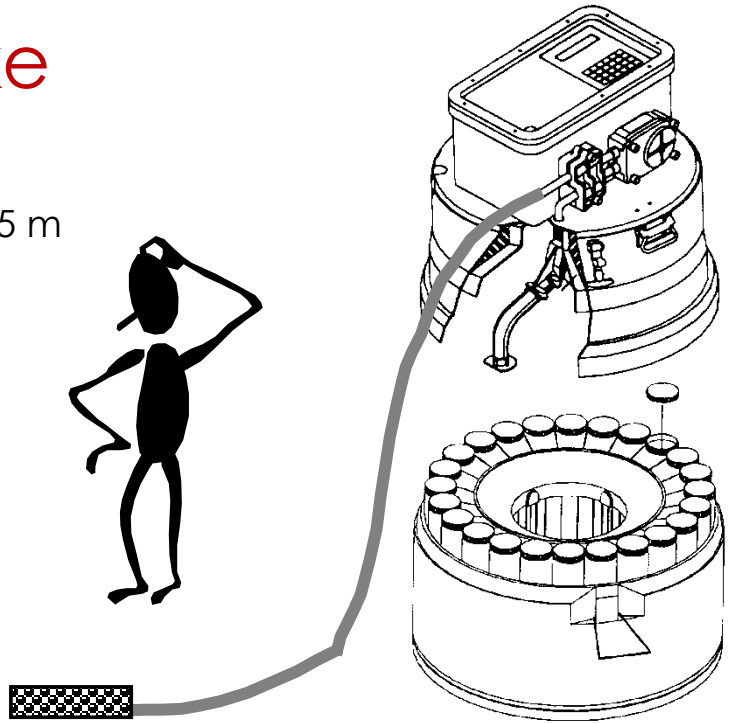
2 ml

# Introduction

## How and where shoud I take a sample ?




Sand and gravels

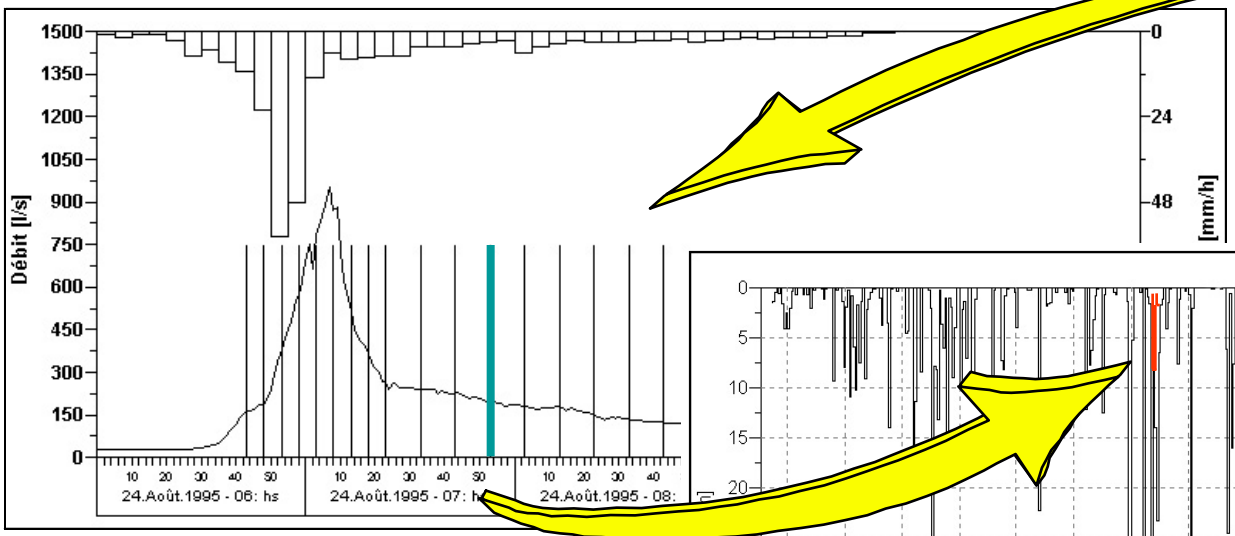


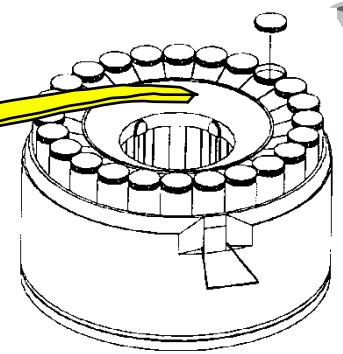
# Introduction

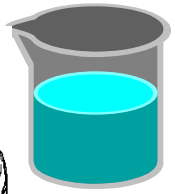
Volume of the sample ? ? ml

Number of samples?

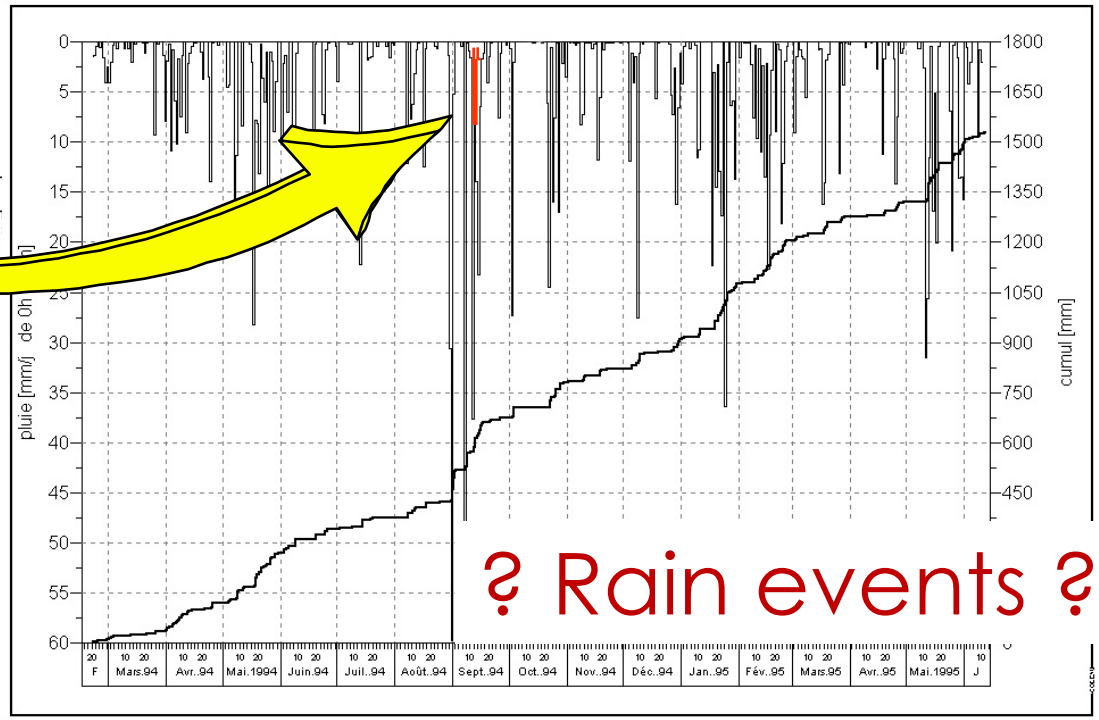
Frequency ?



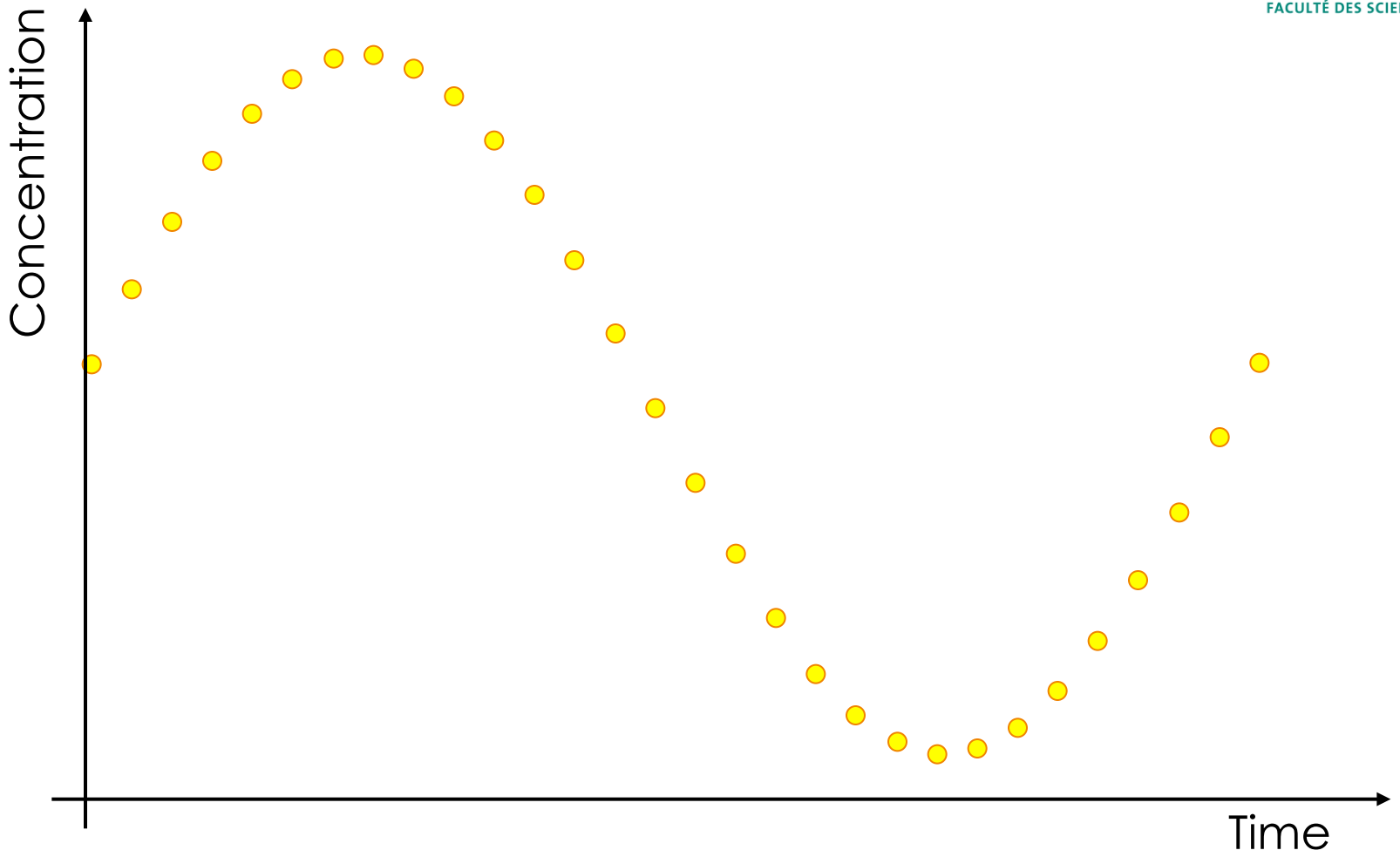


??? Samples

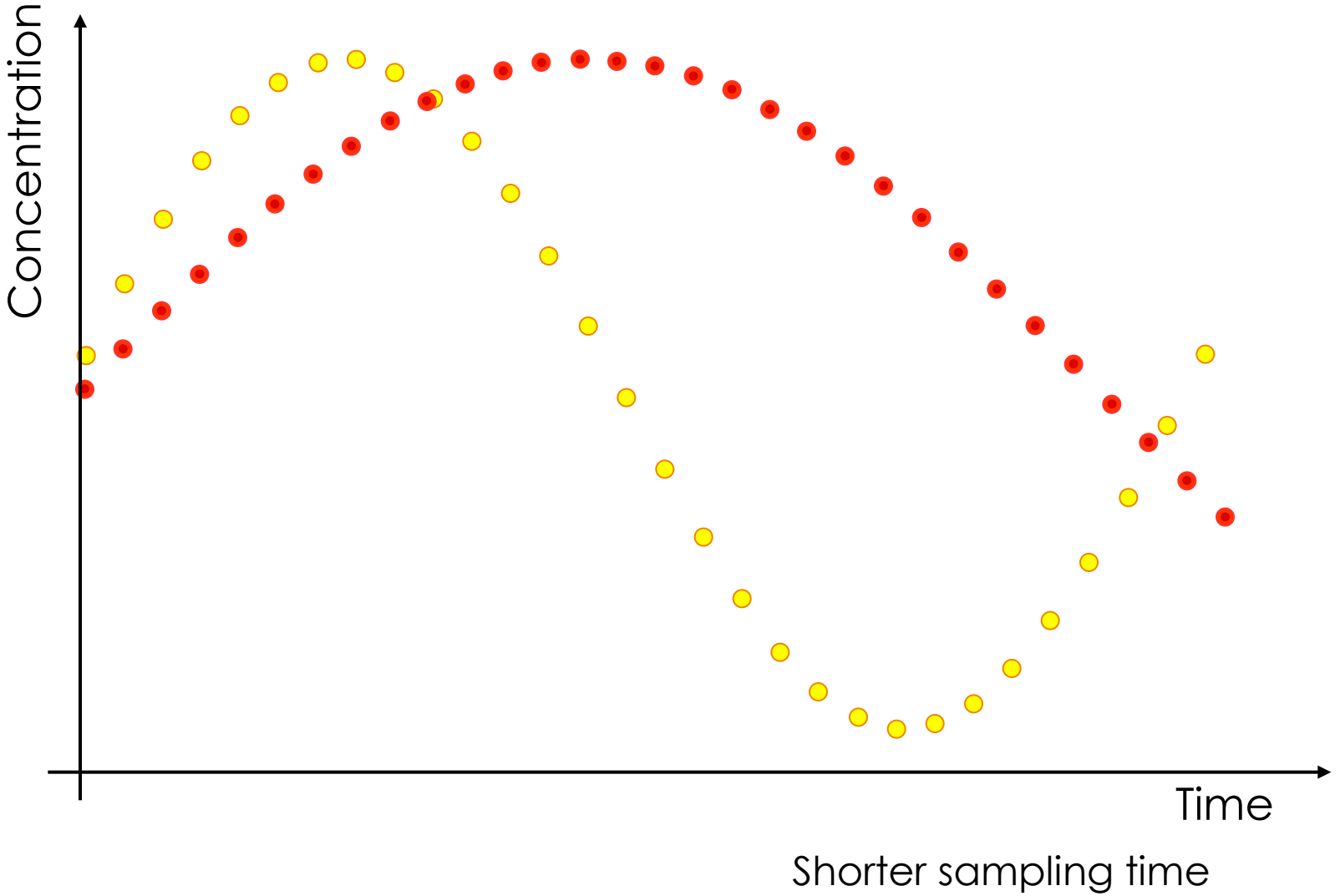



? Rain events ?

