Pumping stations and water transport

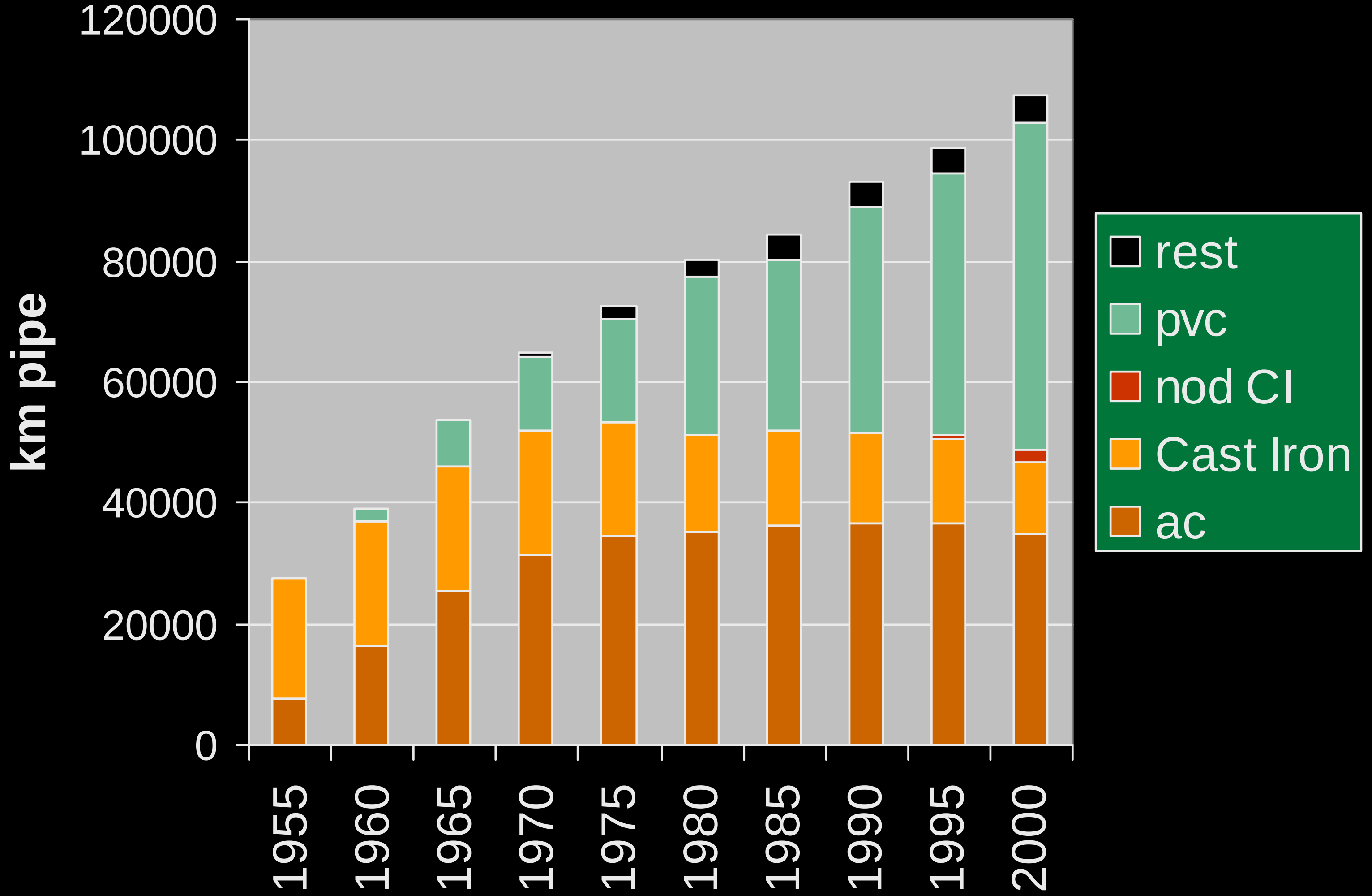
Water quality aspects of drinking water networks

ct5550

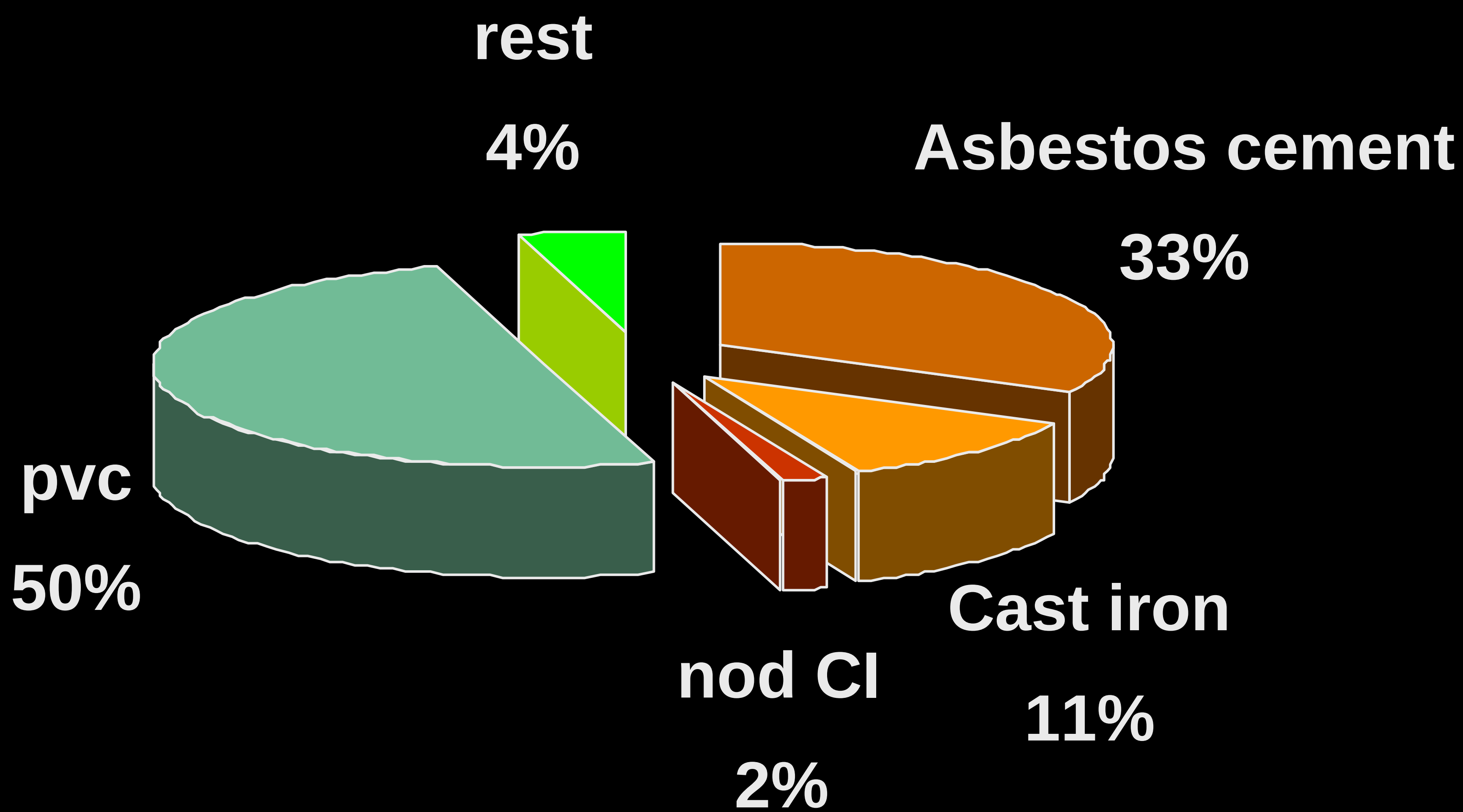
Introduction

- Water quality changes during transport through the network
- Chemical processes: interaction between pipe material and water
- Biological processes: development/regrowth of bacteria and invertebrates
- Physical processes: sedimentation and resuspention

Material composition network



Present material composition



Physical processes

- Main problem: discoloured water
- Primarily a customer related problem: discoloured water is ‘ harmless’
  - Although relation with bacteriological problems
- Focus because of changing attitude of both customer (more critical and out spoken) as water company (more customer oriented)

Early 90’s: red water on the agenda in the Netherlands

- Increased customer complaints
  - more critical attitude
  - more professional registration
- Unexpected
  - decrease in cast iron
  - also in new plastic networks
- Unsatisfactory results of (costly) cleaning programs

Ø100 Cast Iron (1900)

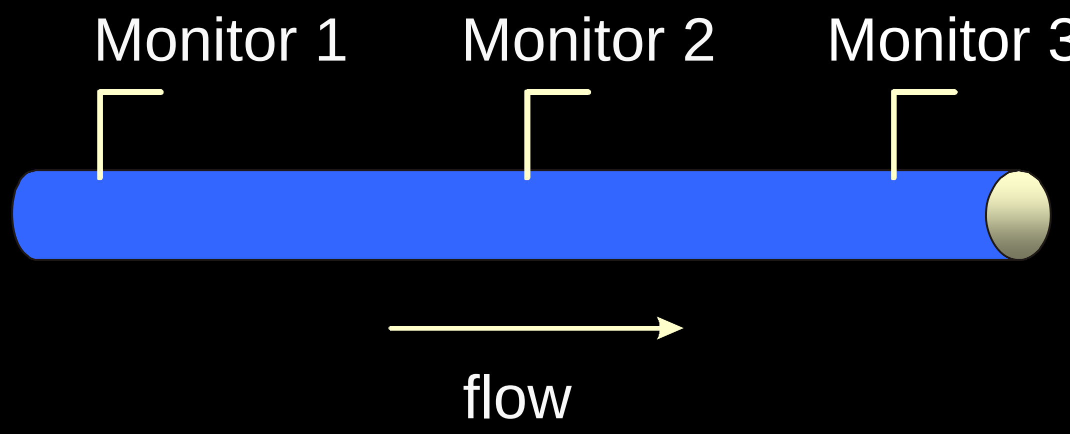
Basic questions

- What is discoloured water
- How to measure discoloured water
- What is the cause and nature of discolourde water
- What can we do about it

What is red water?

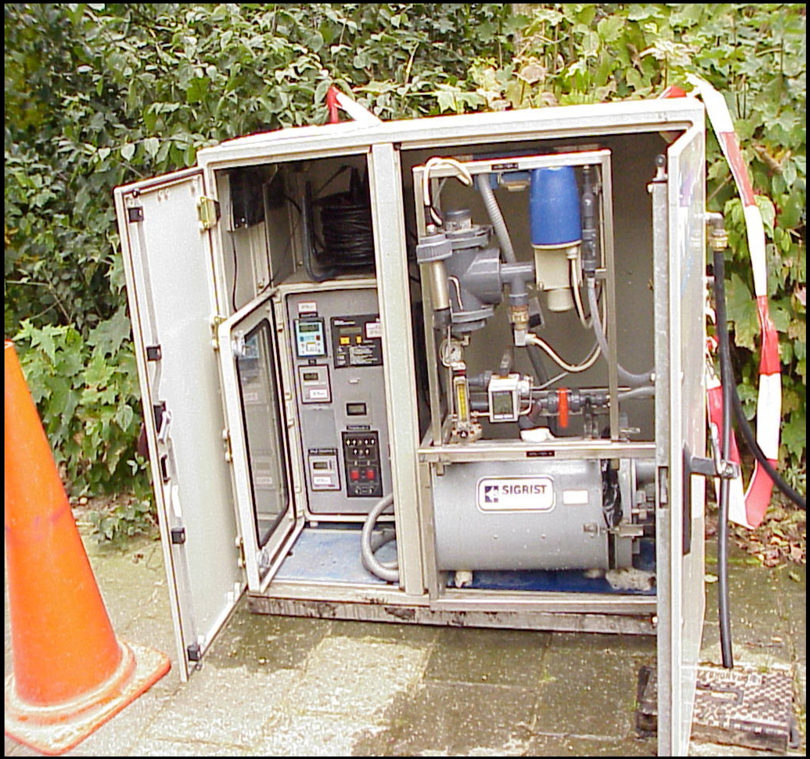
- Water with a turbidity that can be noticed by a customer
- Turbidity is the key factor in red water

How to measure red water: Monitoring System

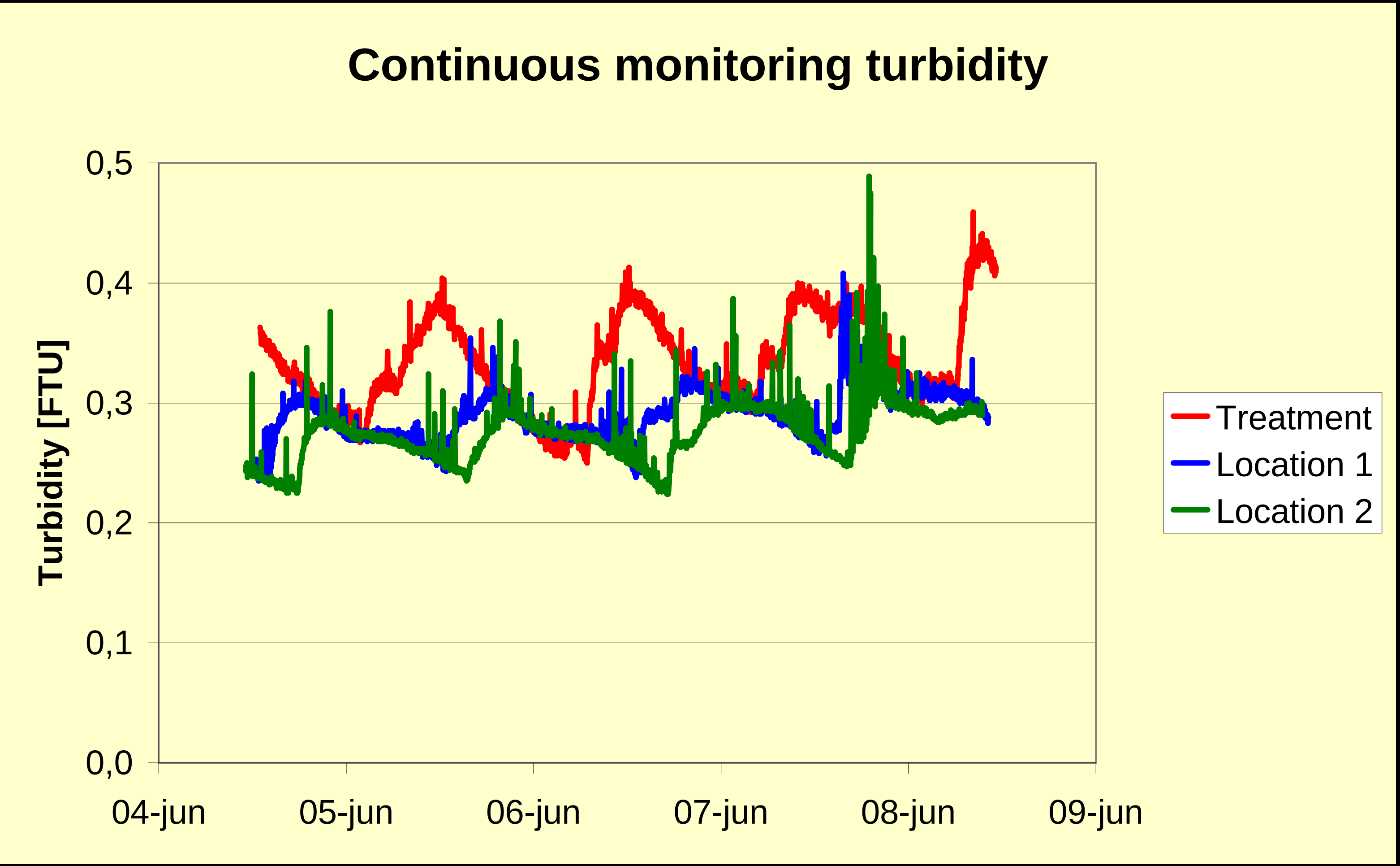


- pH
- Oxygen
- Turbidity
- Temperature
- Conductivity
- Pressure
- (Velocity)