# Sampling interval ?



# Sampling interval ?



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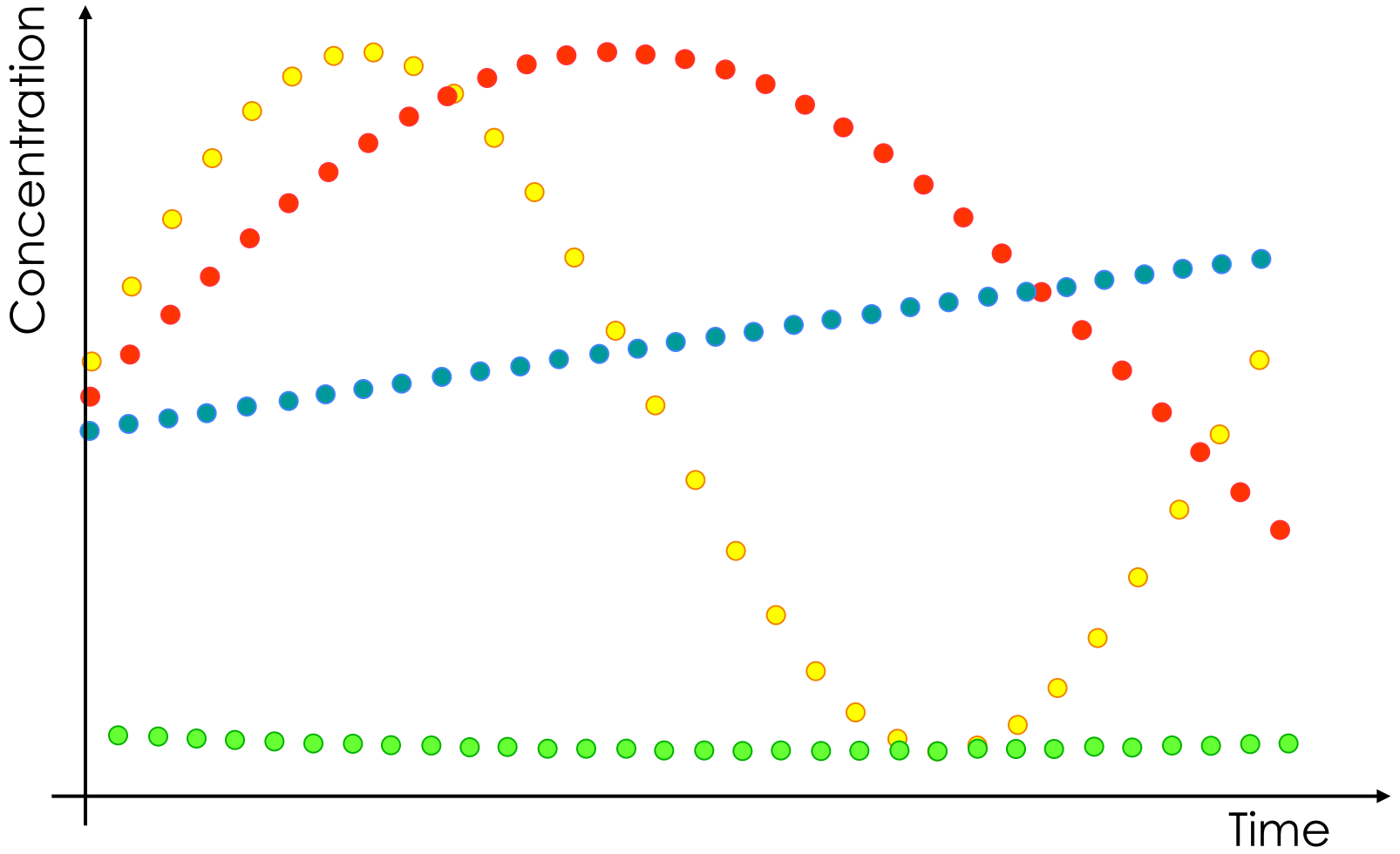
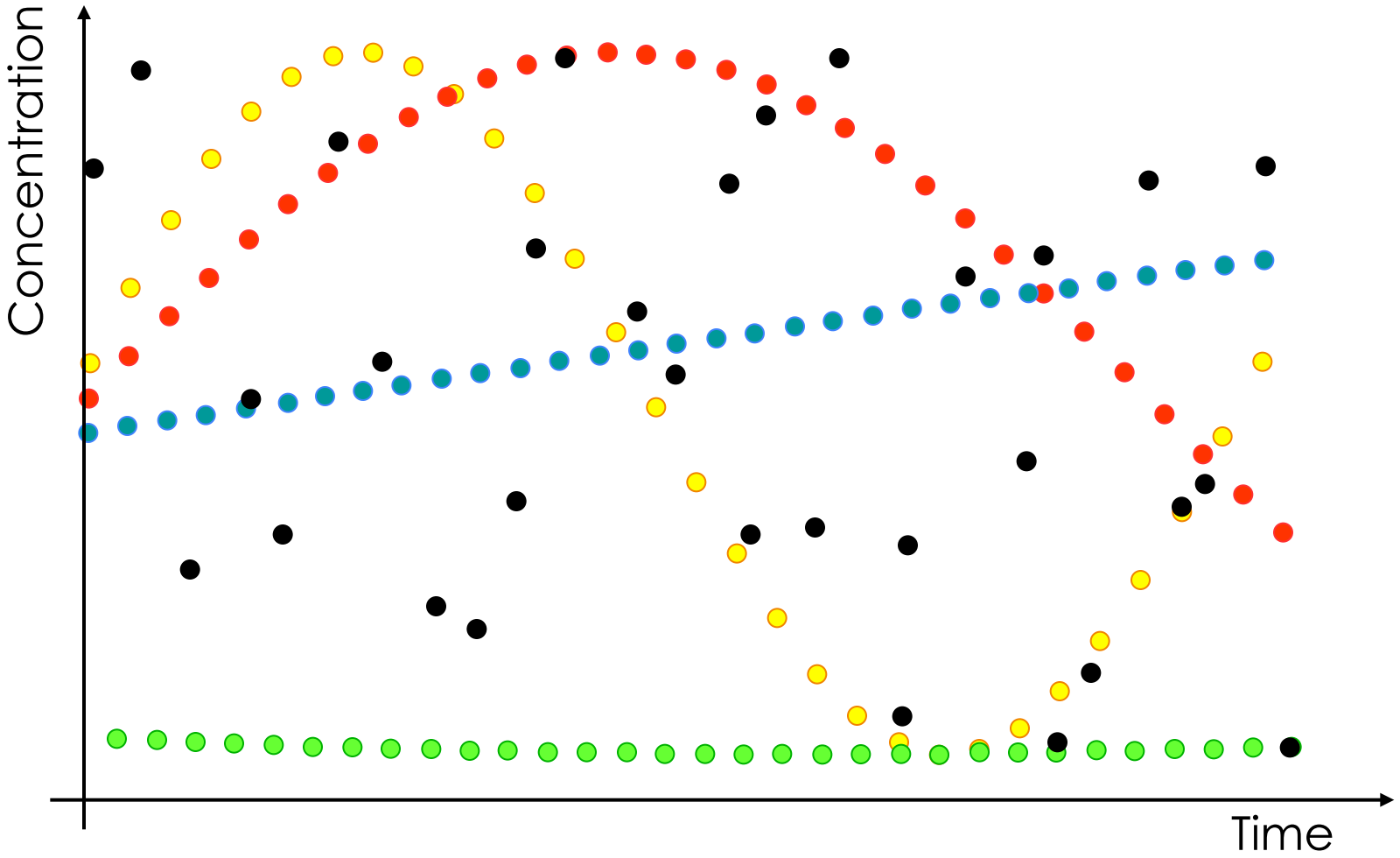
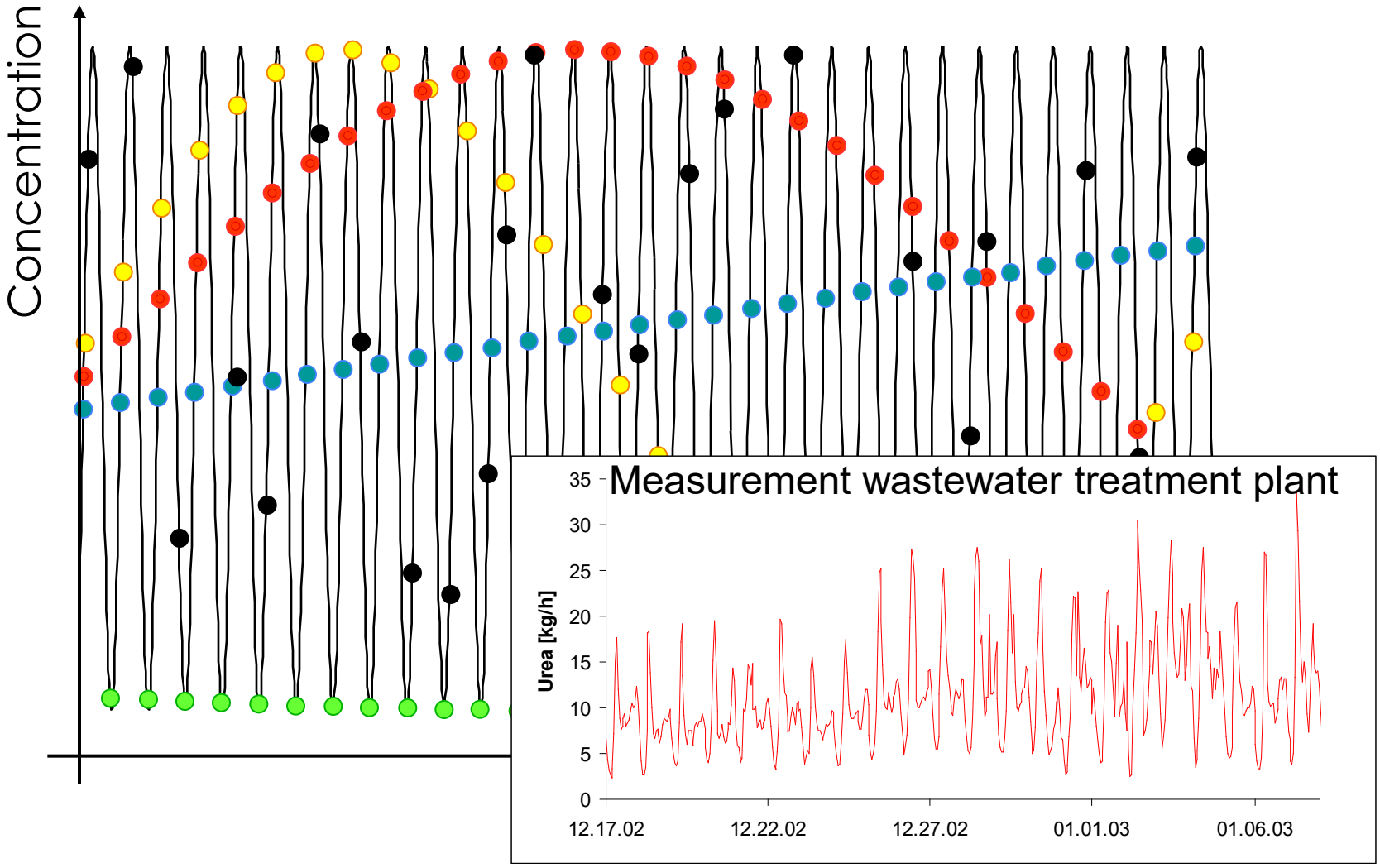


# Sampling interval ?

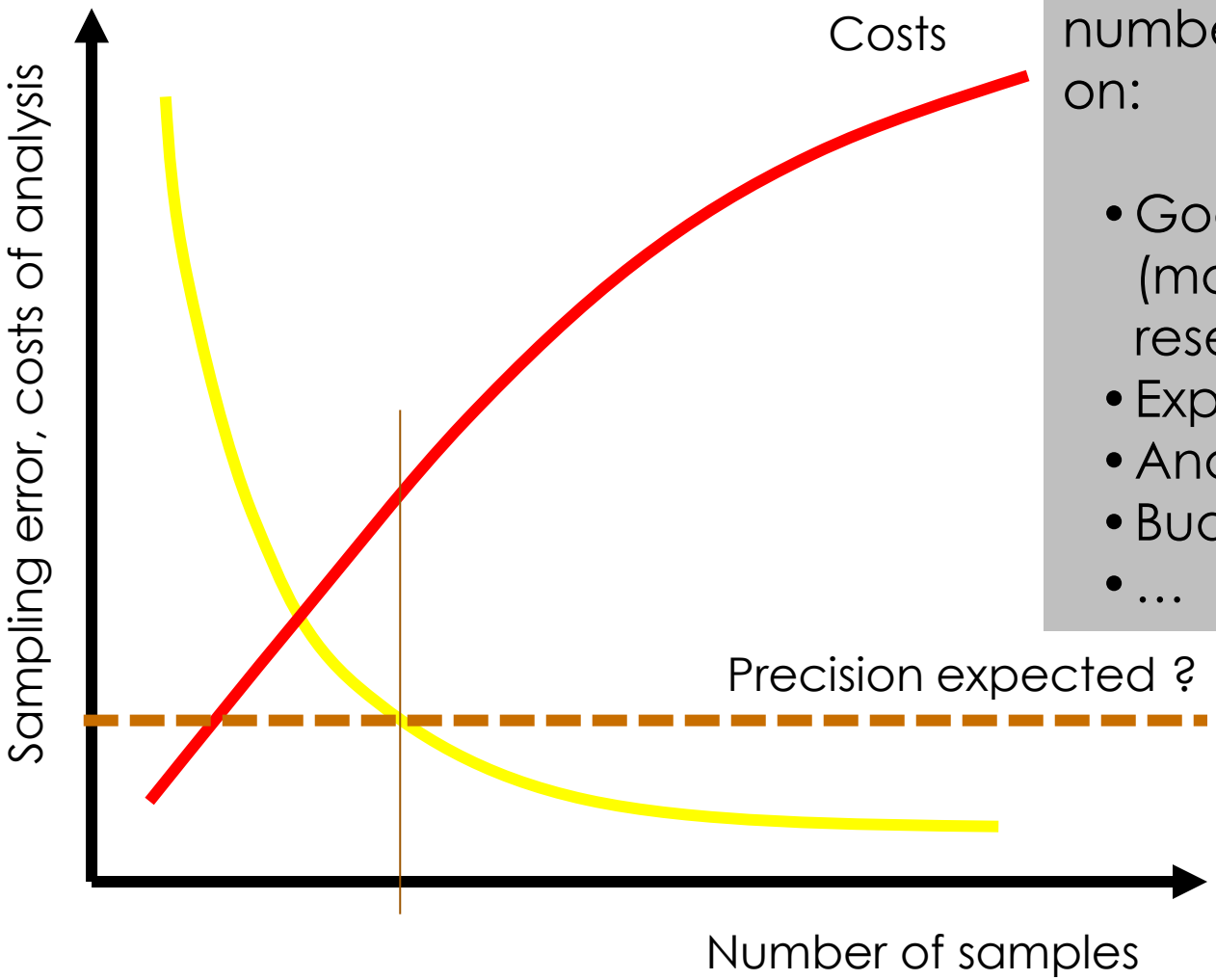



Random sampling

# „Model“


Concentration
Measurement wastewater treatment plant
Urea [kg/h]
35
30
25
20
15
10
5
0
12.17.02
12.22.02
12.27.02
01.01.03
01.06.03

# Cost/benefit analysis of sampling ?

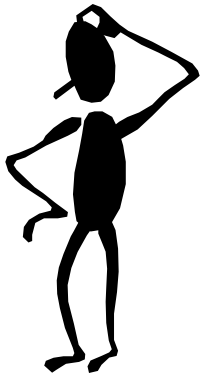



Goals:

Optimization of the number of samples, based on:

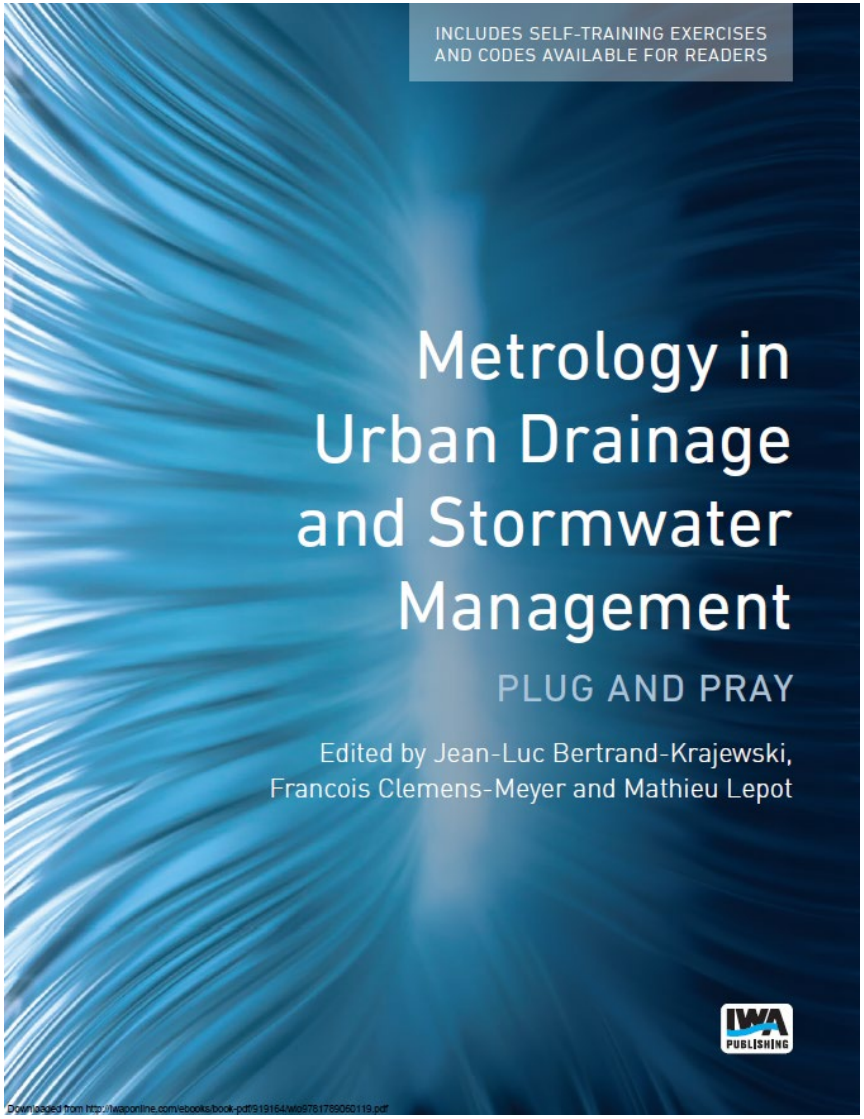
- Goals of the analysis (monitoring, survey, research…)
- Expected errors
- Analytical capacities
- Budget
- …

# Common questions about sampling



1) How, where, when, how many...
2) Financial aspects: is it possible to reduce the number of samples with the same reliability? (optimisation of a sampling strategy)?
3) Errors during sampling phases (always?) How is it possible to estimate and minimize them?

# Common questions about sampling






Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Office fédéral des routes OFROU

DOCUMENTATION

ÉCHANTILLONNAGE DES SYSTÈMES DE TRAITEMENT DES EAUX DE CHAUSSÉE

*Méthodologie*

*Édition 2020 V1.00*
*ASTRA 88004*

**Sewage Pattern Generator (SPG)**
https://www.eawag.ch/en/department/sww/software/

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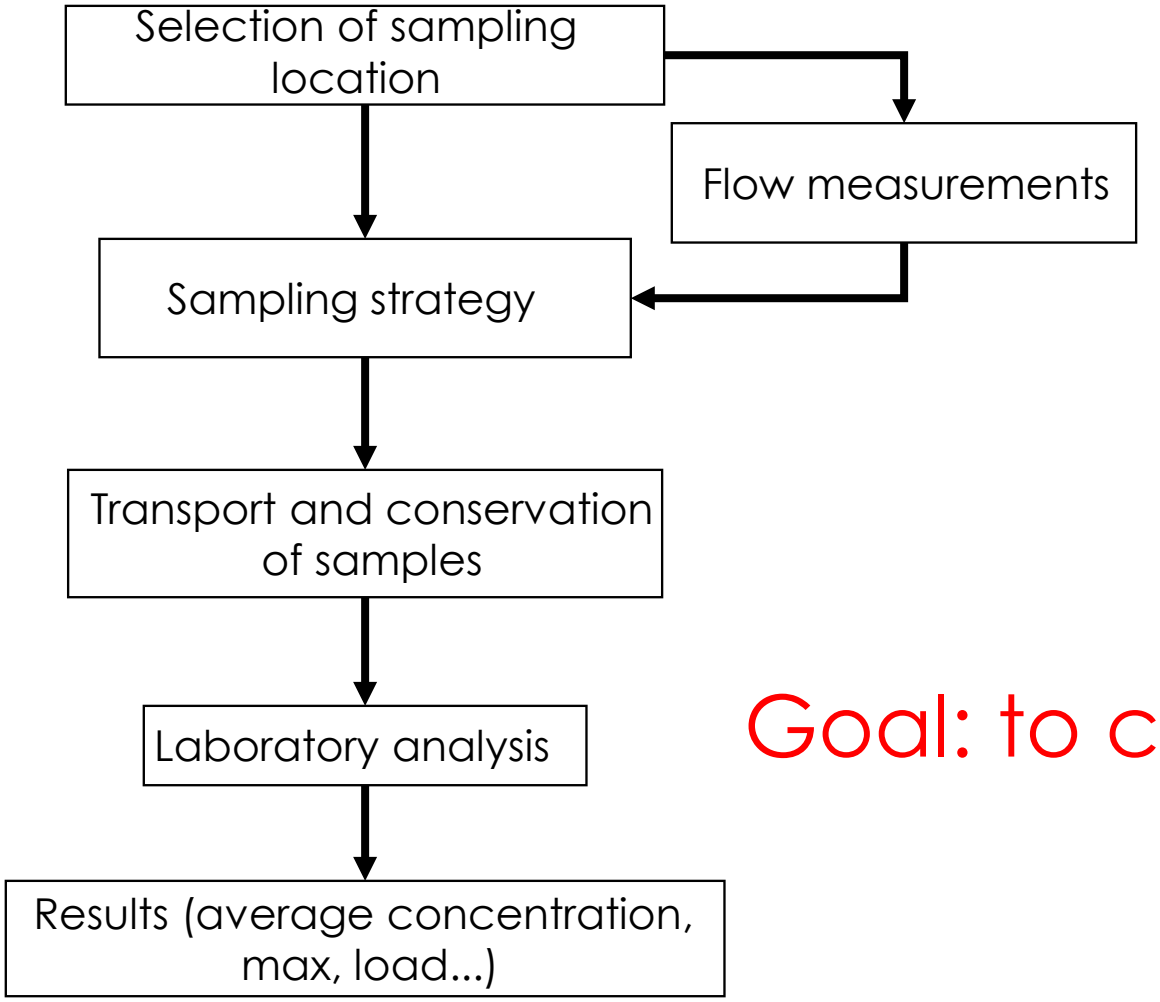
# Analytical procedure




Goal: to control all steps !

# Analytical procedure

Substance

Concentration average / max

Dissolved / adsorbed

Concentration/ load

Profile

Location

Mode

Apparatus

Flow

Handling Transport Preservation

Preparation Analysis

Problem Contract Goals

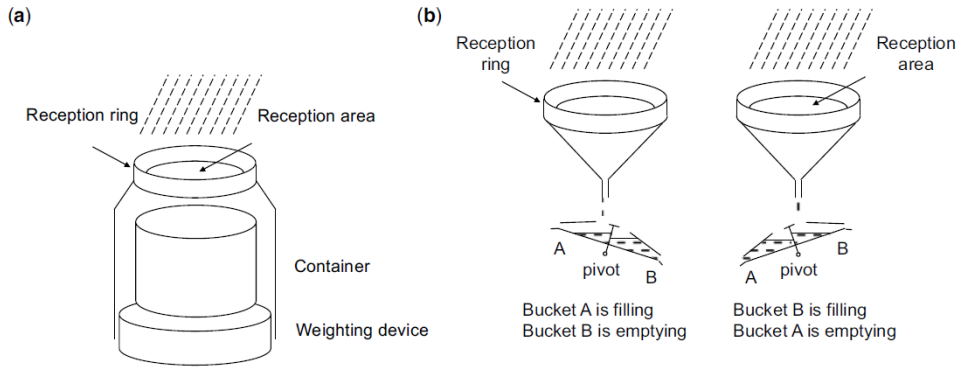
Preliminary knowledge Experience

Sampling strategy

Laboratory

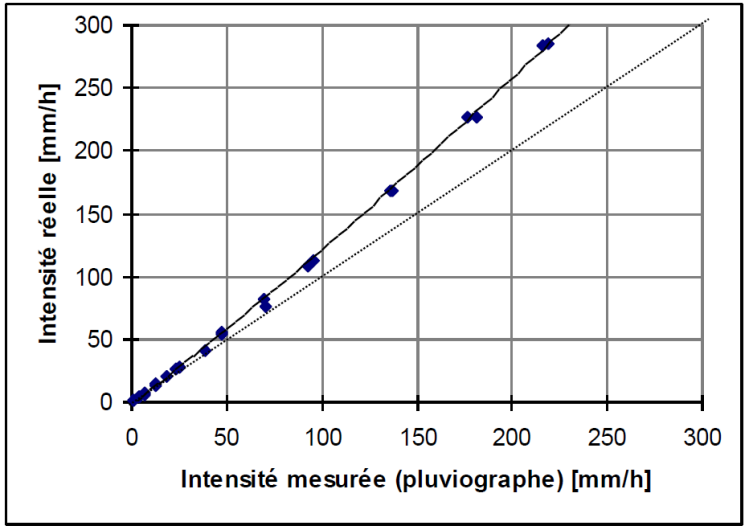
Result Decision Technical solution Modelling

# Analytical procedure
## Rain measurements




(c)

(d)


*Metrology in urban Drainage Jean-Luc Bertrand-Krajewski [2021]*

Always consider several weather stations!
Be careful during winter measurement periods
Radar data: interesting alternative solution

# Measurement location: Criteria

- Vandalism, power supply, accessibility, authorization (commune, canton, police...)
- Security for personal
- Flow measurement requirements (slope, turbulences...)
- Murphy‘s law...