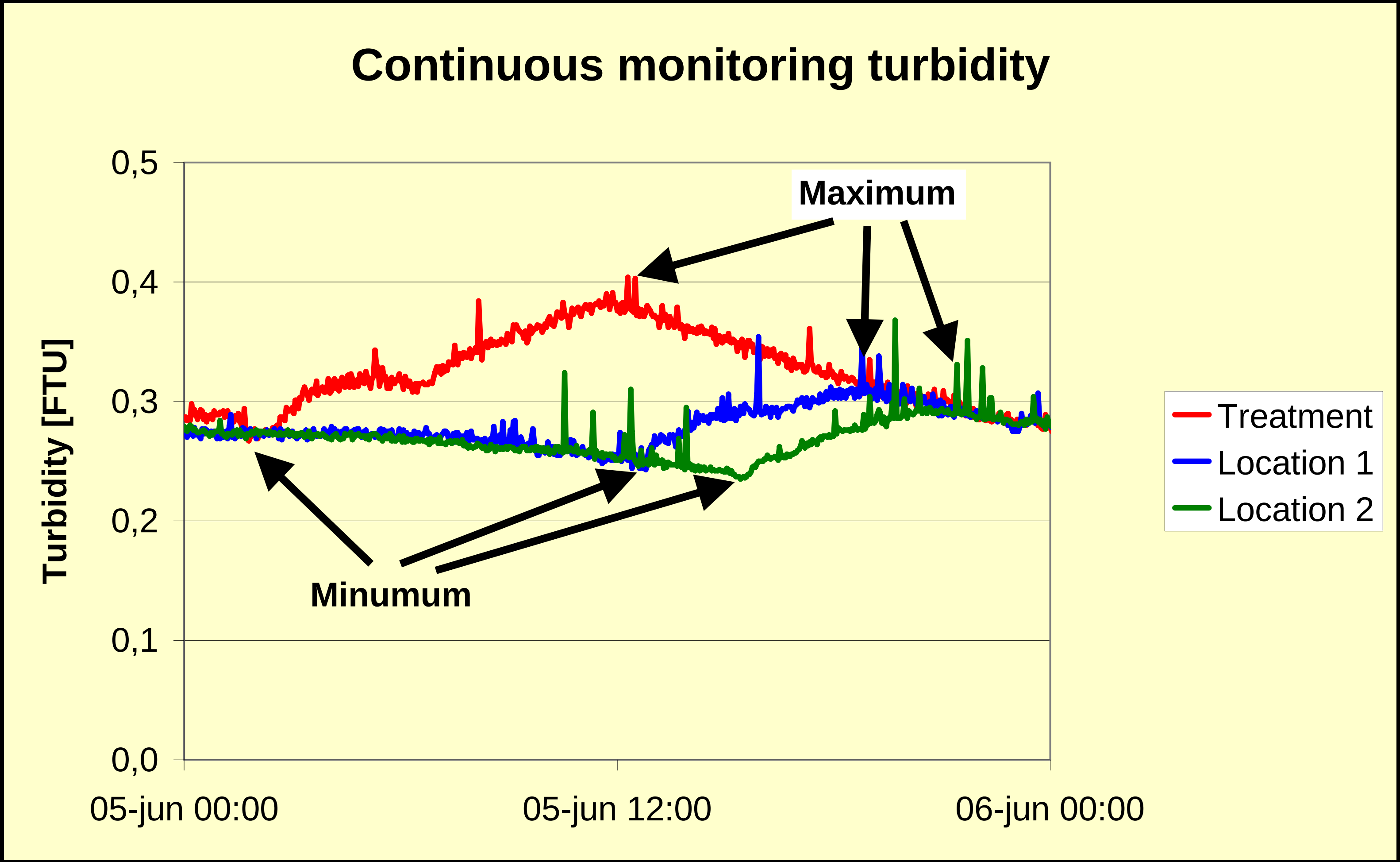
Single Monitoring system



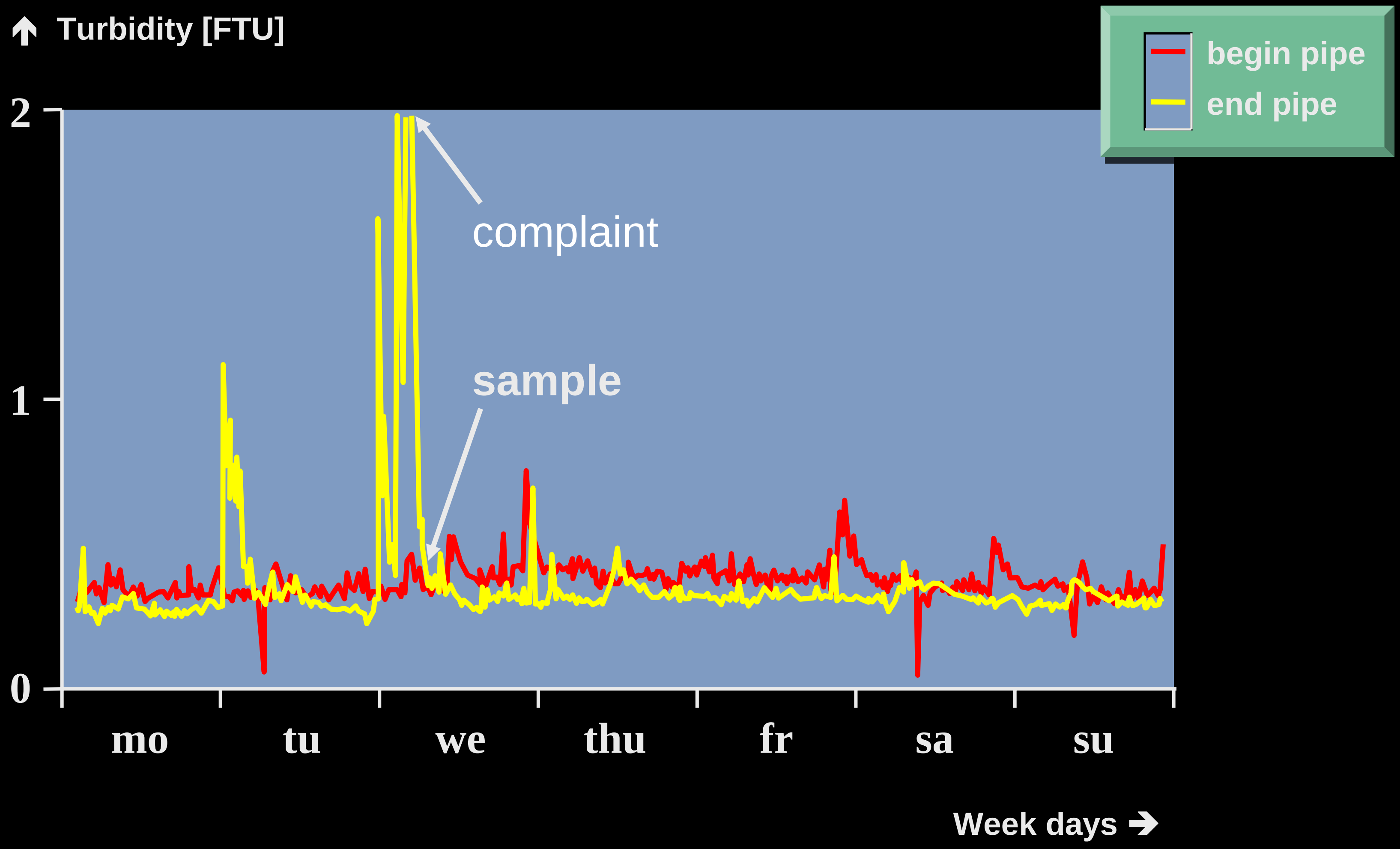
Results monitoring turbidity



Closer detail



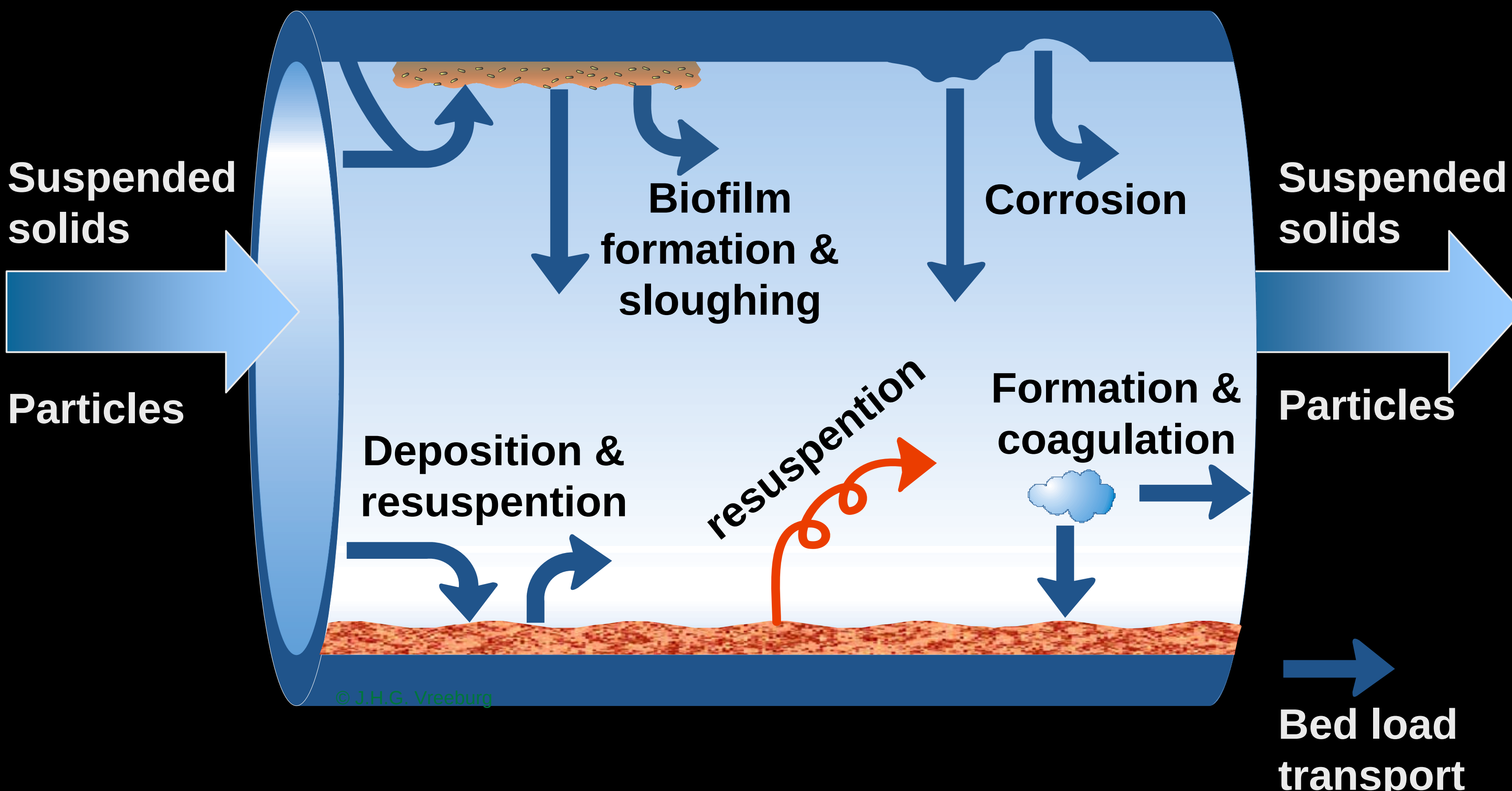
Continuous monitoring of turbidity



Cause of discoloured water

- Resuspension of sediment
- Sediment originates from
  - source/treatment plant
  - network (corroding cast iron, biofilm)
  - mixing different water types
- Sedimentation is promoted by low velocities in the network
- Sudden changes in velocity promote resuspension

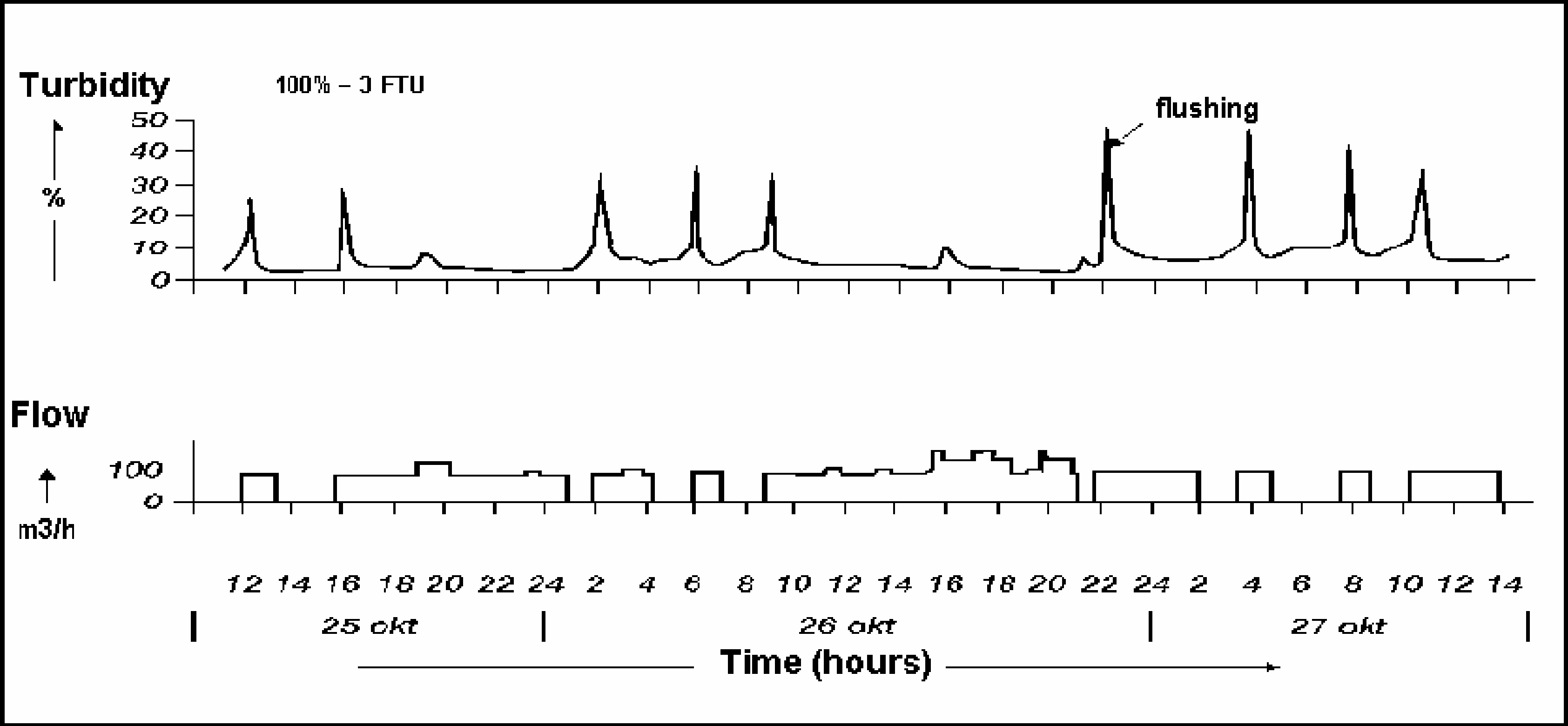
Mass balance in a network



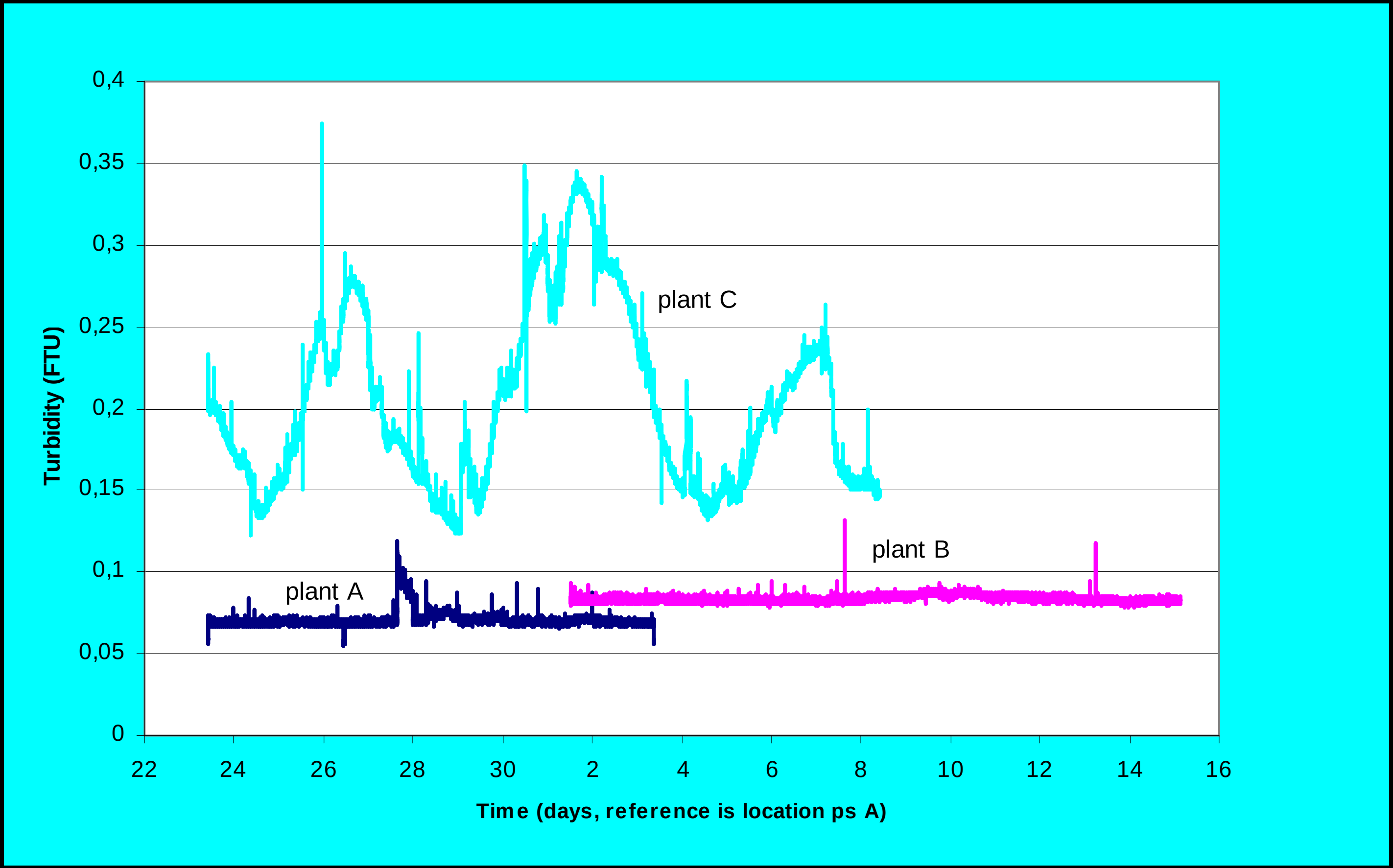
Actions to prevent red water: a three stage rocket