# Measurement location: Criteria

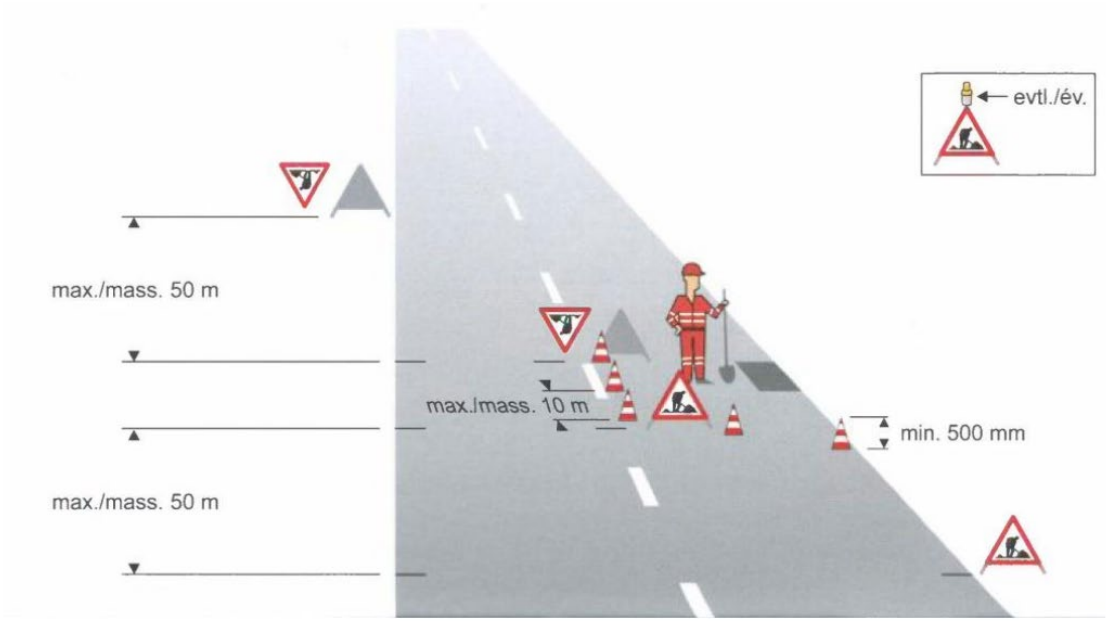
832.30

**Ordonnance**
**sur la prévention des accidents et des maladies professionnelles**

## – Art. 8 Travaux comportant des dangers particuliers

[1] L'employeur ne peut confier des travaux comportant des dangers particuliers qu'à des travailleurs ayant été formés spécialement à cet effet. L'employeur fera surveiller tout travailleur qui exécute seul un travail dangereux.

*Exemple de signalisation des chantiers sur les routes principales et secondaires à l'intérieur des localités*




https://www.advk.ch/upload/docs/mdc_224/signal%202020%20frs.pdf

# Why is flow important?

Selection of sampling location

Flow measurements

Sampling strategy

Transport and conservation of samples

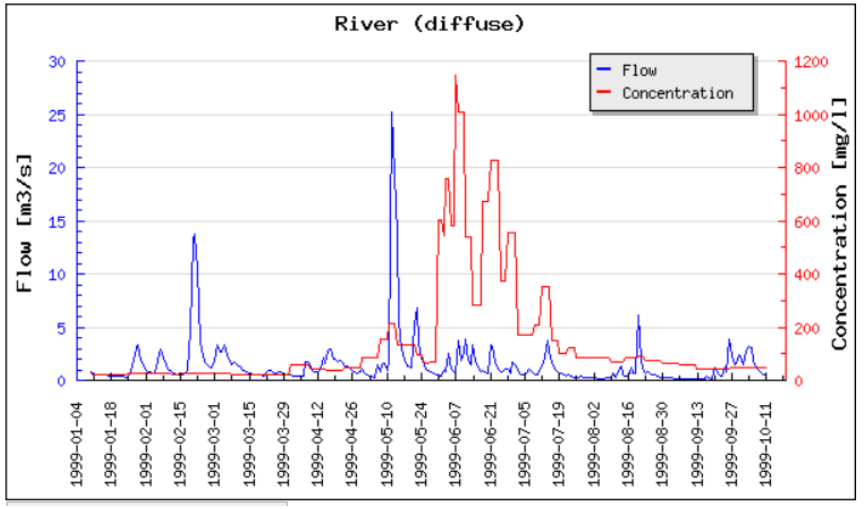
Laboratory analysis

Results (average concentration, max, load...)

Errors on flow measurements directly influence the results

Load = Concentration · **Flow** · Time

mg mg/l l/s s




*River Moenchaltorf, a little river near Zürich (Switzerland) influenced by diffuse agricultural pollution (Atrazine) (Chèvre et al. 2004)*
*Example integrated in Samplinghelper.com*

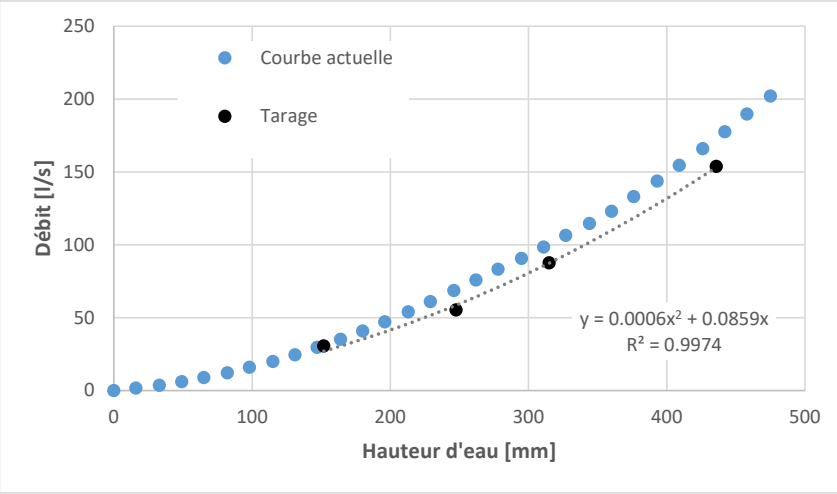
# Flow measurements

Flow = Section x velocity

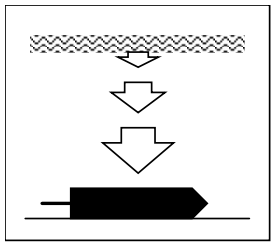
$m^3/s$ $m^2$ $m/s$

Section = f(geometry, water level)

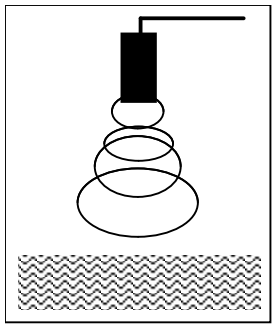
Measurements and/or theoretical rating curves



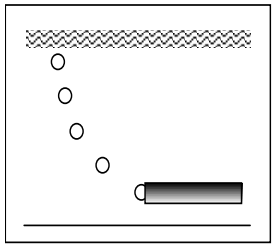

# Typical flow measurements



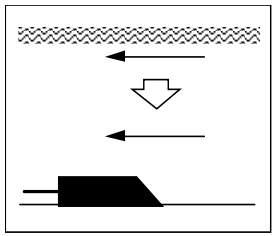
Pressure



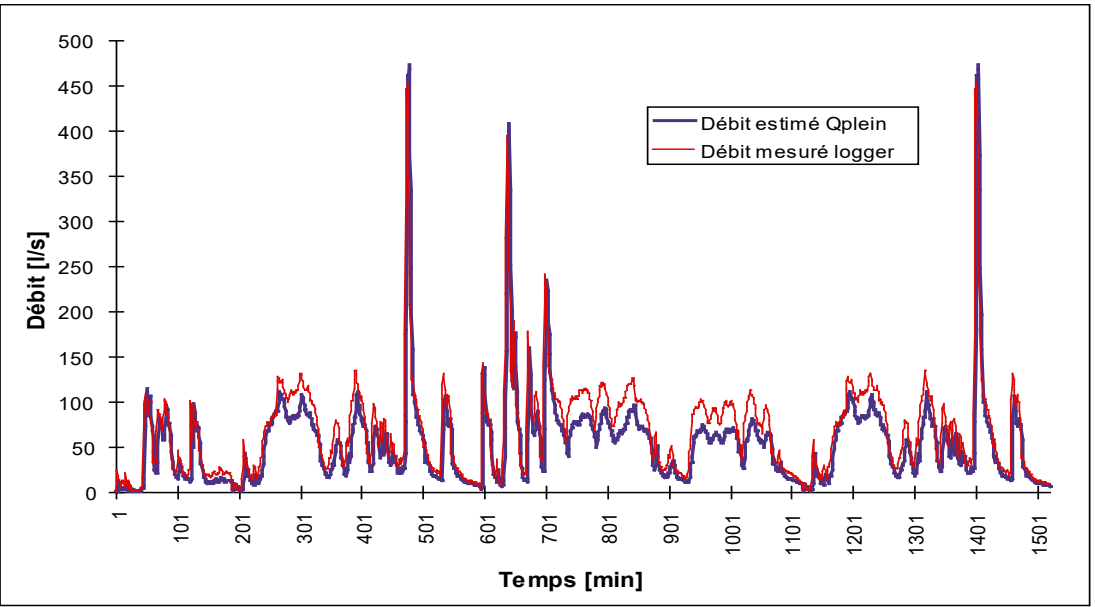
Ultrasonic



« Bubble » system



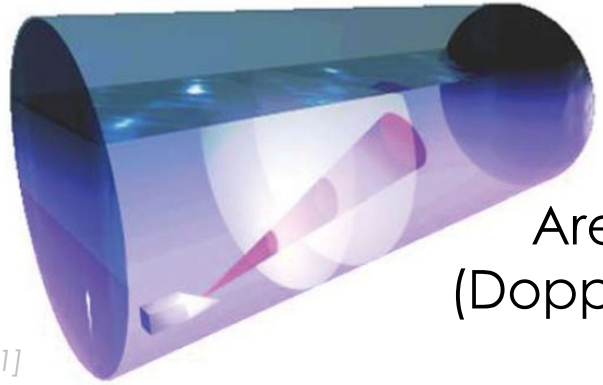
Area velocity (Doppler + pressure)




Level precision in this example: max. +/- 10%

# Typical flow measurements

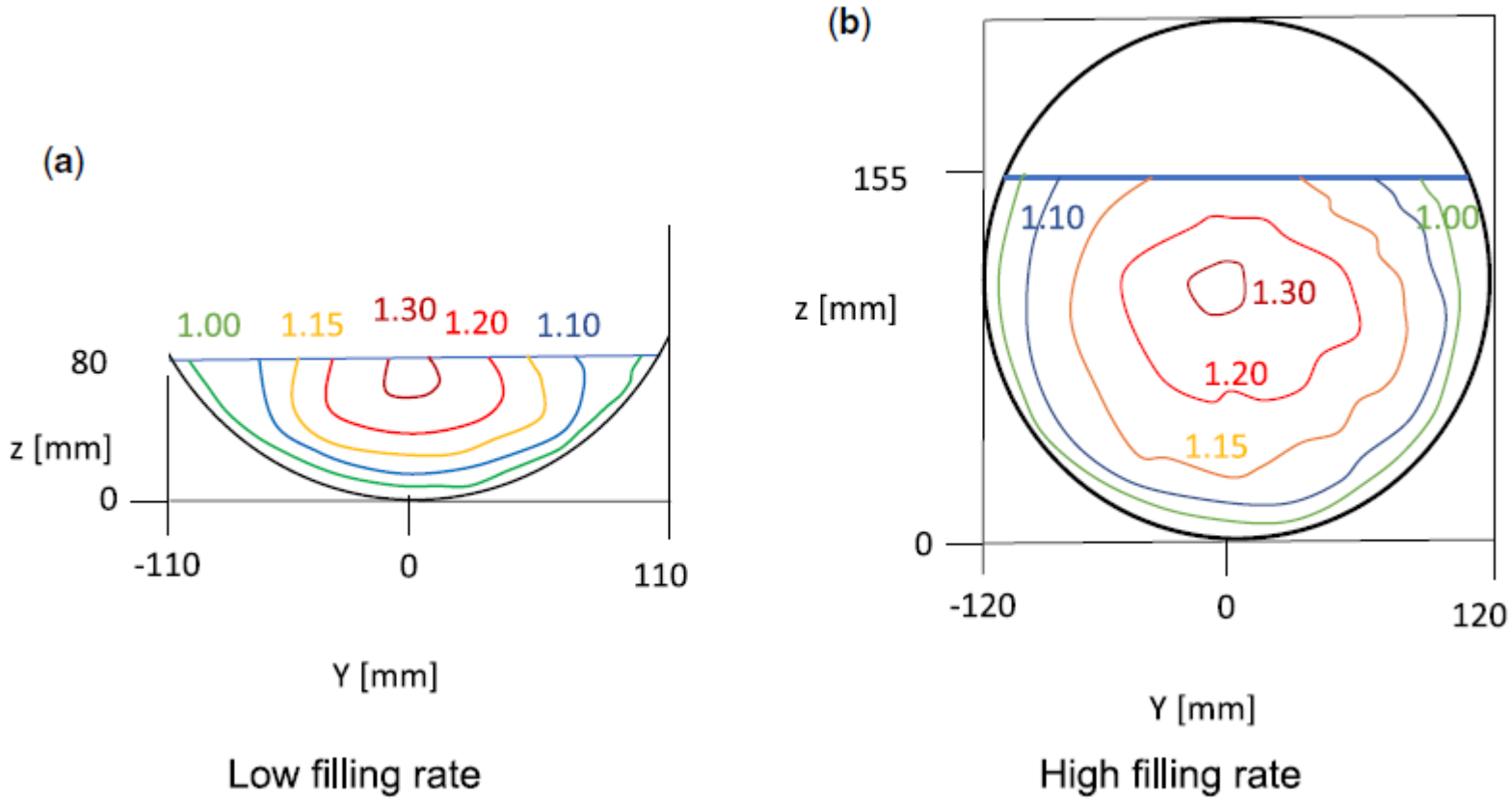
Ultrasonic



Area velocity
(Doppler + pressure)

# Typical flow measurements

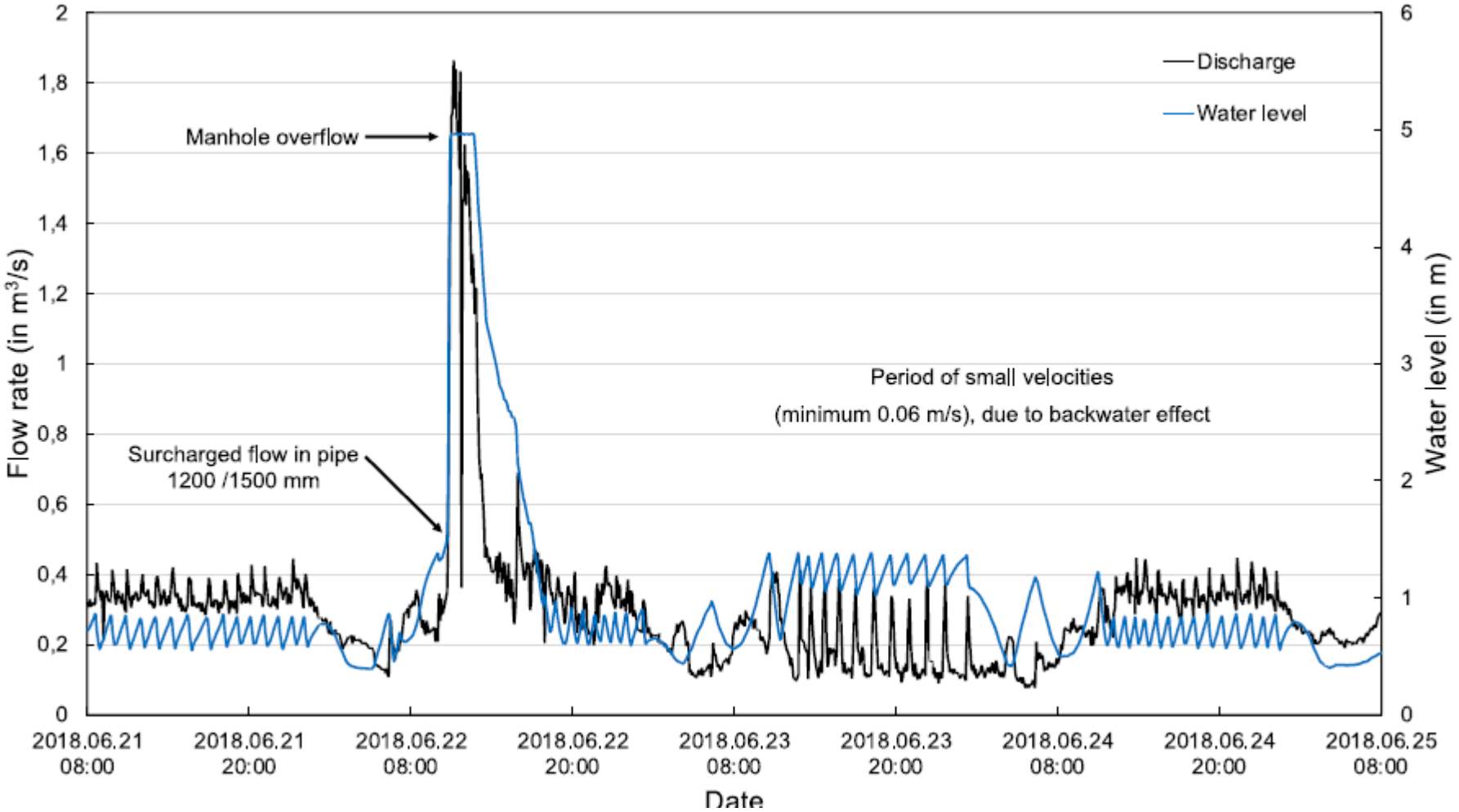
Importance of velocity measurements !




*Metrology in urban Drainage Jean-Luc Bertrand-Krajewski [2021]*

# Typical flow measurements

Importance of velocity measurements !



# Typical flow measurements

Sensor location

Goal for adequate measurement location:

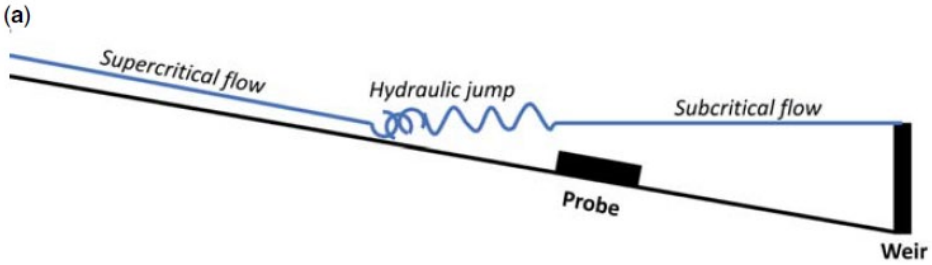
- > 10 x pipe diameter without slope change / water inputs / curve
- Good hydraulic conditions (low turbulence level

*Example EPFL measuring station near Rolex*

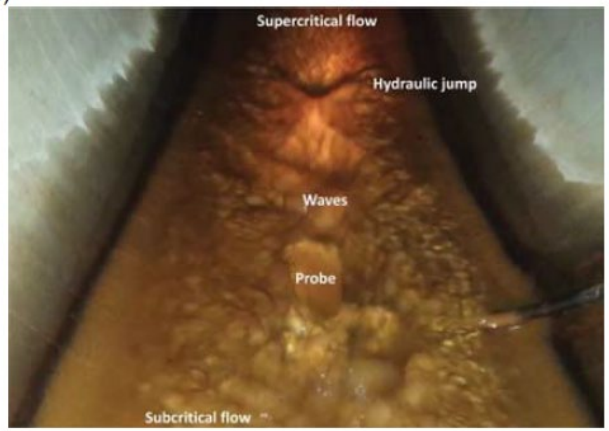
# Typical flow measurements

Sensor location

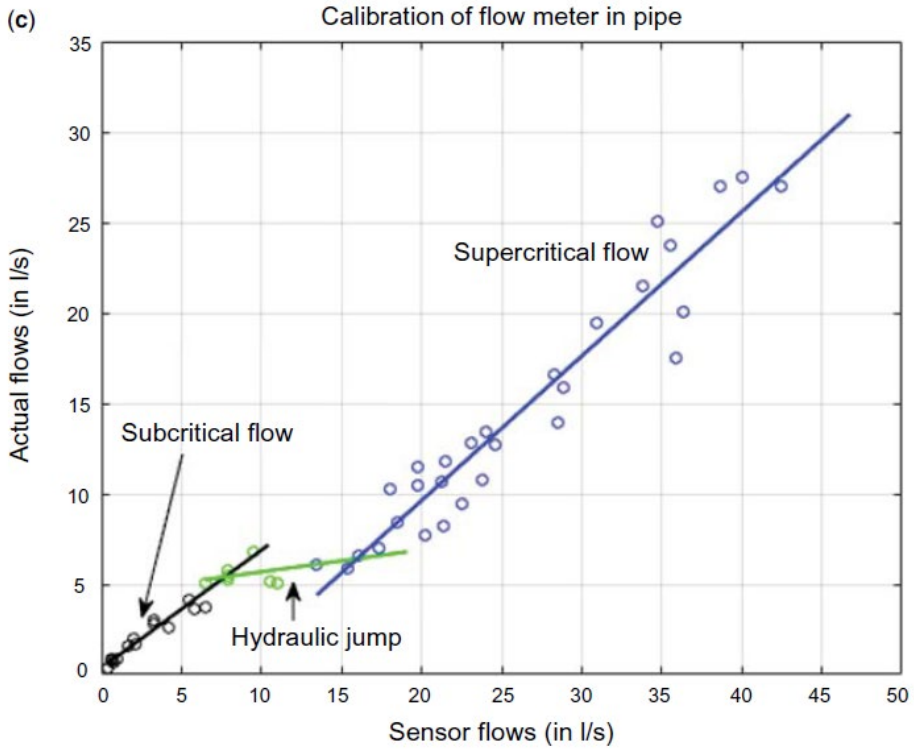
(a)




(b)




(c)

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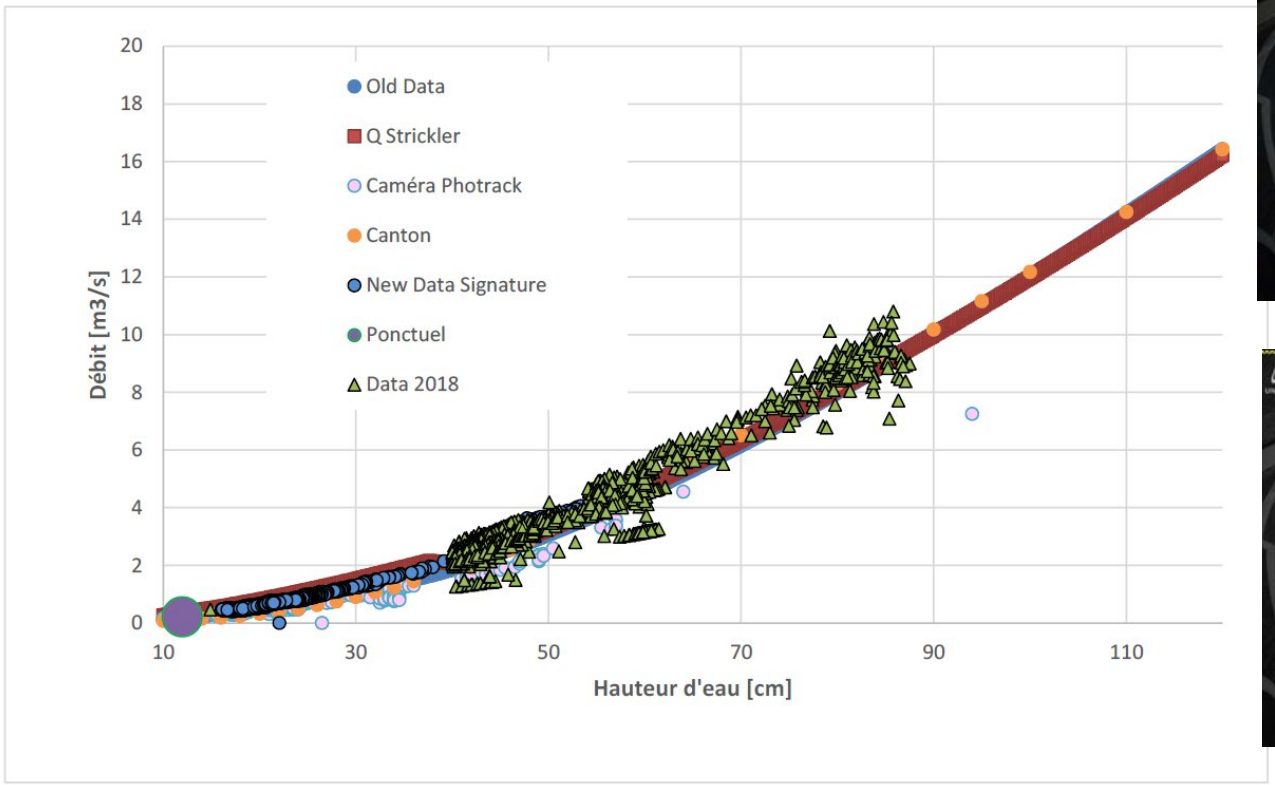
# Typical flow measurements

More sensors, better accuracy ?





# Typical flow measurements

Importance of maintenance !

(a)

(b)

(c)

(d)

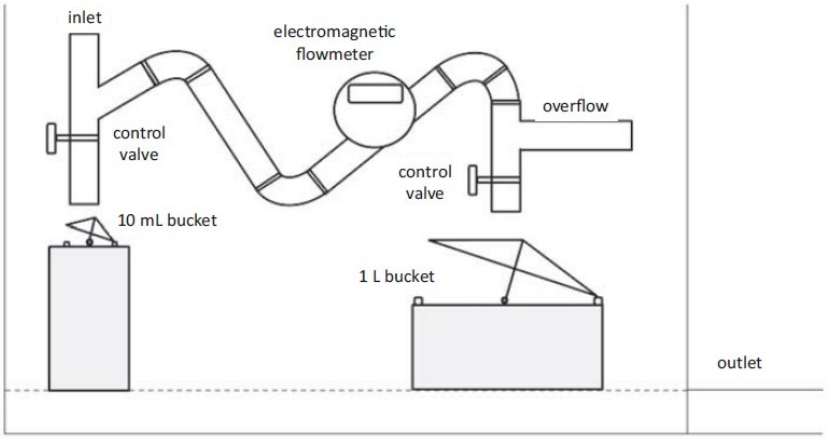
# Typical flow measurements

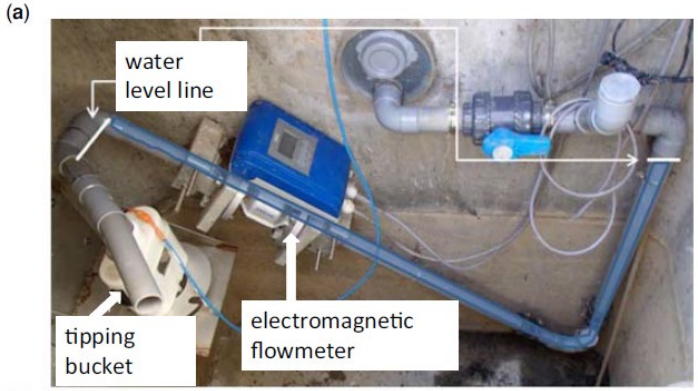
Importance of maintenance !

*Metrology in urban Drainage Jean-Luc Bertrand-Krajewski [2021]*

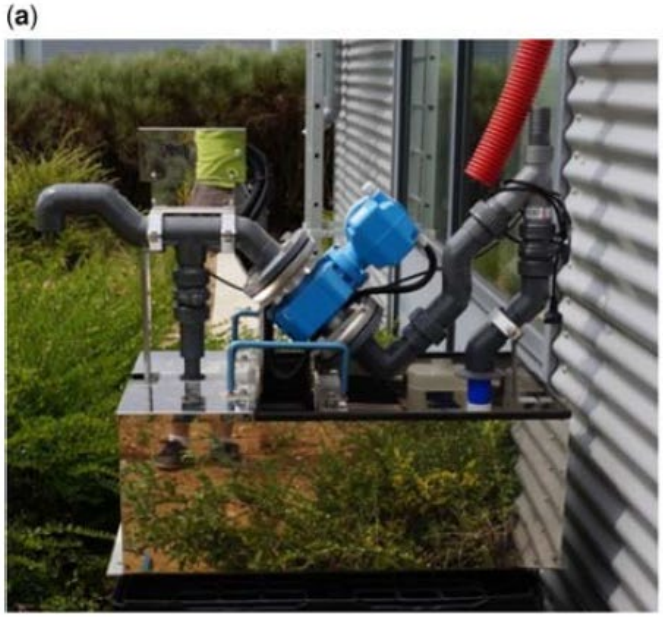
# Typical flow measurements

## Small flow measurements



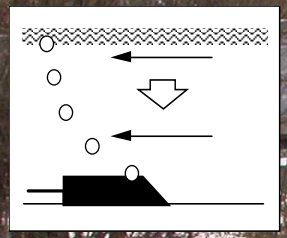


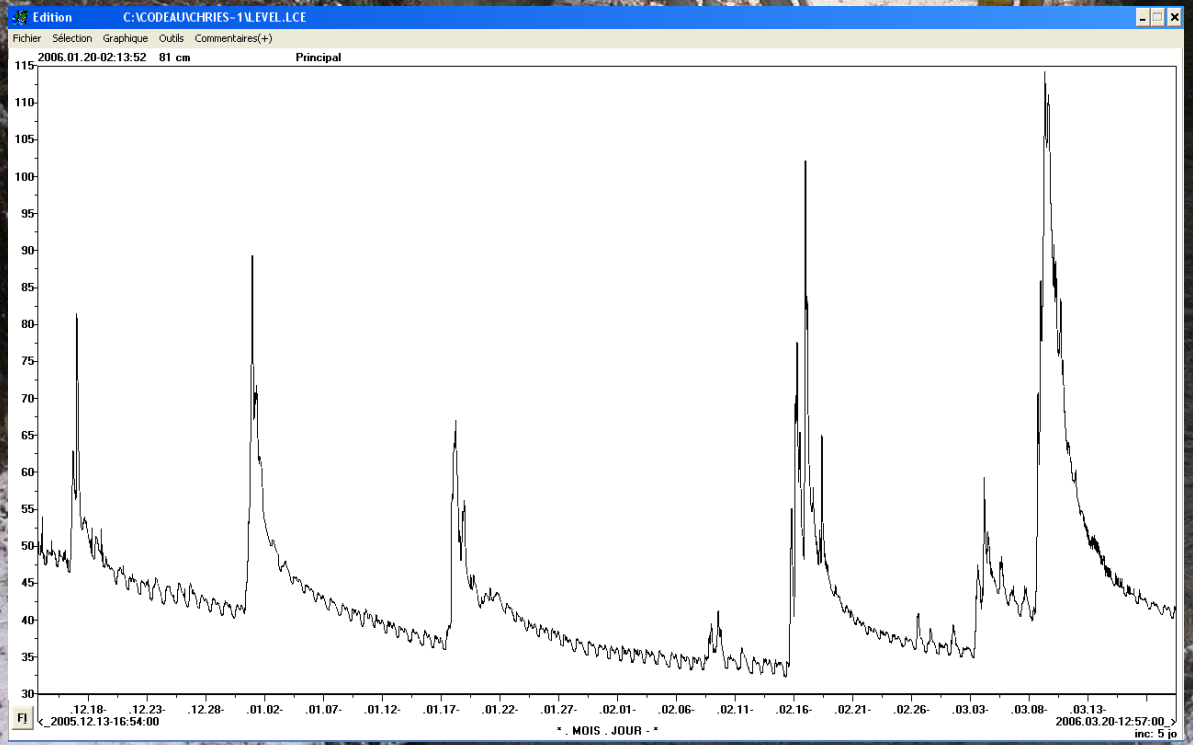




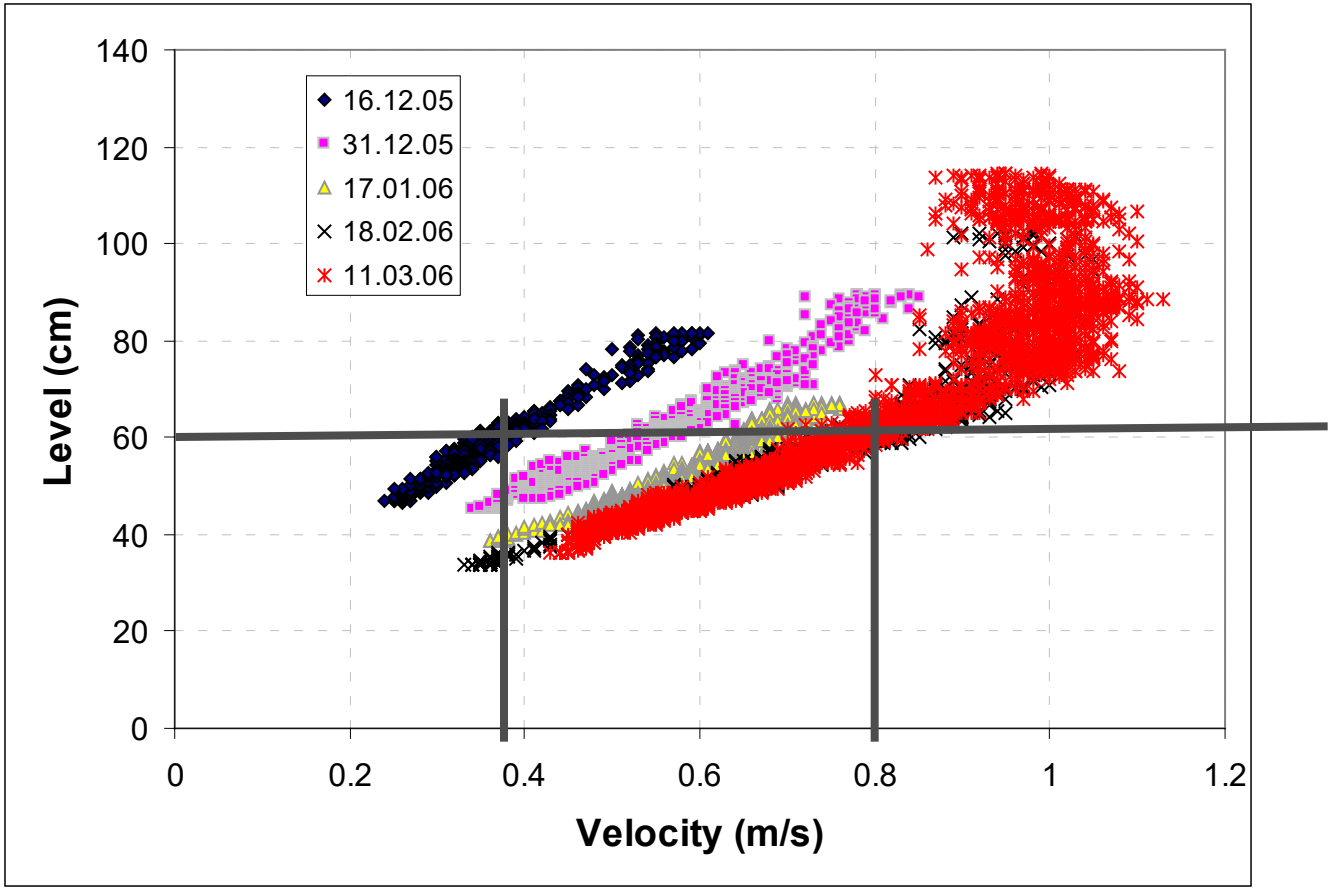
*Metrology in urban Drainage Jean-Luc Bertrand-Krajewski [2021]*

# « Bubble » system + flow velocity (Doppler)





# Flow measurement: rating curves in rivers

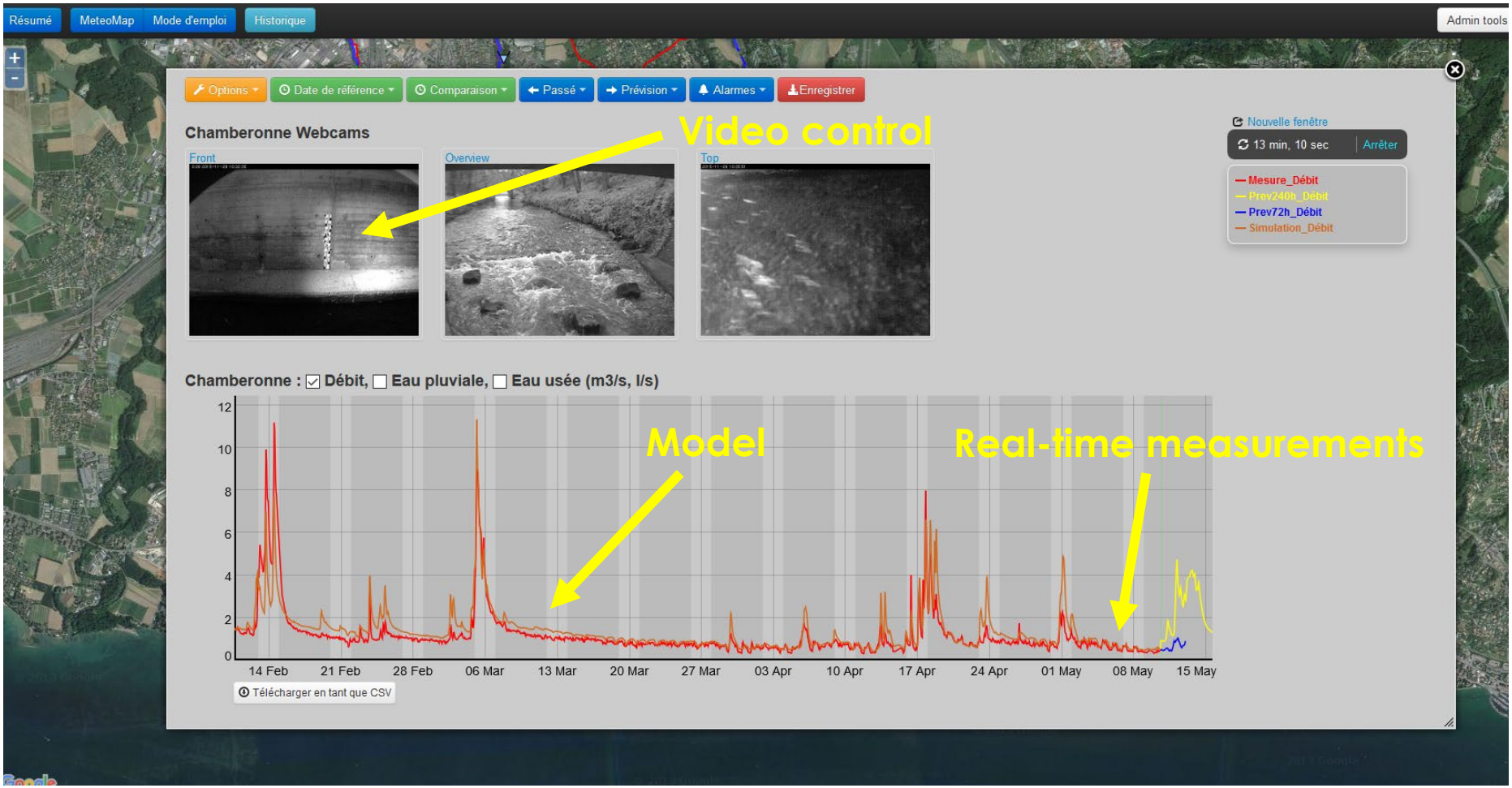



Flow velocity is an key parameter !!!

# Flow measurement: rating curves in rivers

Regular controls of rating curves are necessary !