- Prevent the sediment from entering the network
  - Improve the treatment of water
- Remove sediment swiftly en effectively
  - Conduct cleaning programmes
- Prevent sedimentation of suspended matter
  - Design small diameter pipes: design for self-cleaning capacity

Variation of production capacity and water quality



Turbidity different pumping stations



First stage: improve treatment

- Goal: steady process with low turbidity
- Tools: demand forecasting and clever use of balancing reservoirs

- But: conventional treatment leaves sediment in the water

Second stage: Remove sediment

- Cleaning the network, available techniques
  - Flushing
  - Water/air scouring
  - Pigging
- Measuring method:
  - Resuspension potential

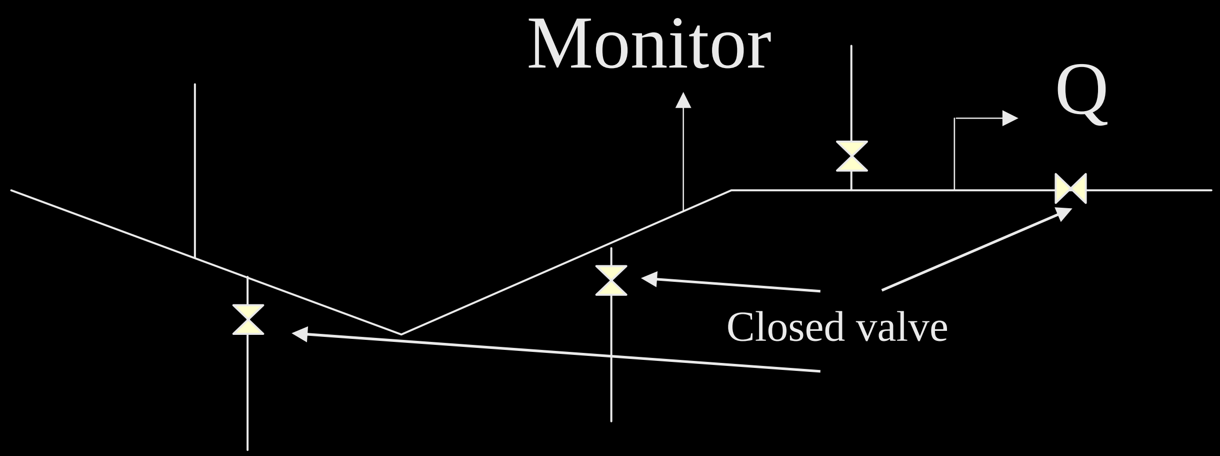
Research tools

- Continuous monitoring turbidity and Particle counts
- Resuspension Potential Method
- Experimental pipe test rig
- Analysis of concentrate MF-installation

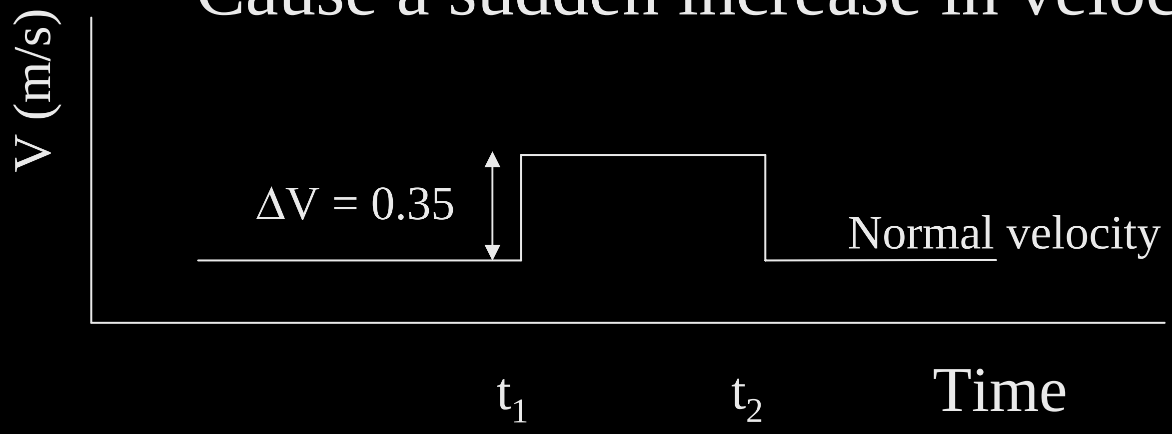
Resuspension Potential Method

- Principle
  - resuspension of sediment by sudden increase of velocity
  - 0,35 m/s on top of normal velocity
  - turbidity monitoring
  - no impact on the customer