# Flow measurement: Validity of measurements?



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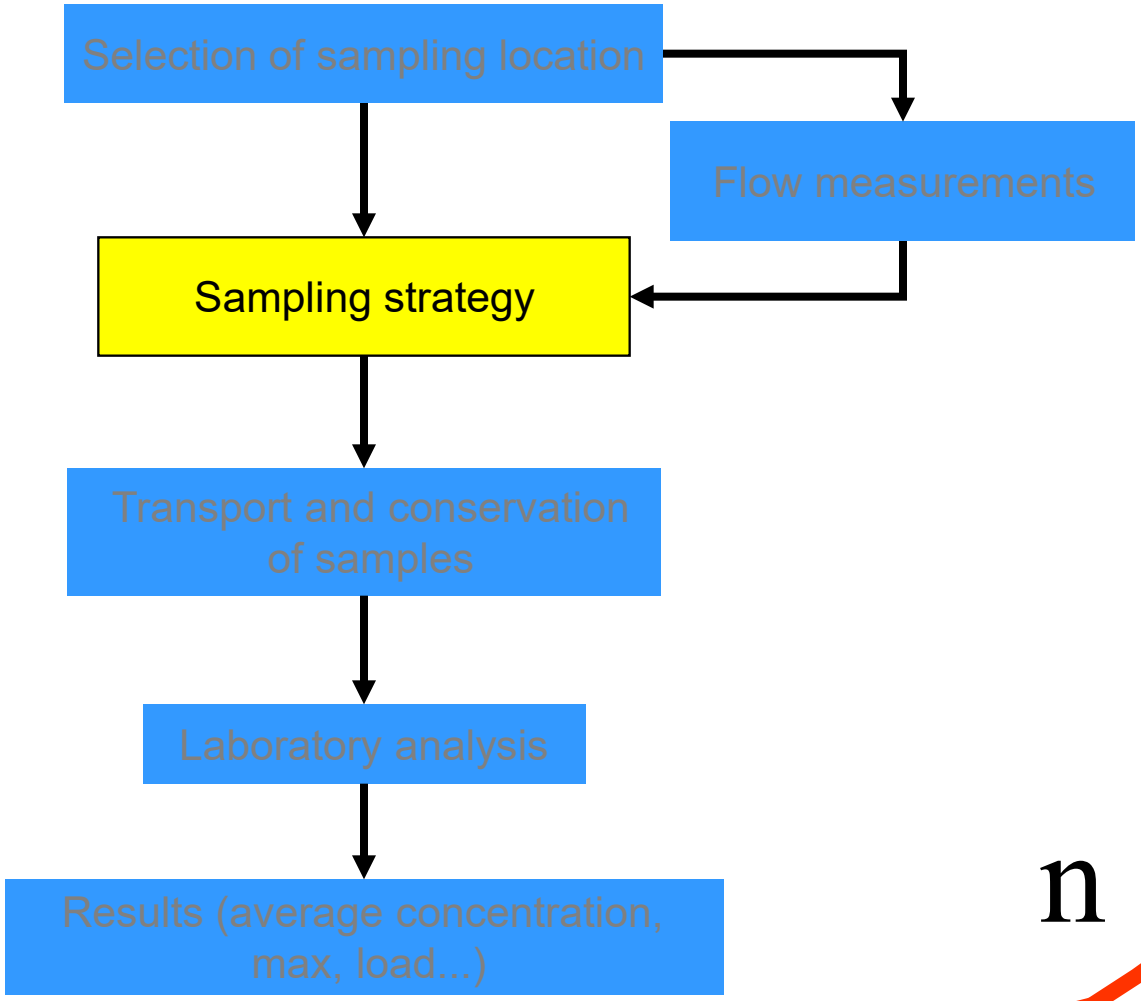
# Analytical procedure



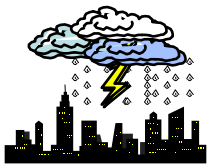

How ?

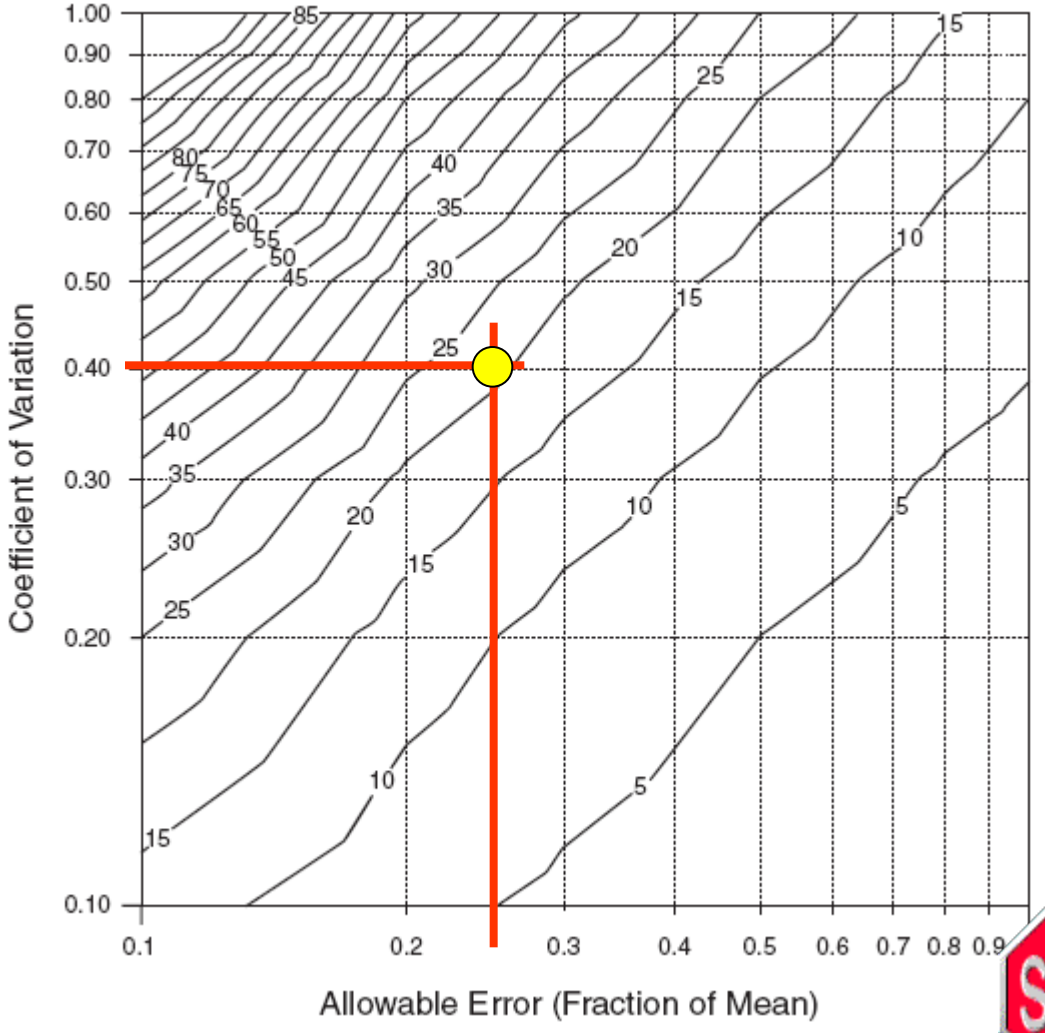
How many ?

$$n = \frac{B}{P_A}$$

No !

# No ideas about the number of samples needed? → rough estimation






$$n = \left[ \frac{CV \cdot Z_{1-\alpha}}{Error} \right]^2$$

Example:

Mean value 1.5 mg/l
Standard-dev. 0.6 mg/l

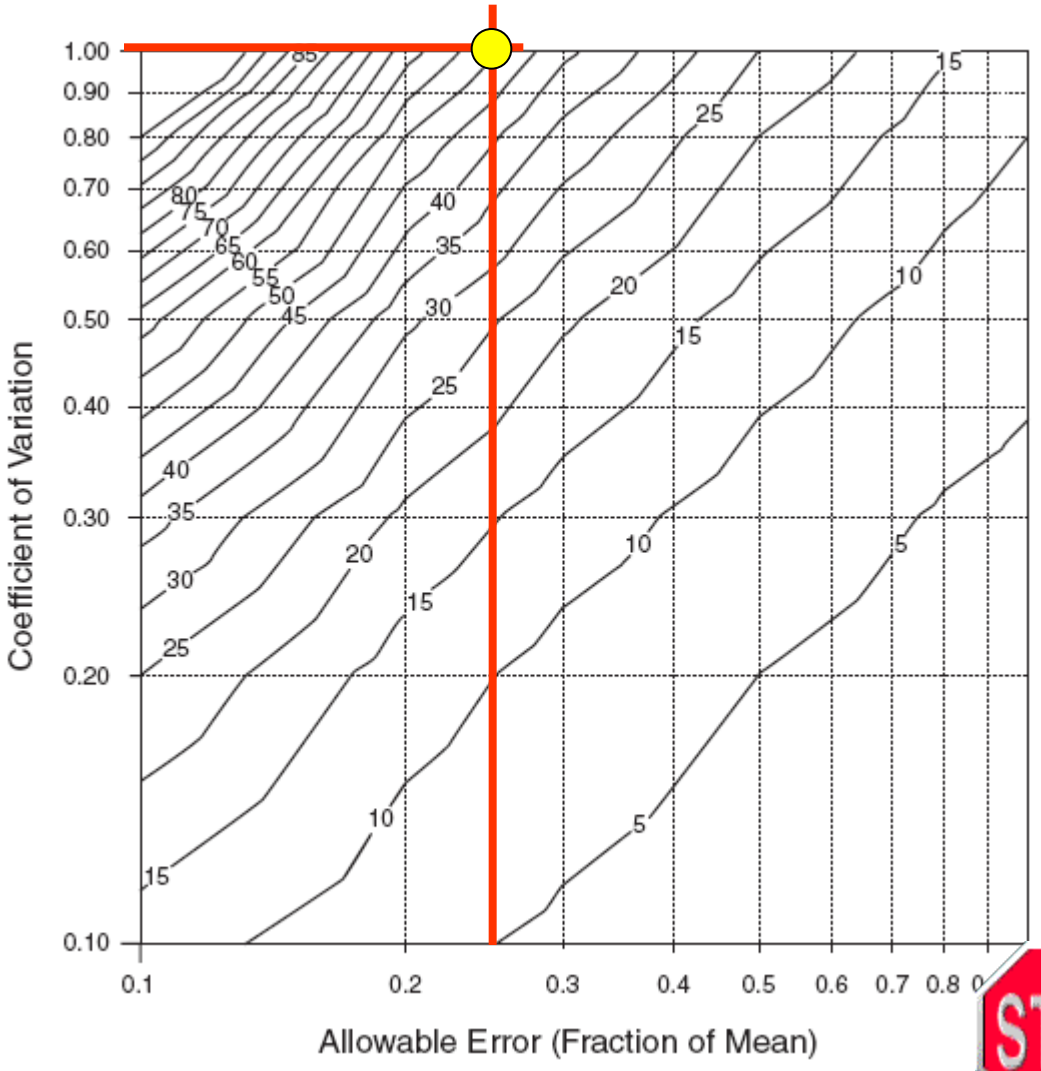
CV = Std/M = 0.4

Allowable error = 25%

**n = 20**


Normal distribution
No auto-correlation

# No ideas about the number of samples needed? → rough estimation




$$n = \left[ \frac{CV \cdot Z_{1-\alpha}}{Error} \right]^2$$

Example:

Mean value 1.5 mg/l

Standard-dev ~~0.6~~ 1.5 mg/l

CV = Std/M = ~~0.4~~ 1.0

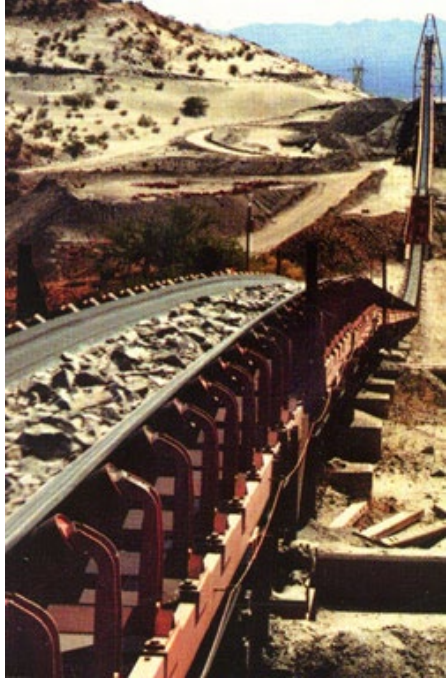
Allowable error = 25%

n = ~~20~~ 50


Normal distribution

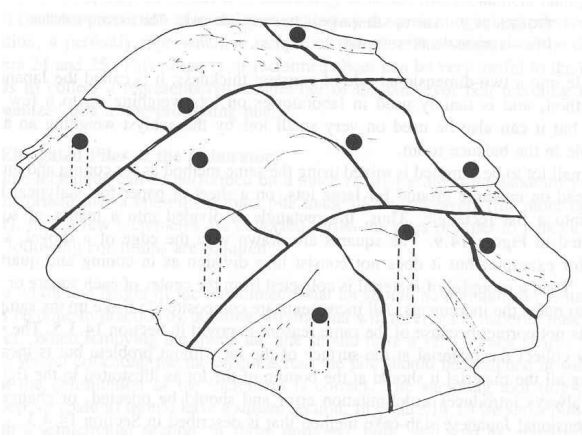
No auto-correlation

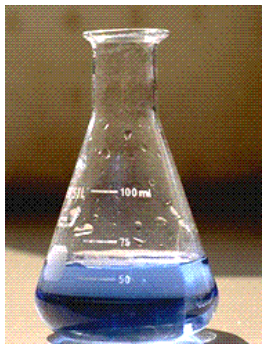
# Pierre Gy‘s sampling theory



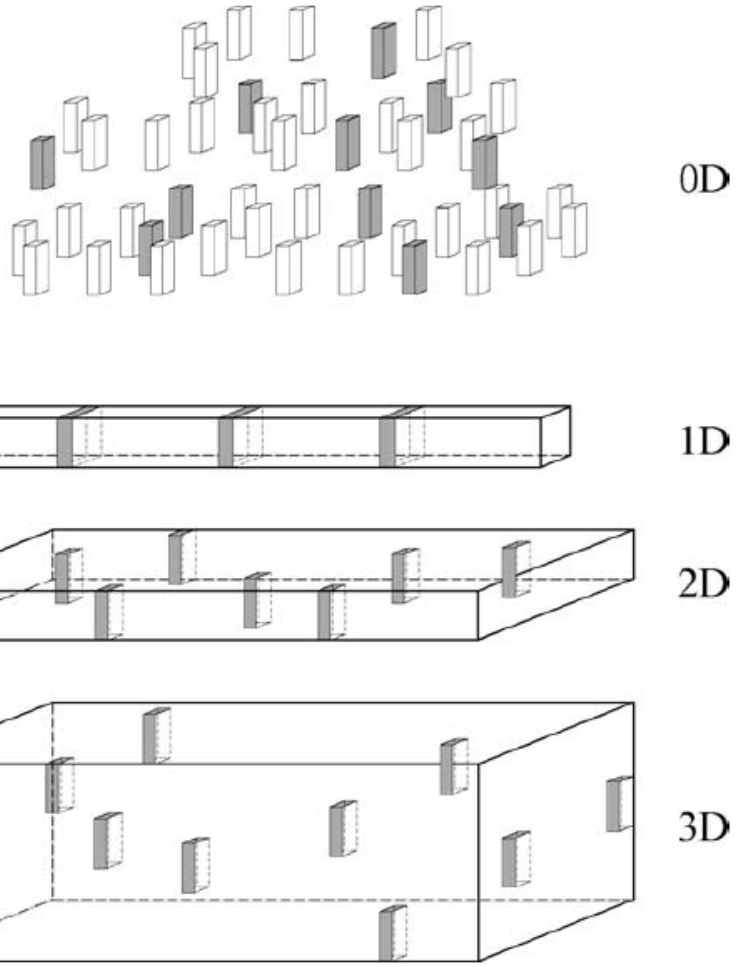
- Scientific approach of sampling
- Application specifically developed for mines and particulate materials;
- Application in different topics, also for the environment (hazardous waste, water quality...);
- Multidimensional application: zero dimension, one-dimensional lot (stream, conveyor belt), two-dimension, three-dimension lots (geological application);
- “Intuitions” into mathematical concepts
- Numerous uncommon concepts...

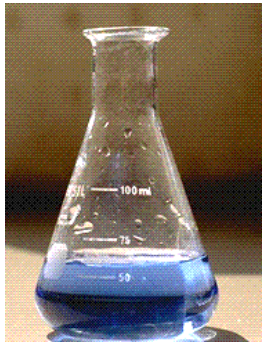
*Petersen et al. 2005*

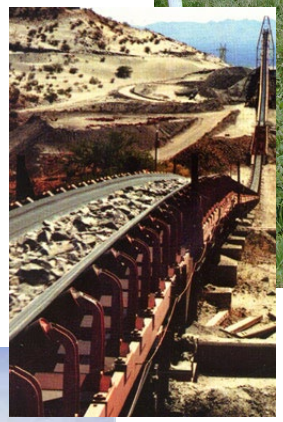


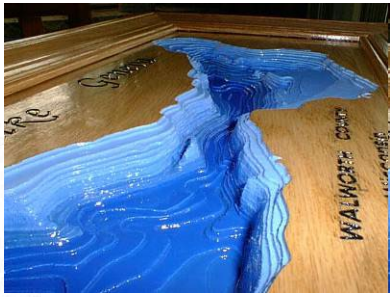



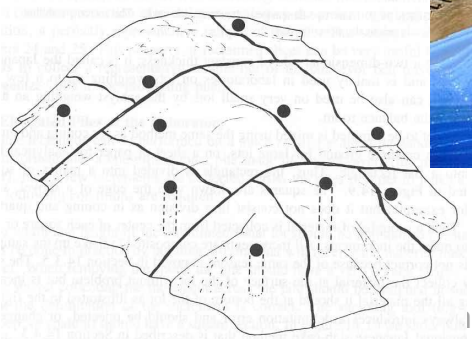
# Pierre Gy‘s sampling theory



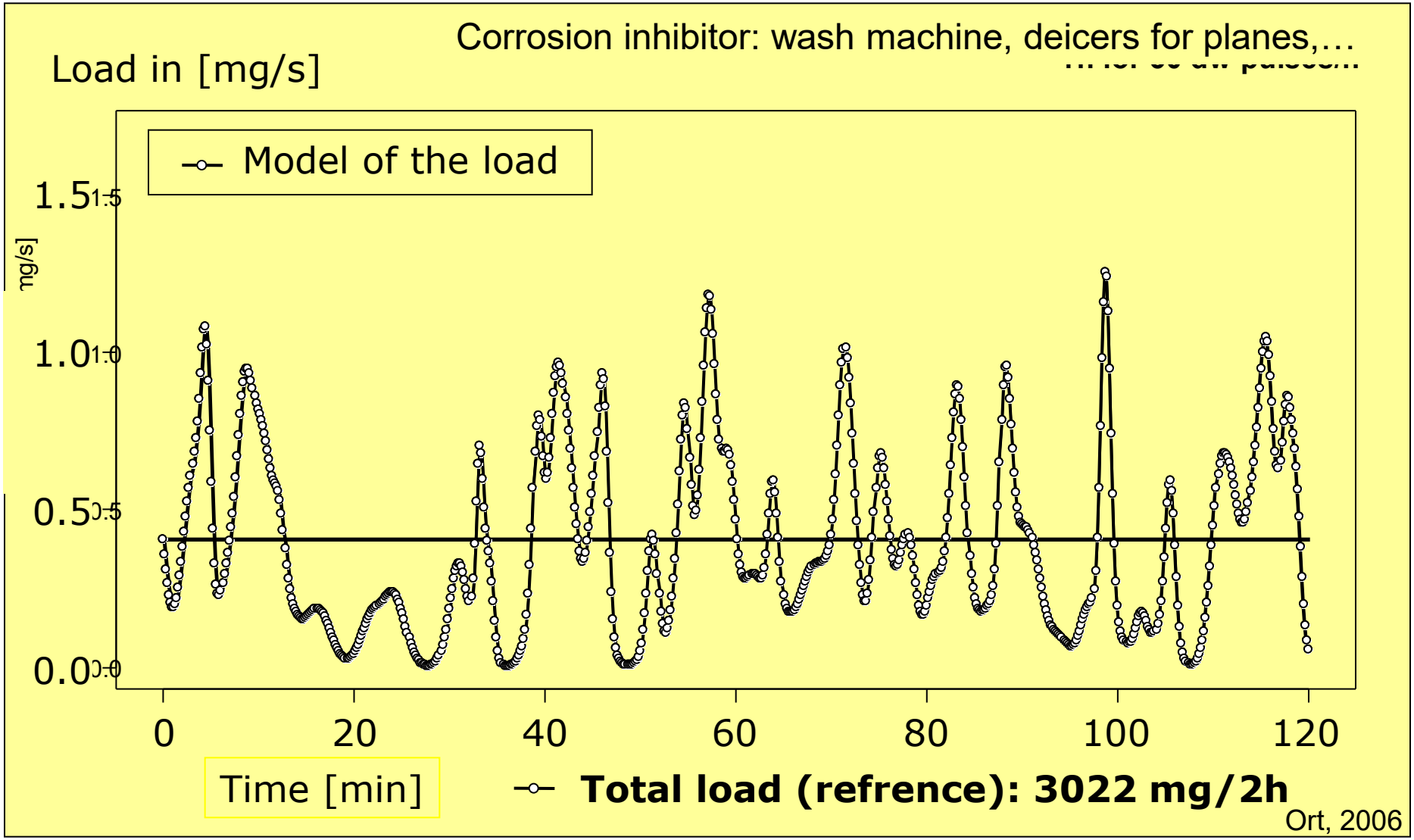






*Petersen et al. 2005*

# Heterogeneity and number of samples: example benzotriazol in a sewer system



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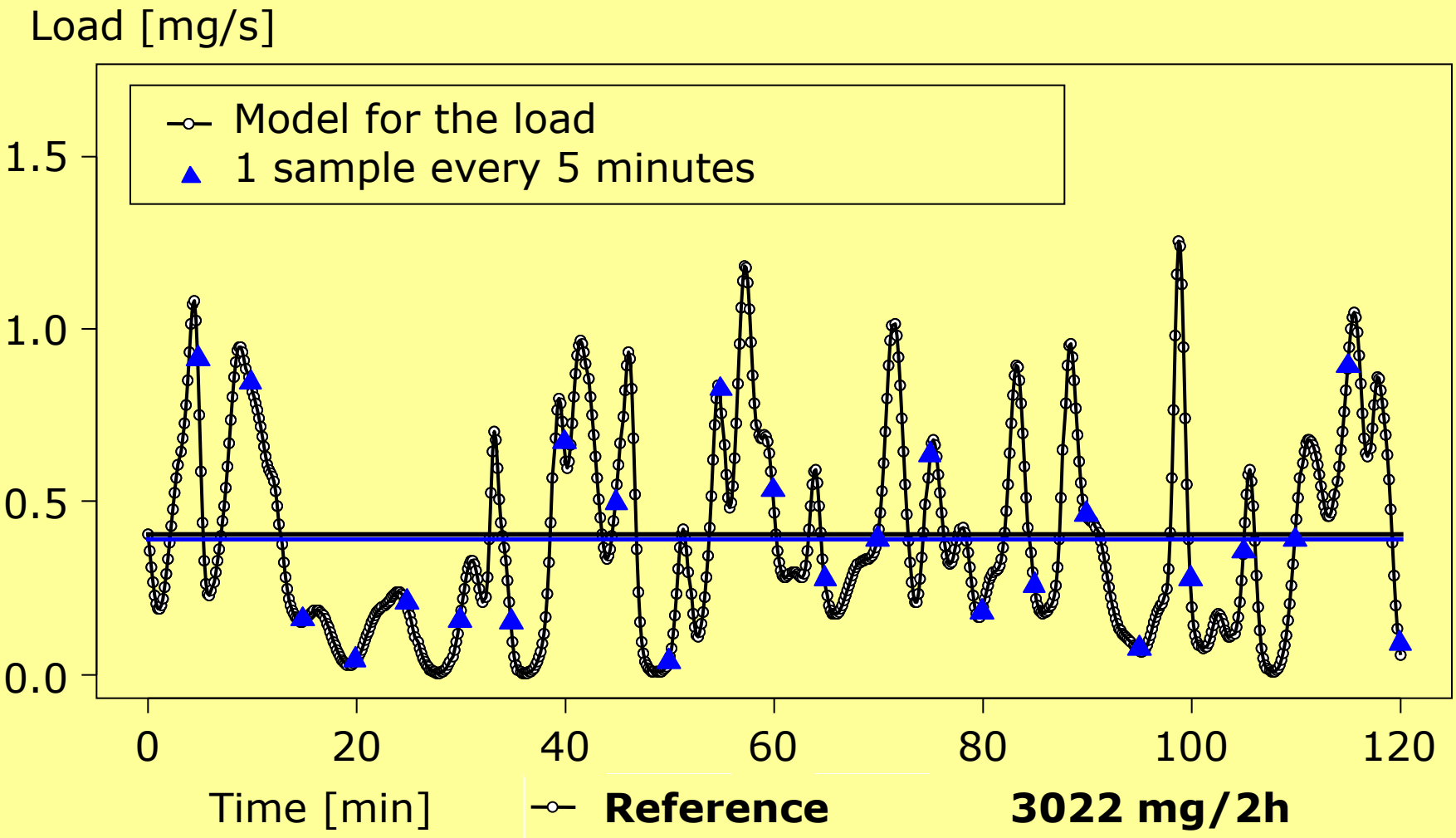
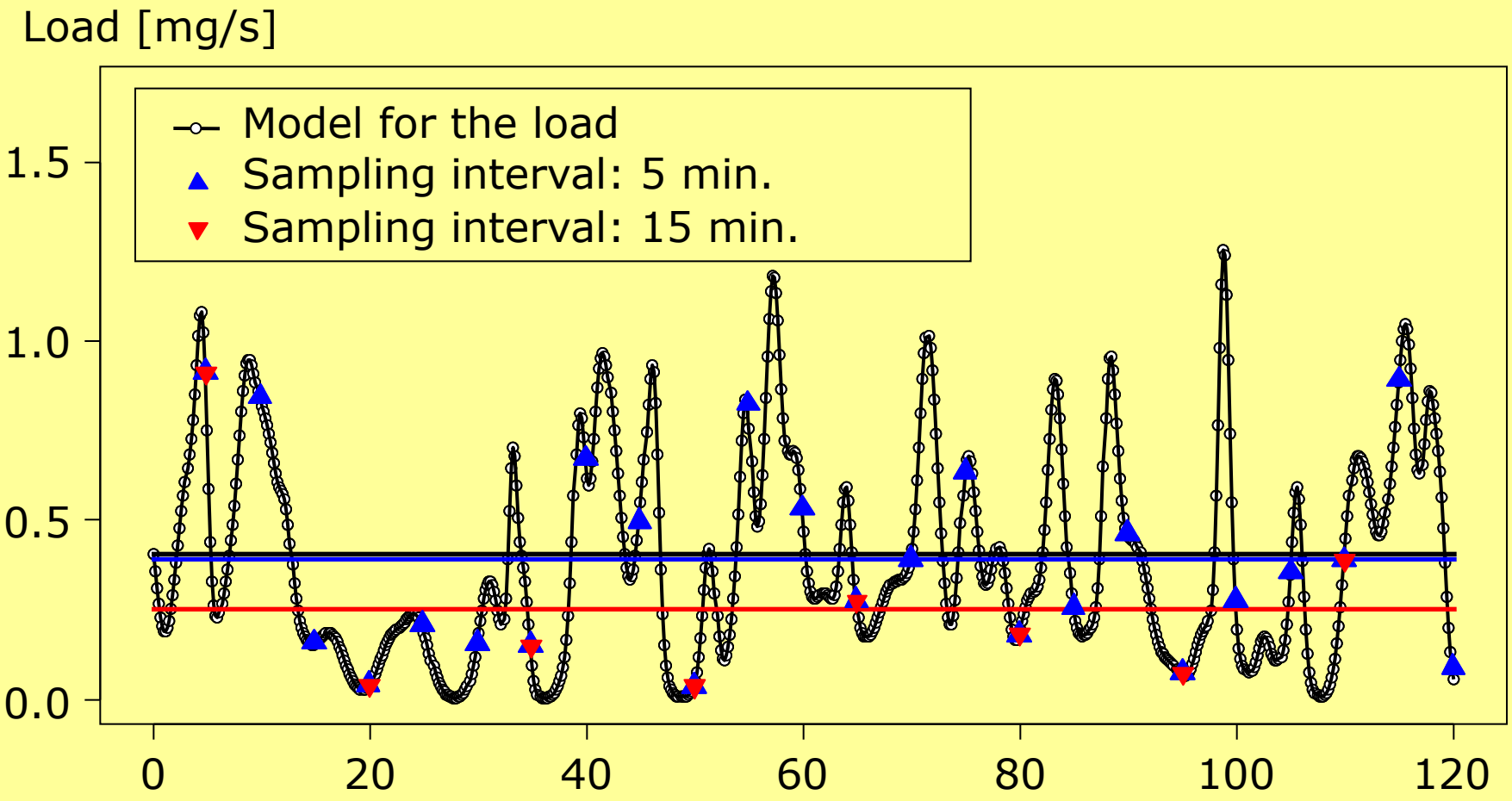



**Reference** **3022 mg/2h**

**Load over 2 hours 2954 mg/2h (-2.3%), 24 samples**

Ort, 2006

# Heterogeneity and number of samples: example benzotriazol in a sewer system

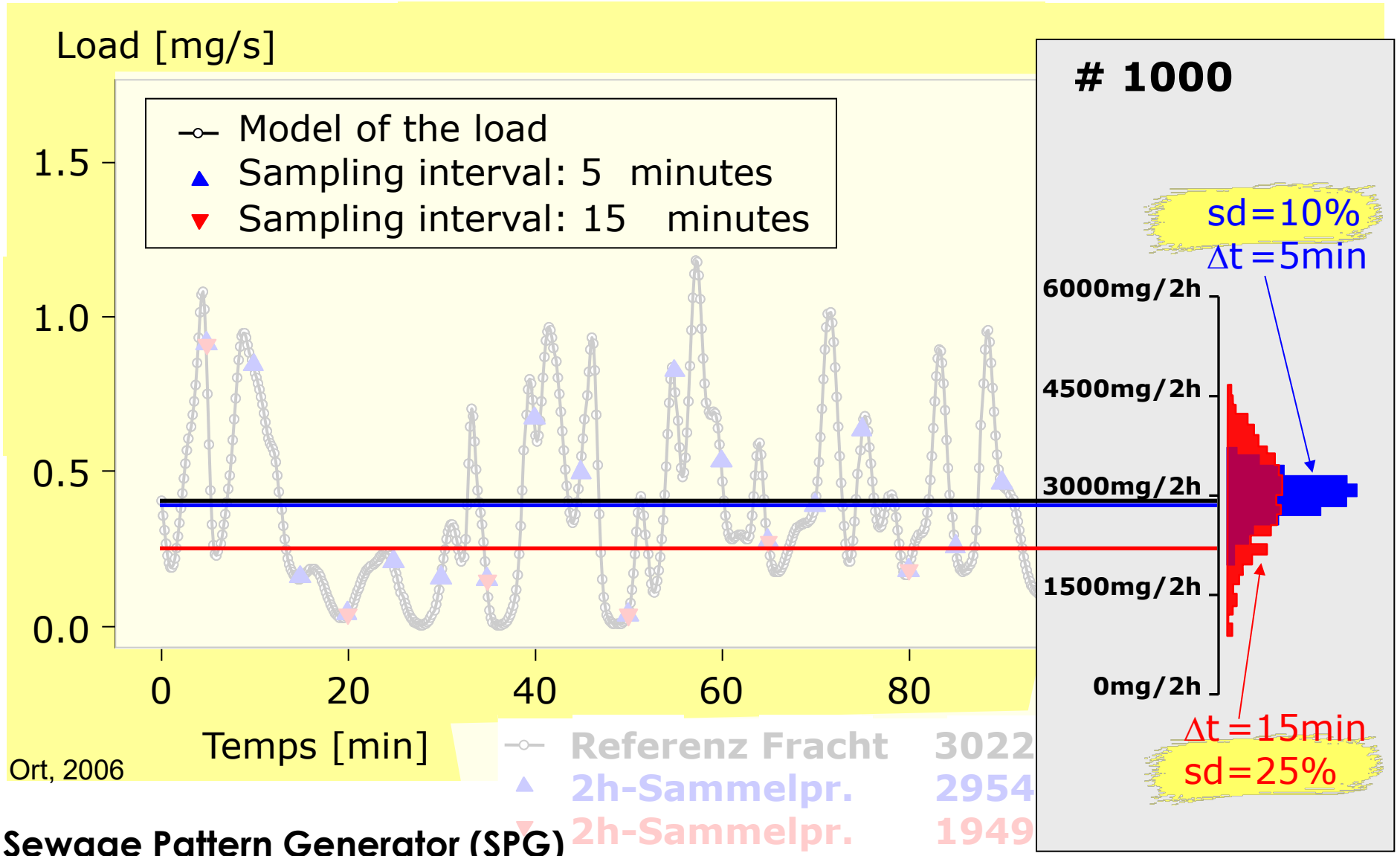



| | | |
|---|---|---|
| | **Reference** | **3022 mg/2h** |
| ▲ | **Samples 2h** | **2954 mg/2h ( -2.3%)** |
| ▼ | **Samples 2h** | **1949 mg/2h (-35.5%)** |

**8 samples**

Ort, 2006

# Heterogeneity and number of samples: example benzotriazol in a sewer system

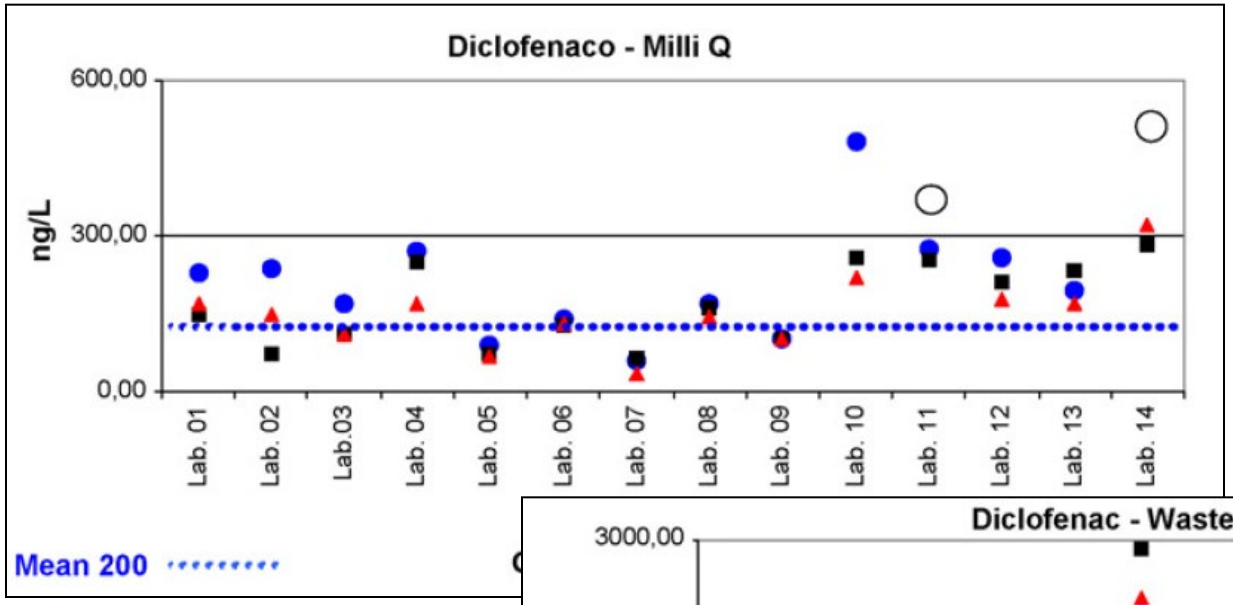



**Sewage Pattern Generator (SPG)**

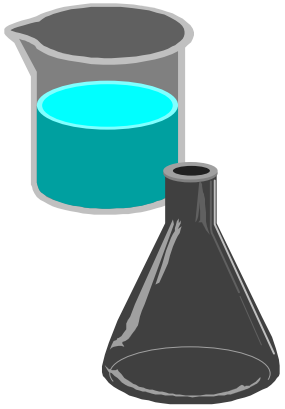
https://www.eawag.ch/en/department/sww/software/

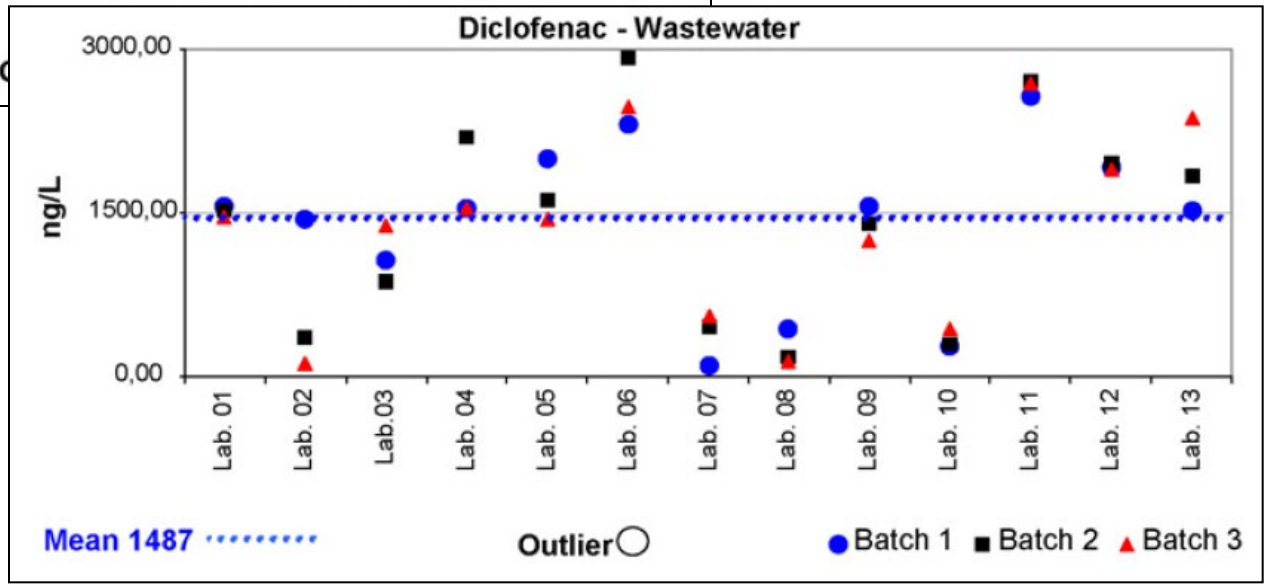
# Uncertainties in laboratory analysis

*"First interlaboratory exercise on non-steroidal anti-inflammatory drugs analysis in environmental samples"* Farré et al., Talanta 76 (2008) 580–590



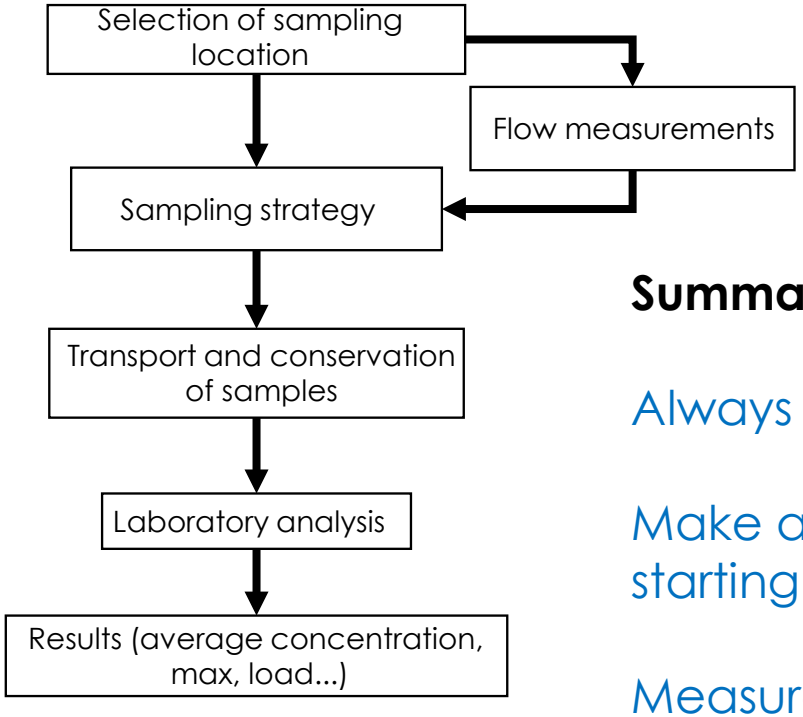

**Participation to ring tests !**






https://sisu.ut.ee/wp-content/uploads/sites/18/estimation_of_measurement_uncertainty_printout_2016-2.pdf