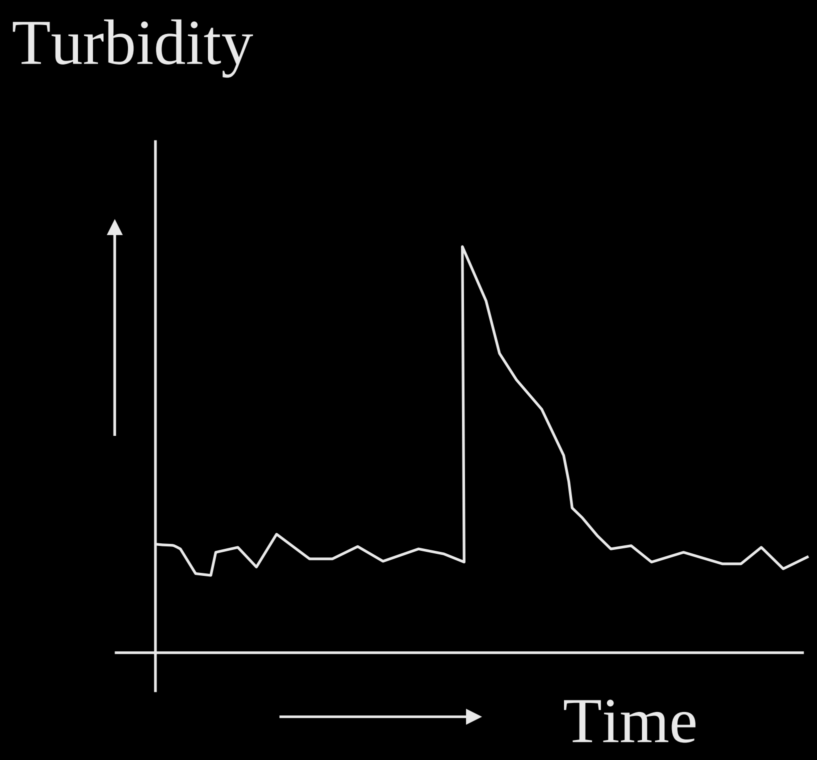
Resuspension Potential Method



Cause a sudden increase in velocity

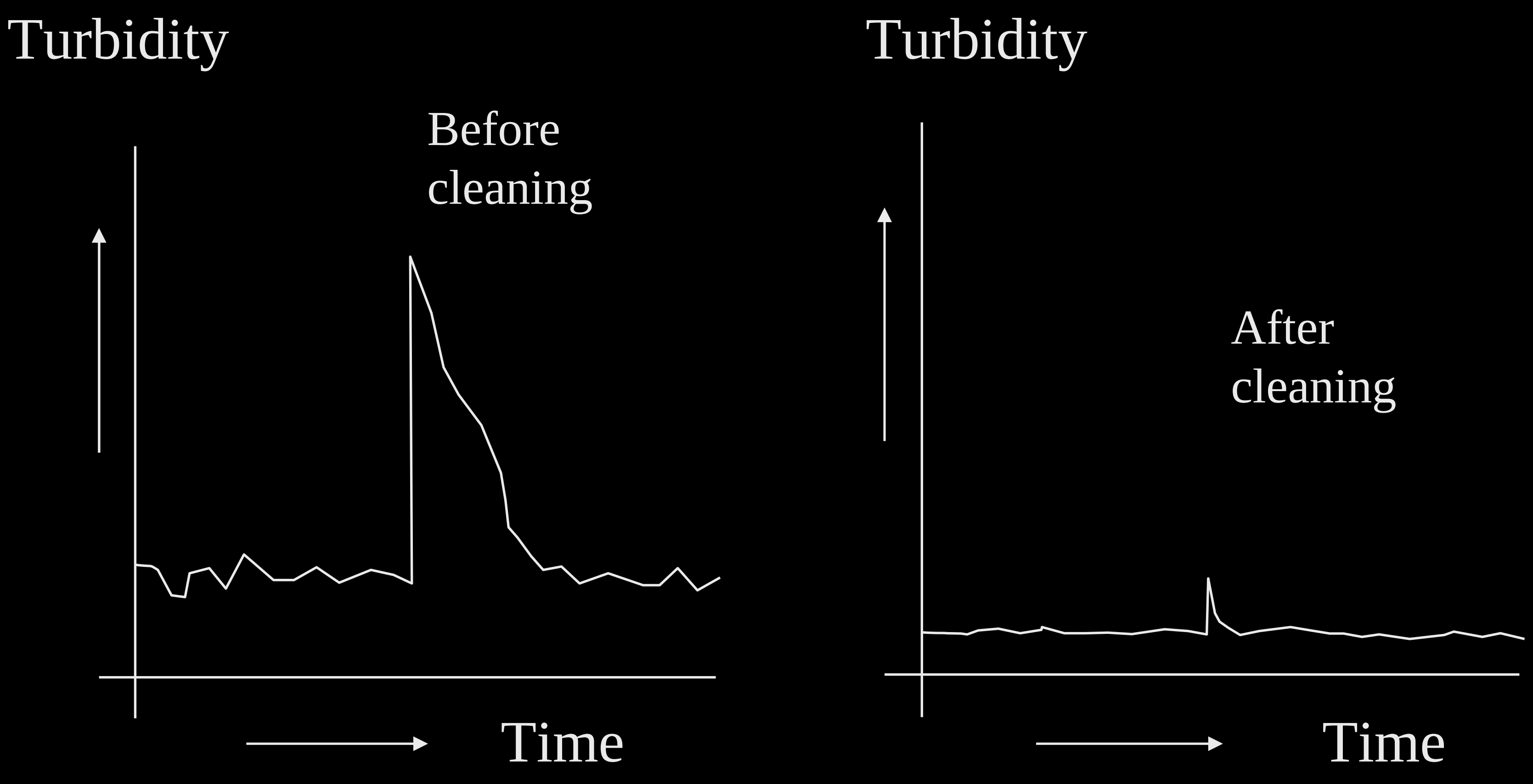


Typical RP curve



High resuspension potential indicates polluted network: cleaning network, e.g. flushing

Effect of flushing monitored with resuspension potential



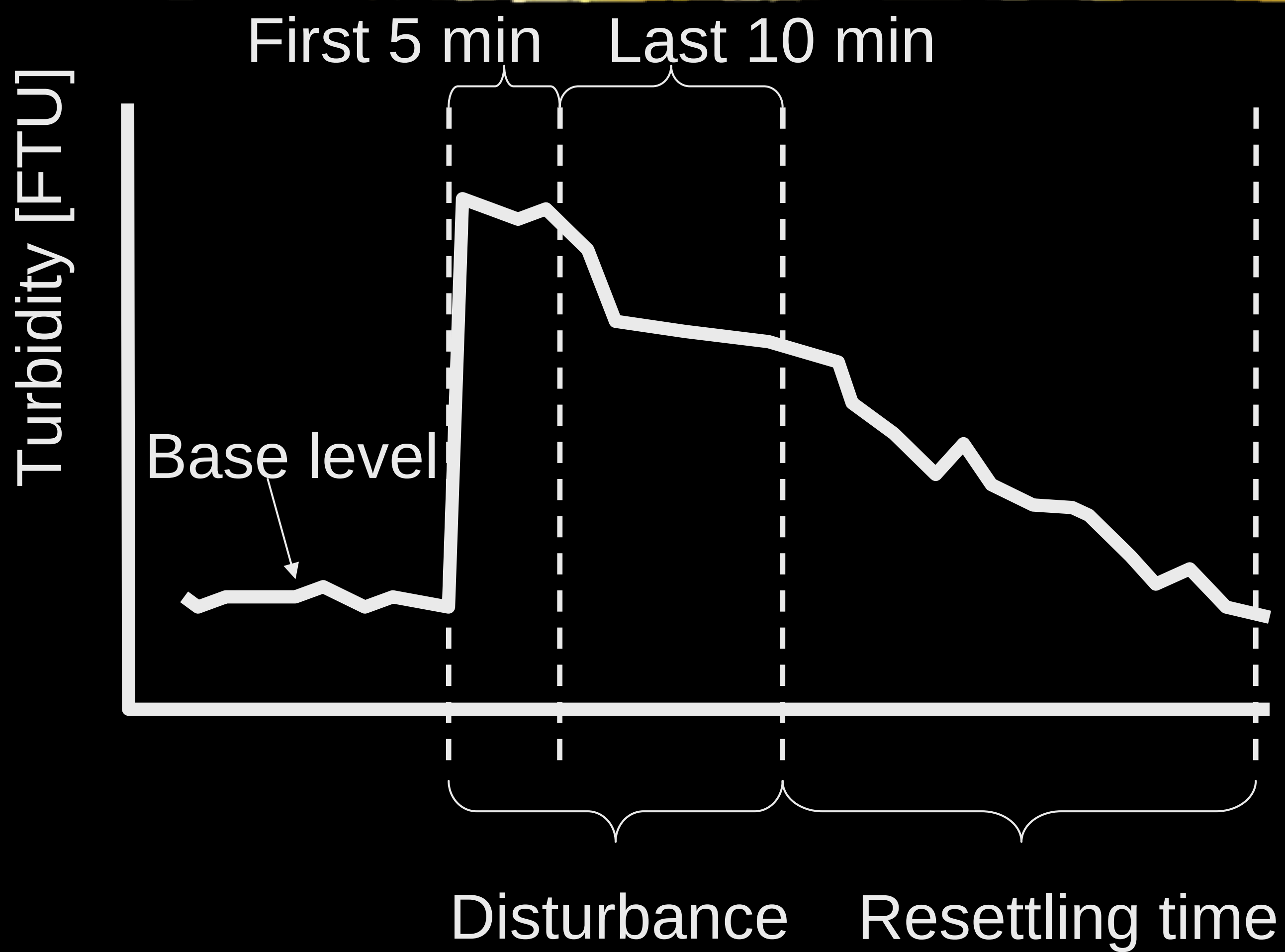
Pictures monitor connection

Resuspension Potential Method

Resuspension Potential Method

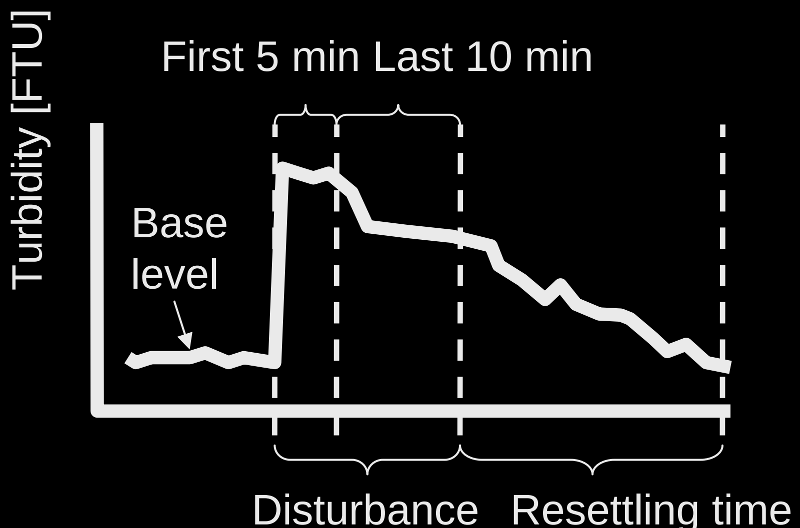
Resuspention potential method
Sample measuring

Typical RPM curve



Relative interpretation RPM

- 5 aspects determine the RP:
  - Absolute maximum turbidity first five minutes
  - Average turbidity first five minutes
  - Absolute maximum turbidity last ten minutes
  - Average turbidity last ten minutes
  - Resetling time
- 0 to 3 ‘points’ per aspect