# Analytical procedure




**Summary**

Always conduct a pre-sampling campaign test

Make assumption / sampling model before starting measurement : «What if…»

Measurement uncertainties:

- Flow ± 20%
- Environmental samples ± 30%

Always quantify uncertainties in your results

Anticipate results and interpretation: « if I have all data available…»

# Table of content

- Introduction
- Analytical procedure
- Flow measurements
- Scientific approach of sampling:
  - How and where should I take samples?
  - How many samples do I need?
  - What are the sources of uncertainties?
- **New trends in sampling and flow measurements**

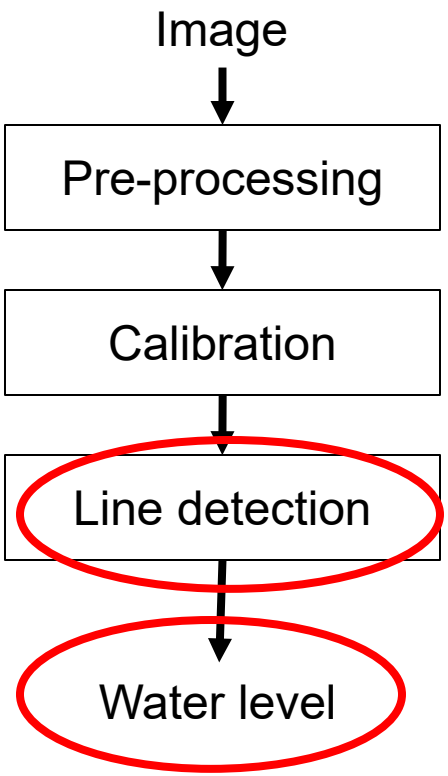
# New : Flowrate measurements based on video monitoring



« Dischargekeeper »
SEBA technology
www.seba-hydrometrie.com

www.photrack.ch/

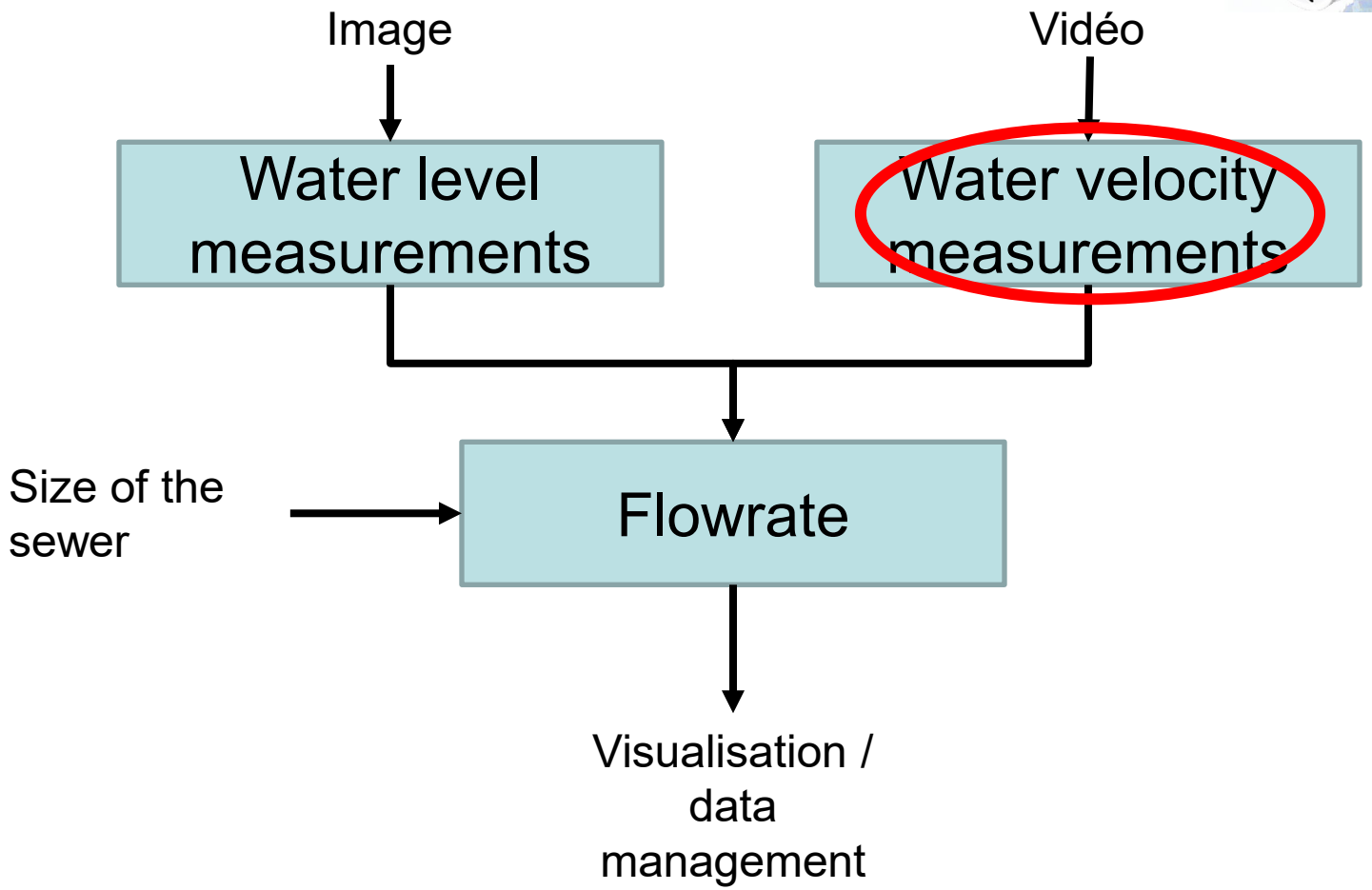
# New : Flowrate measurements based on video monitoring



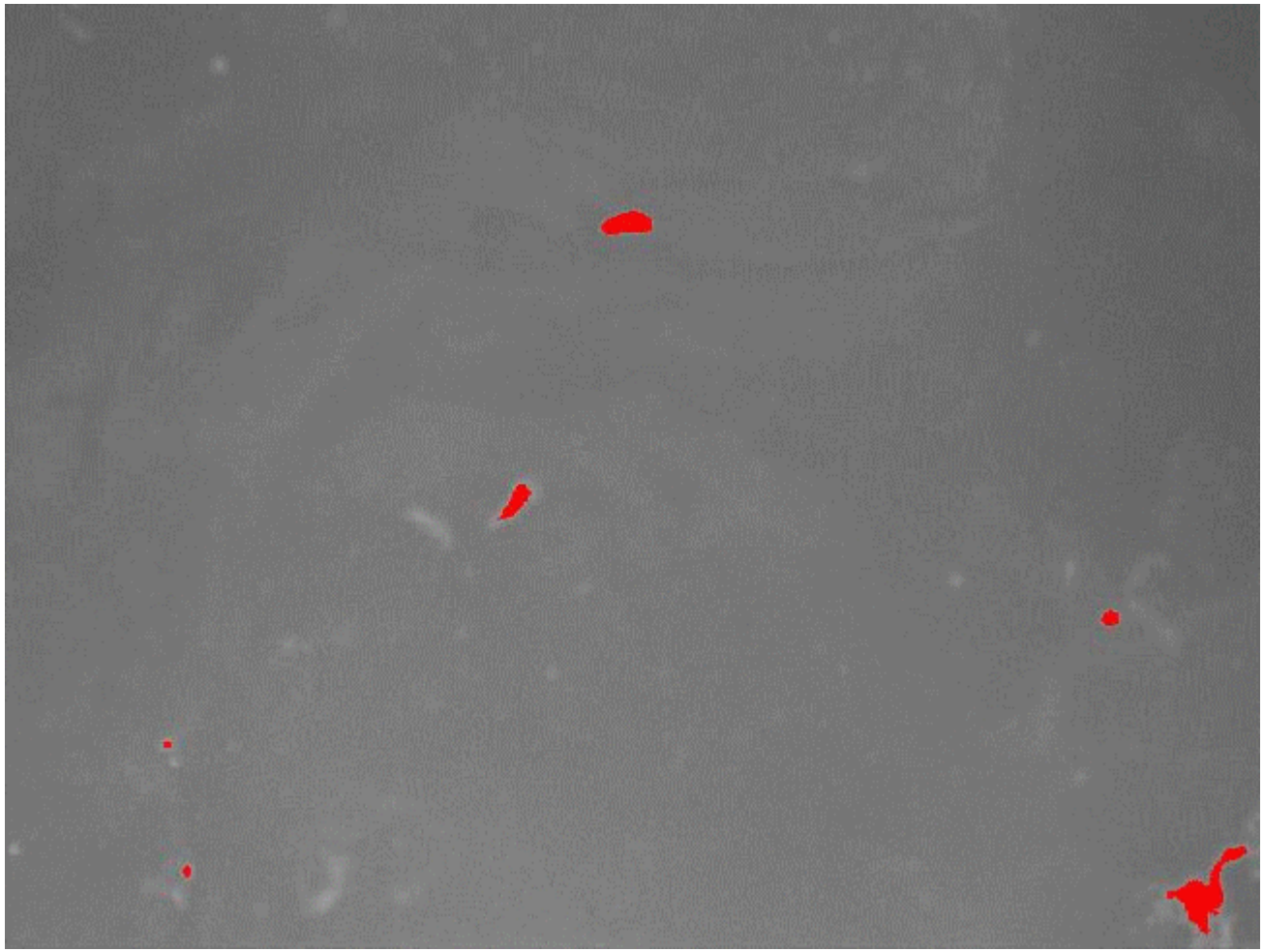


*Nguyen L, Schaeli B, Sage D, Kayal S, Jeanbourquin D, Barry DA, Rossi L (2009) Vision-based system for the control and measurement of wastewater flow rate in sewer systems. Water Science and Technology 60.9: 2281-2289*

# New : Flowrate measurements based on video monitoring



# Example of results (entry of WWTP Vidy)



# Example of results (CSO Berna)

# On-line measurements

- No sampling errors
- Important number of measurement ≈„samples“, but with less „accuracy“
- Correlation with lab analysis
- Maintenance and calibration on a regular basis
- A signal is always generated...

# On-line measurement devices: examples




http://www.ch.endress.com/fr/instrumentation-terrain-sur-mesure/analyse-liquides-produits
www.wtw.com
www.hach.com

Also in ecotoxicology: On-line effects detection systems (Daphnia, Microtox, mussels…) as early-warning systems

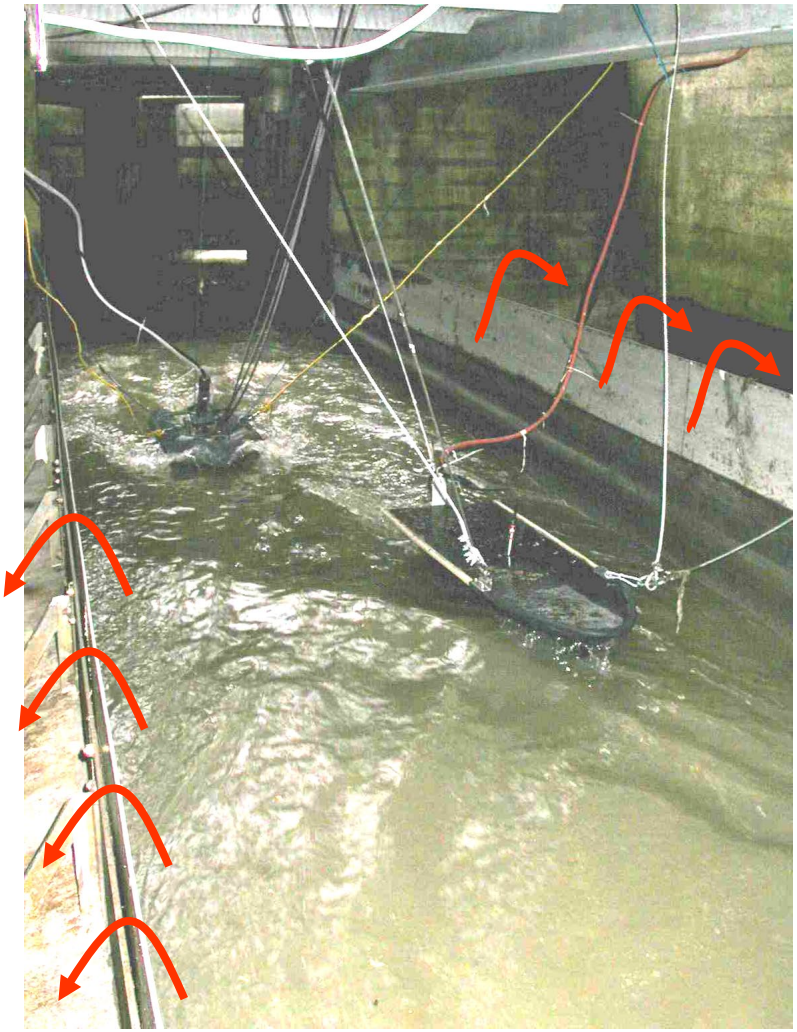
http://www.analyzersonline.co.za/toxicity/analyser-products/modern-water-analyzers/toxicity