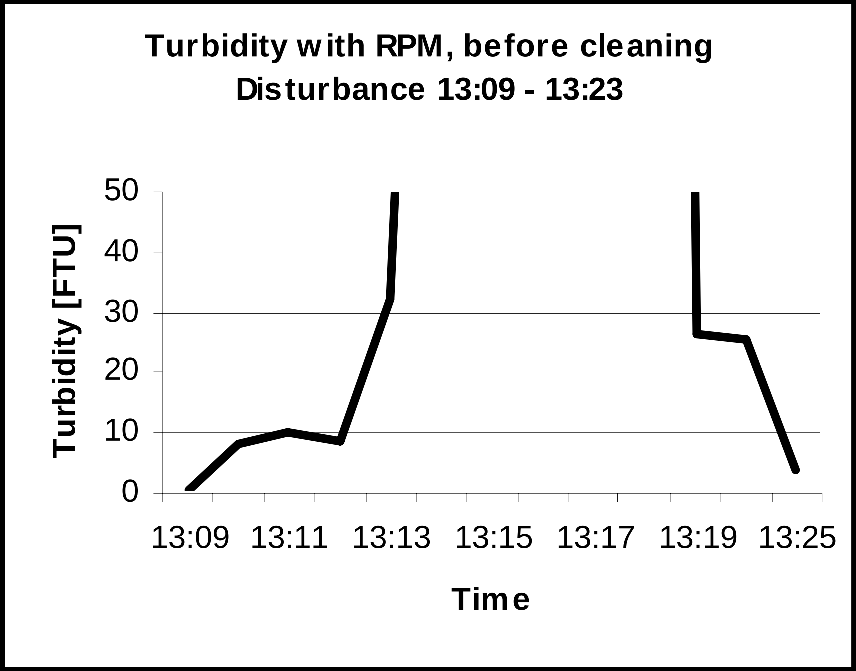


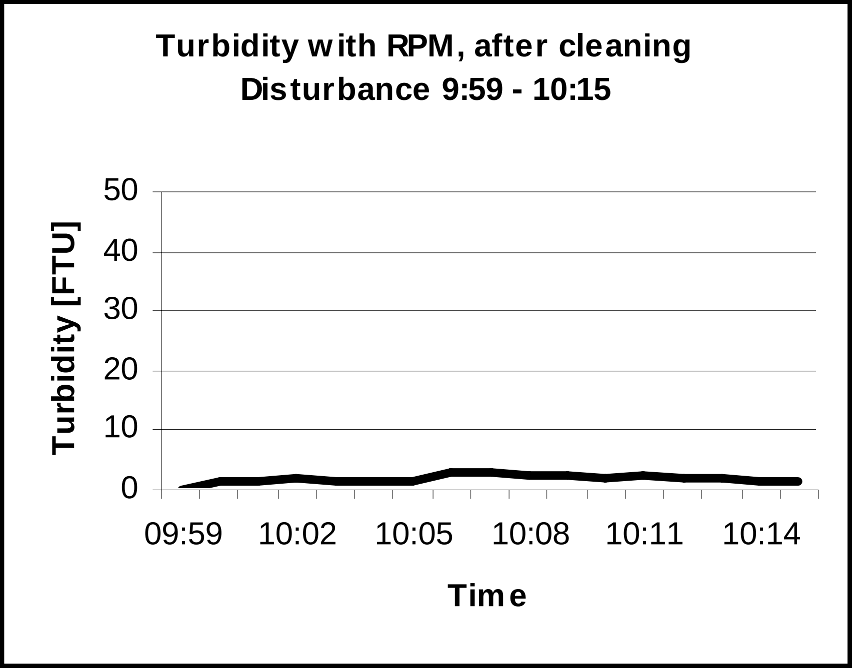
Ranking RPM

Turbidity Dr Lange, Hydrant measuring

Category \ points	0	1	2	3
Absolute max first 5 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Average first 5 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Absolute max last 10 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Average max last 10 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Time to clear	< 5 min.	5-15 min	15-60 min	>60 min