# On-line measurement: examples

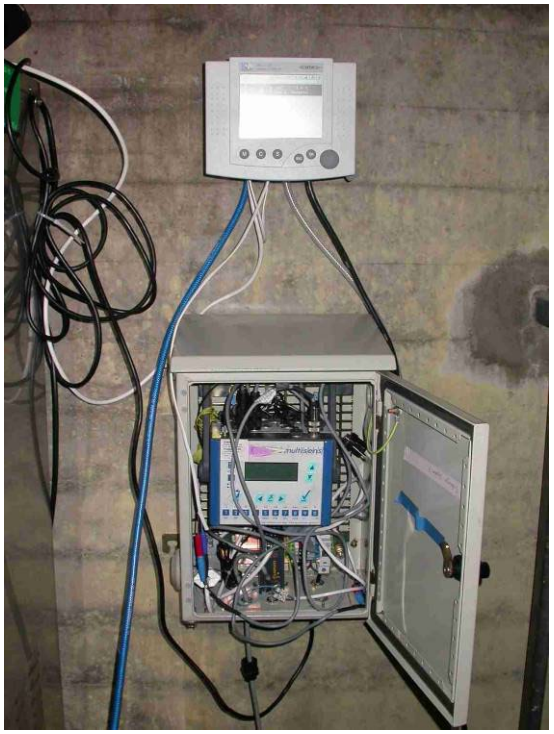

**Absorbance with submersible UV-VIS spectrometer**


http://www.s-can.at/fr/

# On-line measurements: examples at the inlet of a WWTP

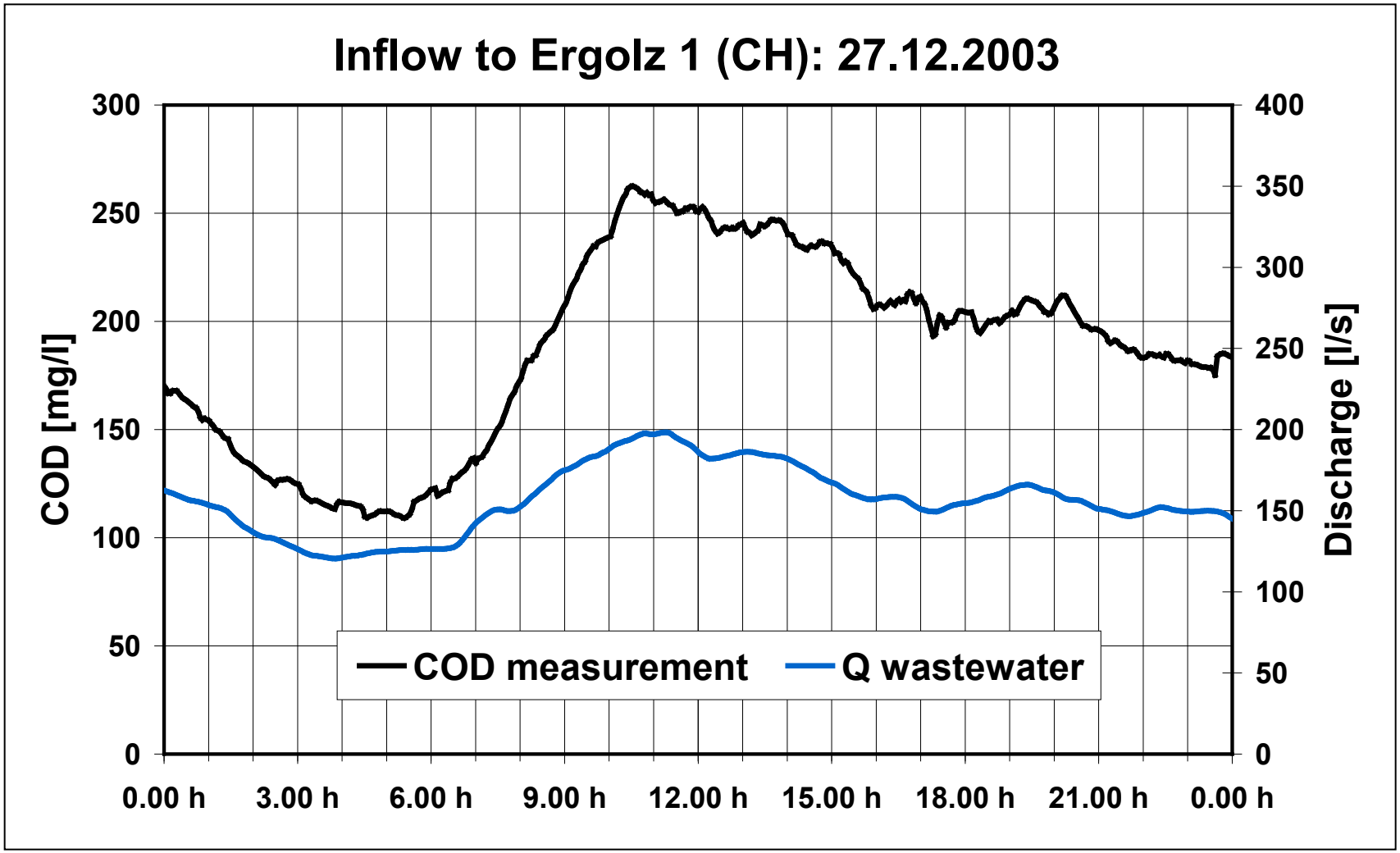


- Flowrate
- Online Ammonium
- S::SCAN



# On-line measurements: S::CAN

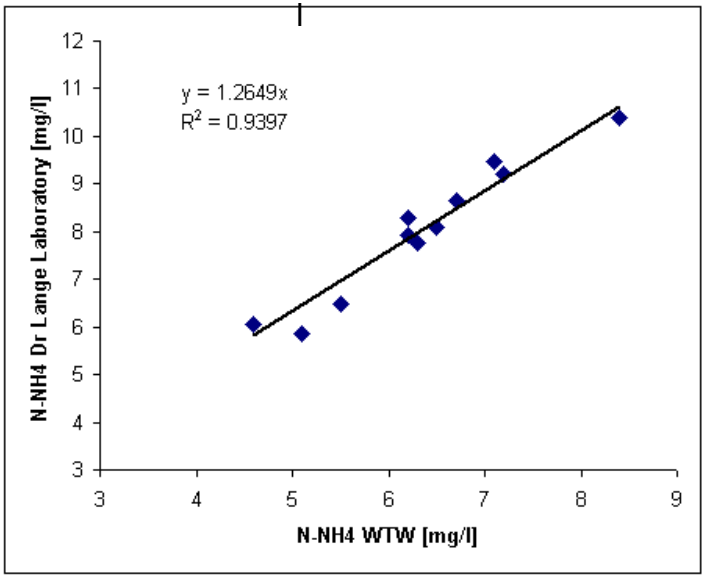
## example: COD time series in Ergolz



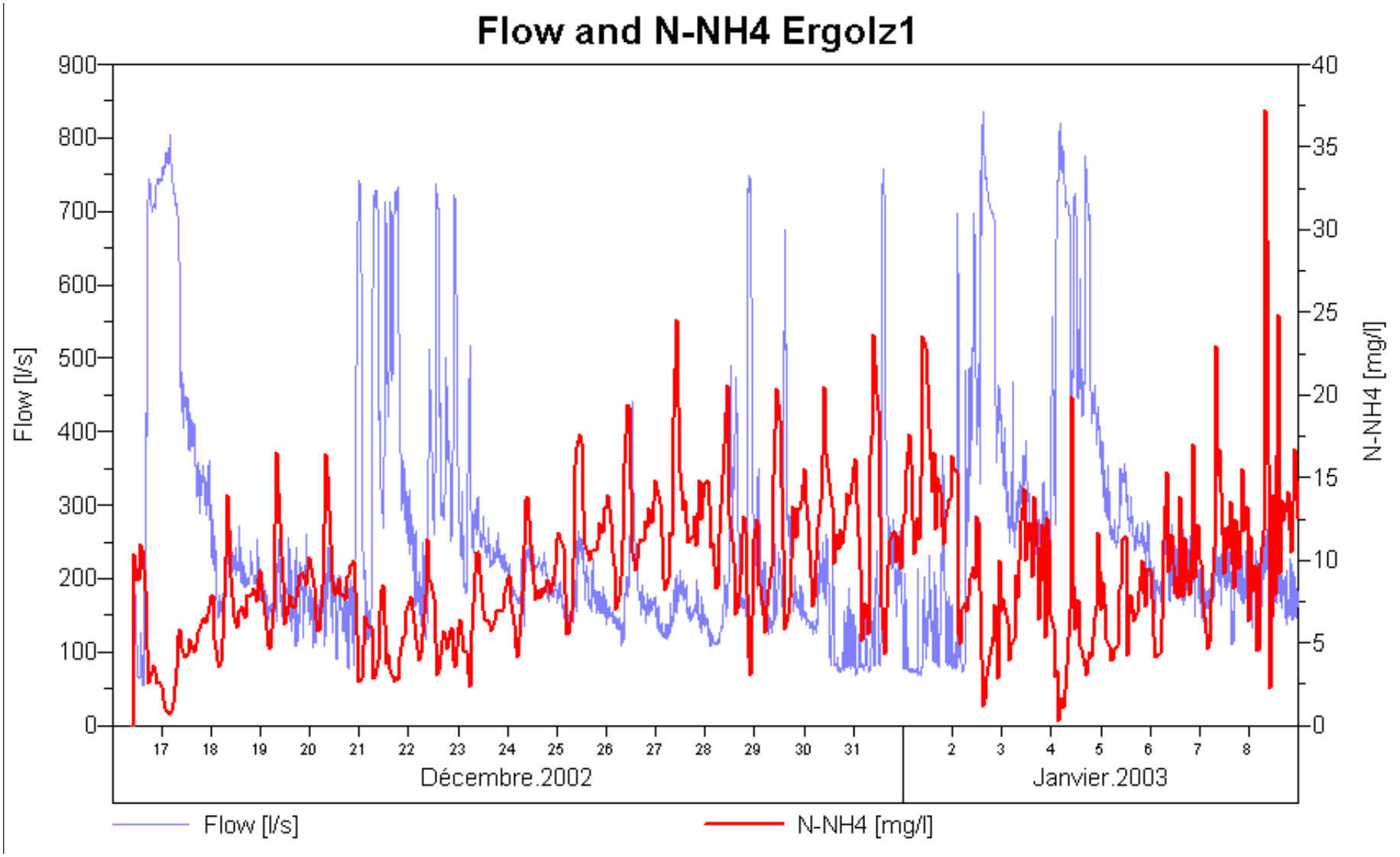
# On-line measurements: ammonia


www.wtw.com/en/home.htm

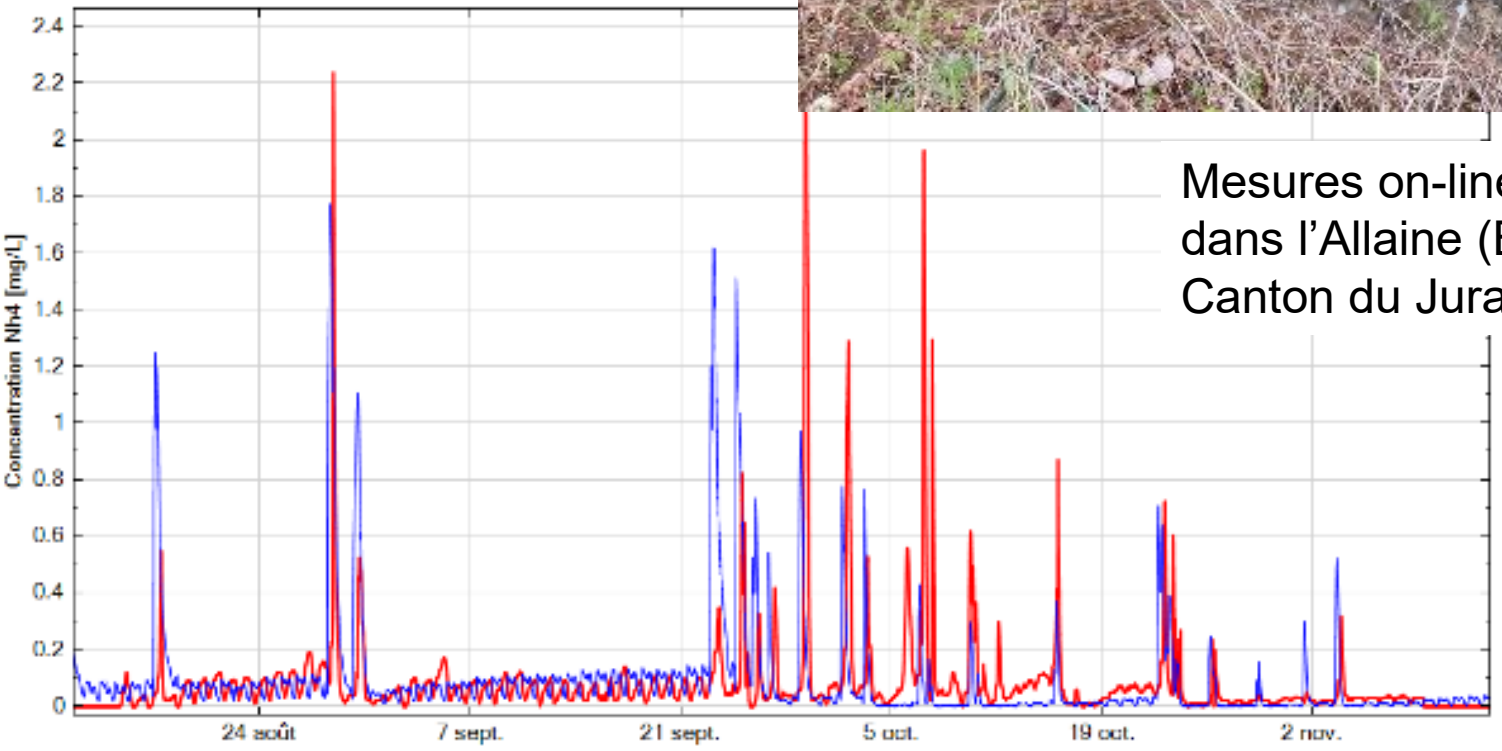
- WTW selective membrane
- Auto-cleaning system (compressed air)
- Measurement every minute
- Special floating device



# On-line measurements: ammonia



# On-line measurements: ammonia




Mesures on-line ammonium dans l'Allaine (Boncourt, Canton du Jura)

# On-line measurements: micropollutants


Eawag Project MS2FIELD

Online and continuous measurement of dissolved micropolluants directly near the river (On-line SPE, MS/MS Spectrometry)

Numerous pollutants (e.g. herbicides) found in very high concentrations, especially during rain events!

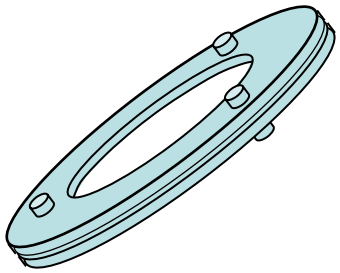
# „Passive sampling“

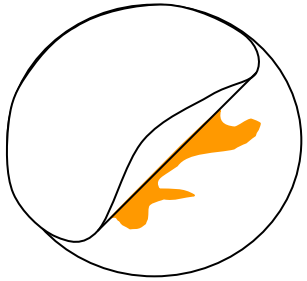
- Integration of the pollutant dynamic on/in a medium over a relative long period of time (2-3 days until 1-2 months)
- Enrichment processes, allowing measurement of very low concentrations
- No sampling errors ?
- Flow indirectly considered ?
- Future: Internal concentrations in organisms simulated with selective membranes (bio-mimétisme)

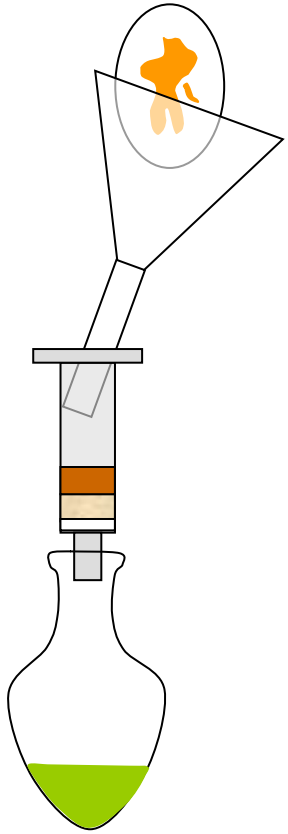
*„POCIS“ Membranes (Polar Organic Compound Integrative Sampler)*

# Example of application – POCIS: Endocrine substances

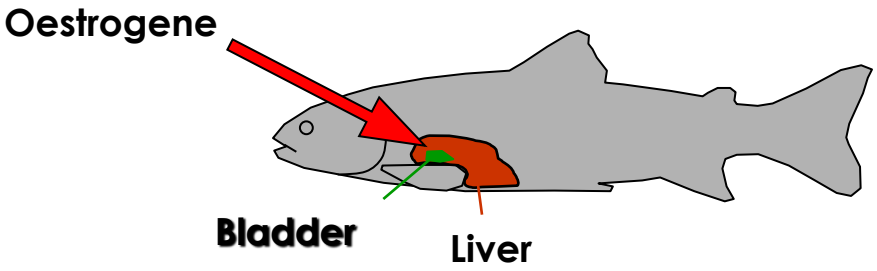
"**P**olar **O**rganic **C**ompound **I**ntegrative **S**ampler"

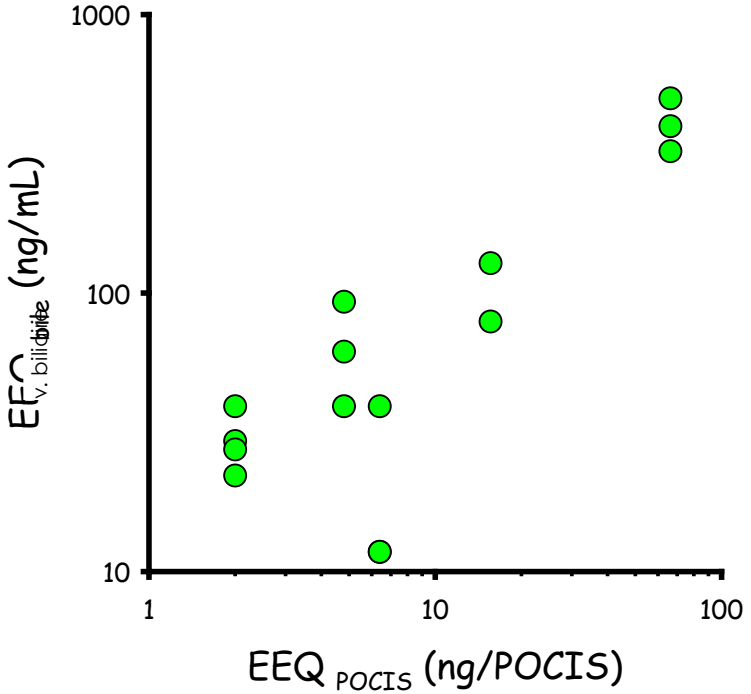






# Endocrine substances and contamination of fish: estimation of effects through passive samplers

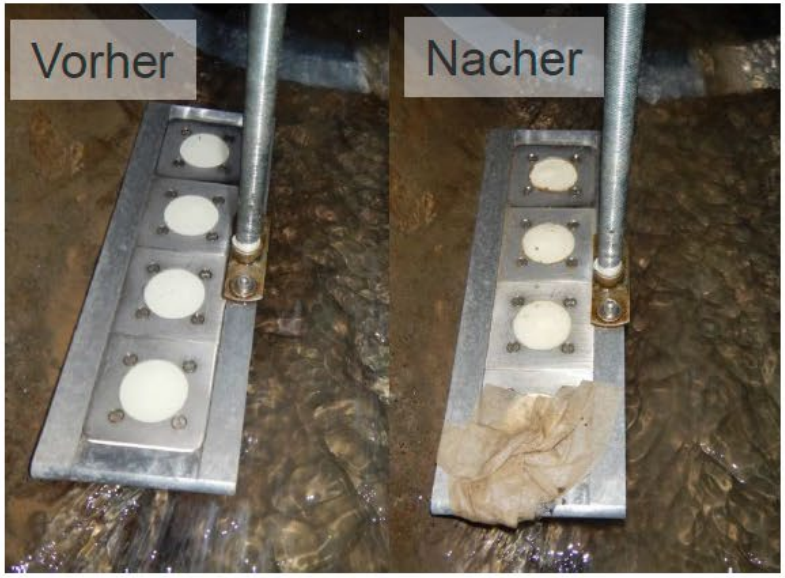



*From Dr. Etienne Vermeirssen, Eawag*


# Installation im Kanal

## Passivsammler




## Aktive Probennahme


$\Delta t$ = 5min

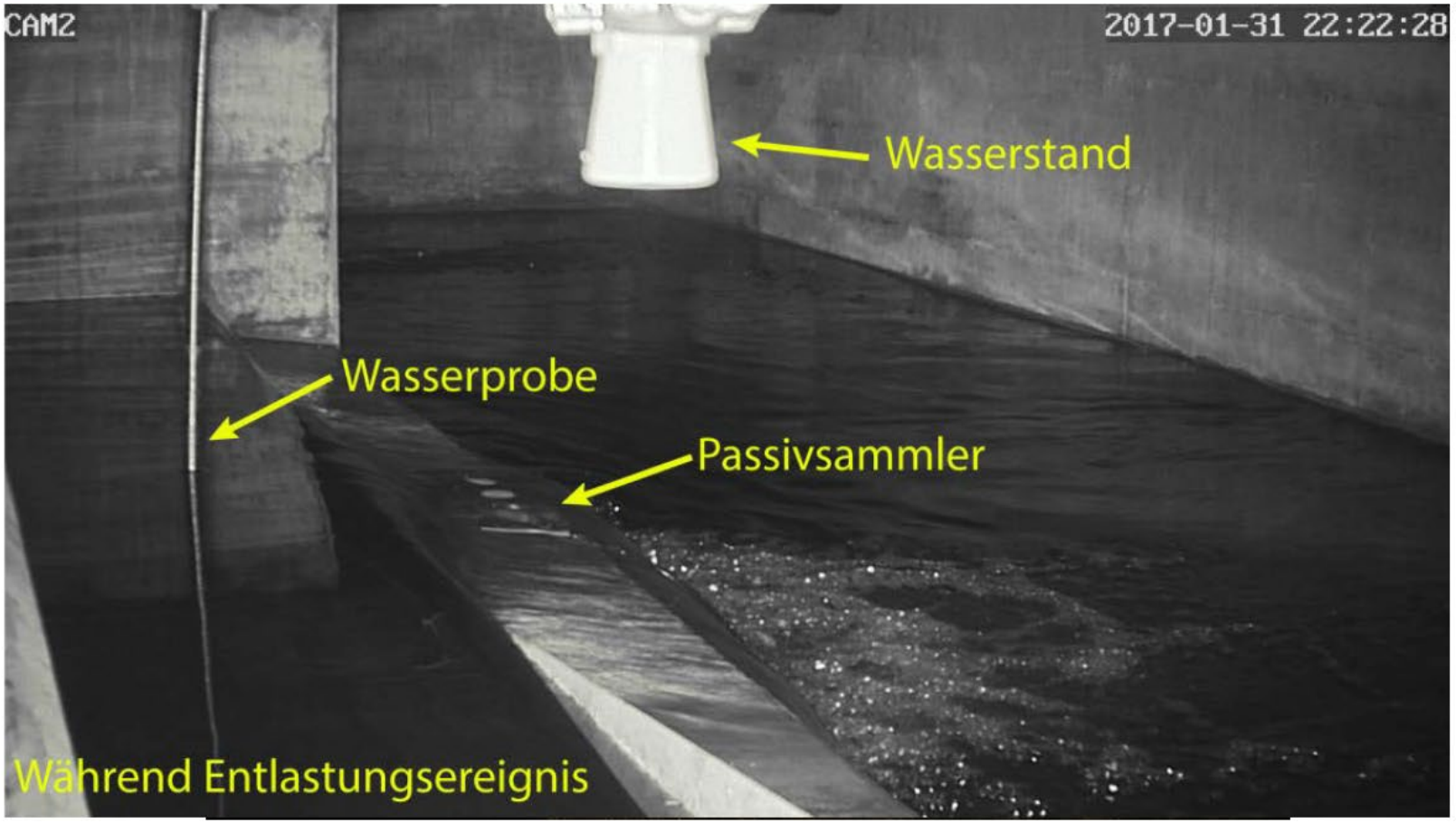
4 Proben pro Flasche (20min)

24 Flaschen

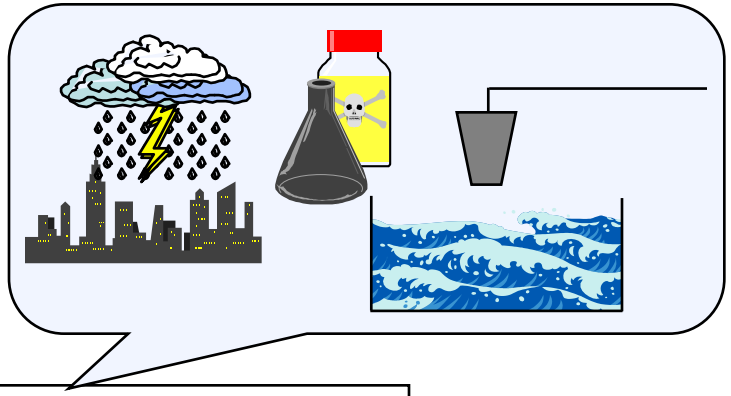
8h (on/off)


# Installation in Mischwasserentlastung

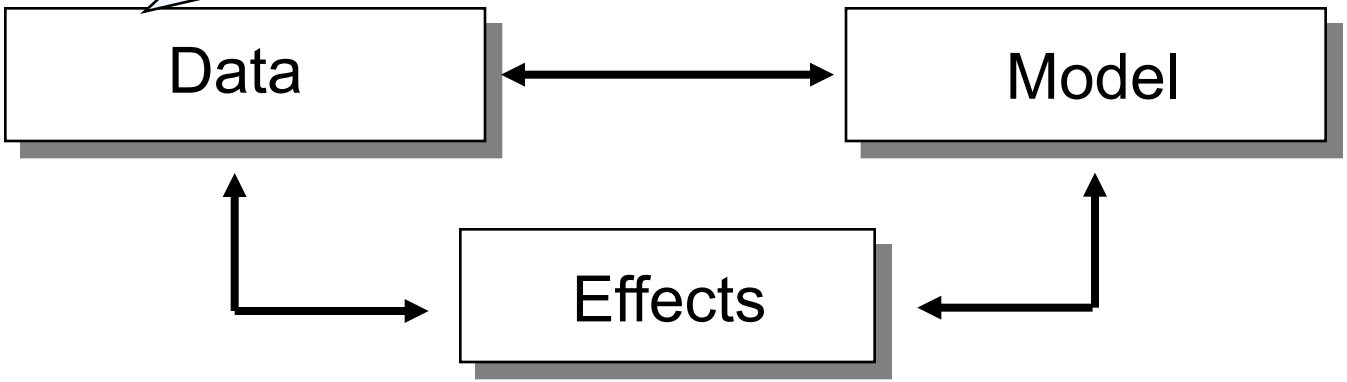
eawag aquatic research



# Goals of sampling



**Sampling: preliminary indispensable step for all analysis**




$$\frac{PEC}{PNEC} > 1\ ?$$