Typical RPM results
Pre and Post cleaning

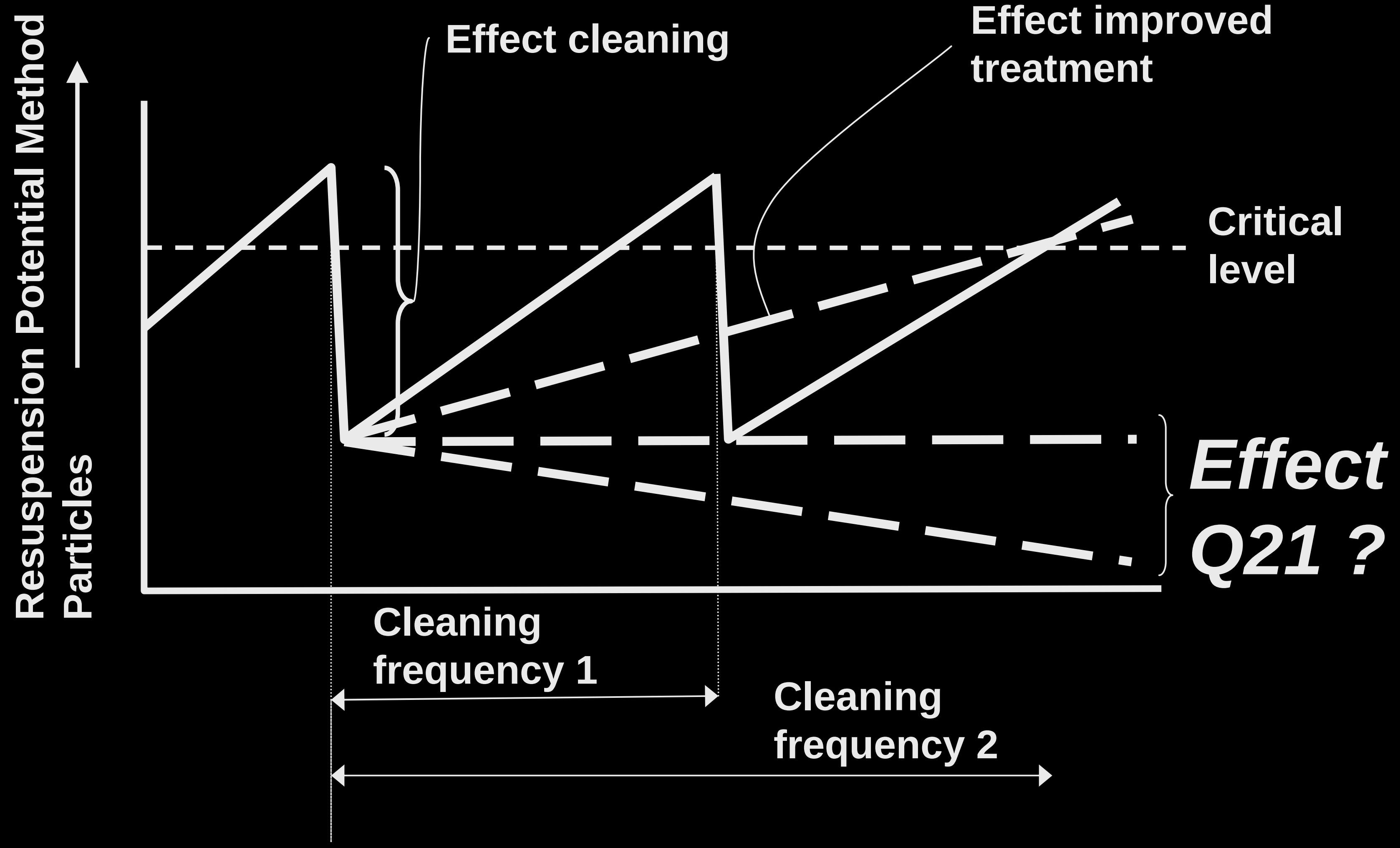




Score 12

Score 0

Hypothesis effects improved particle load



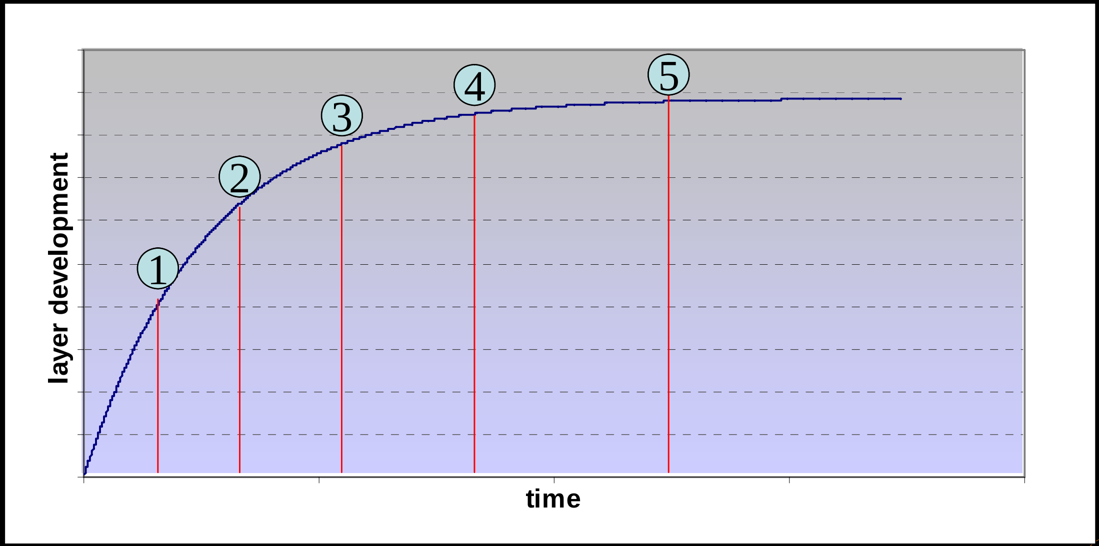
Additional research

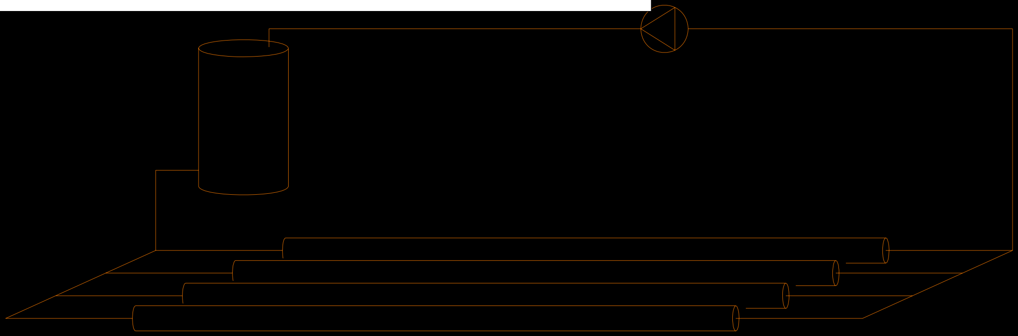
- Particle load present system
  - Large volume sampling
  - Test rig Ø100
  - “new” test rig multiple pipes
- Goals:
  - Determine characteristics present drinking water
  - Develop new measurement methods and tools
  - Trigger students

Test pipe rig Ø100

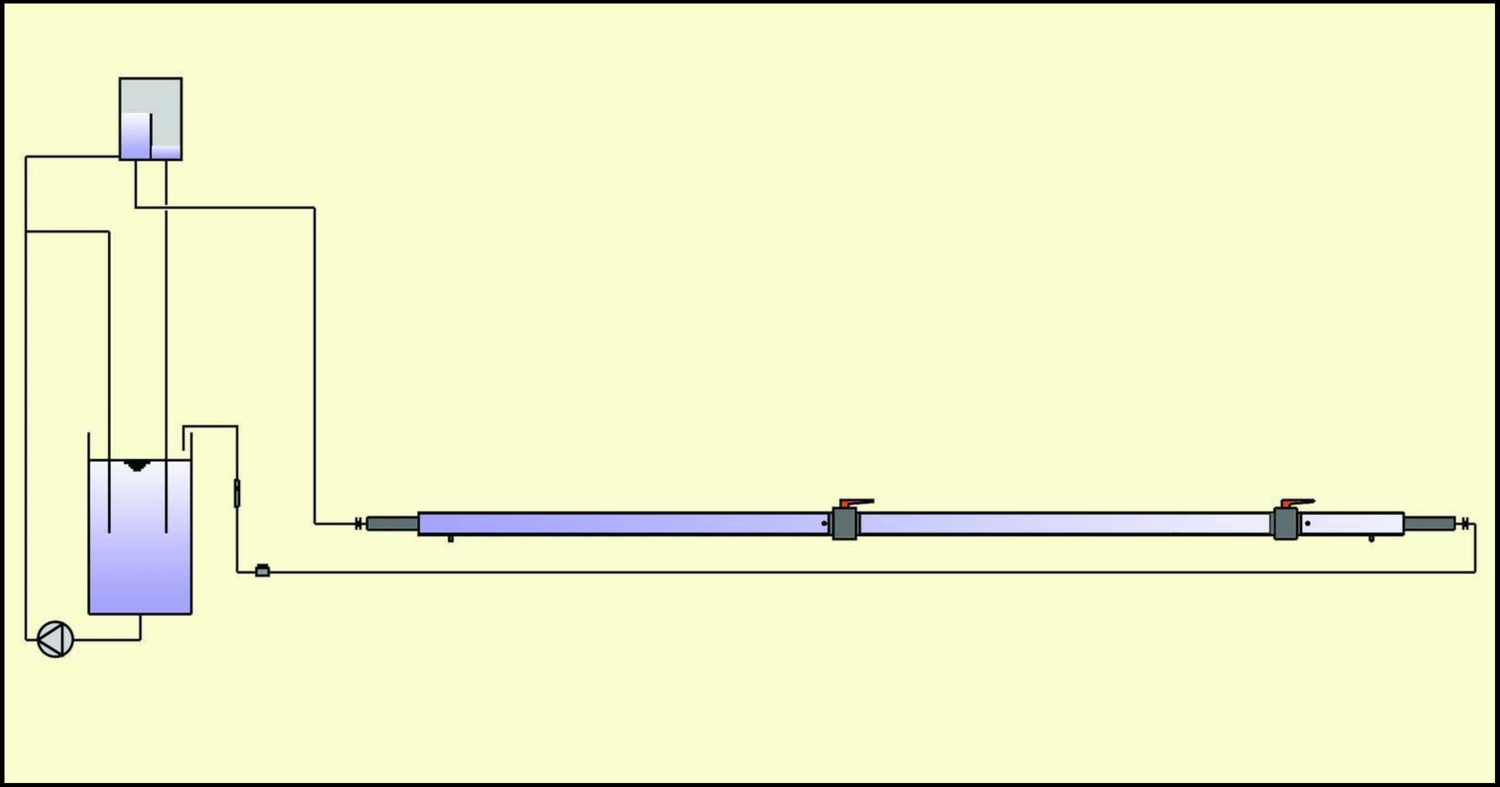
Charge with concentrate

Original set up test rig

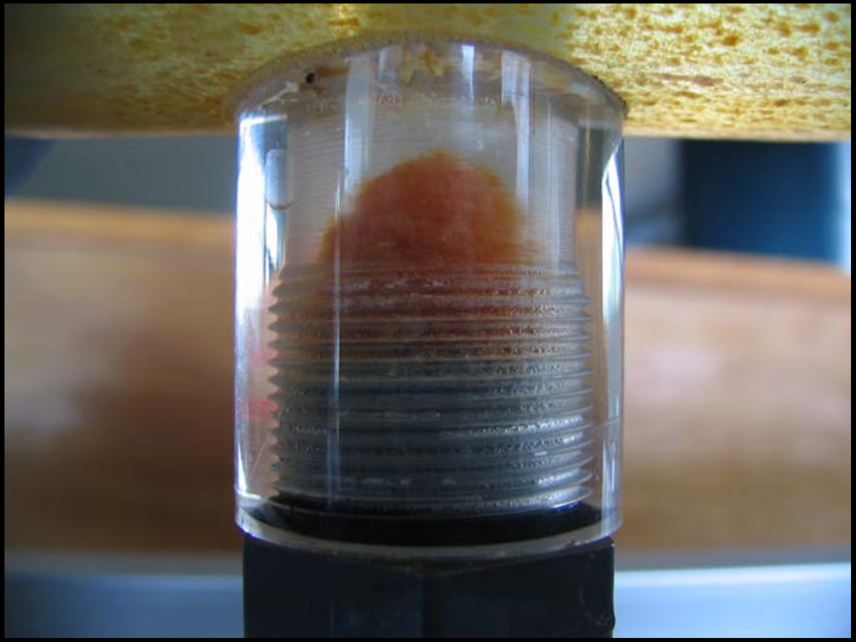




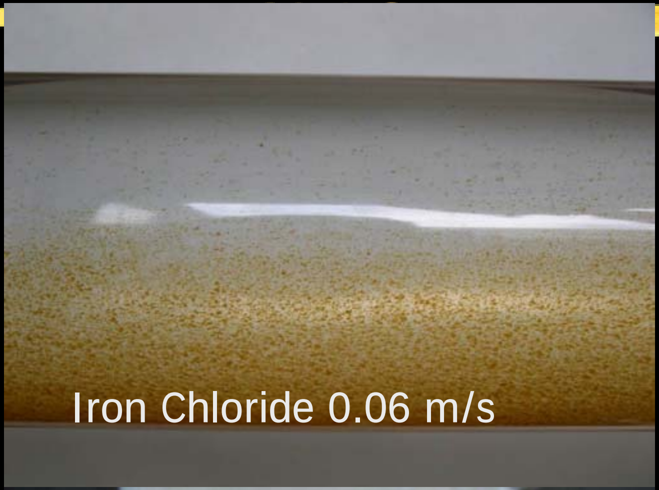
Practical set up

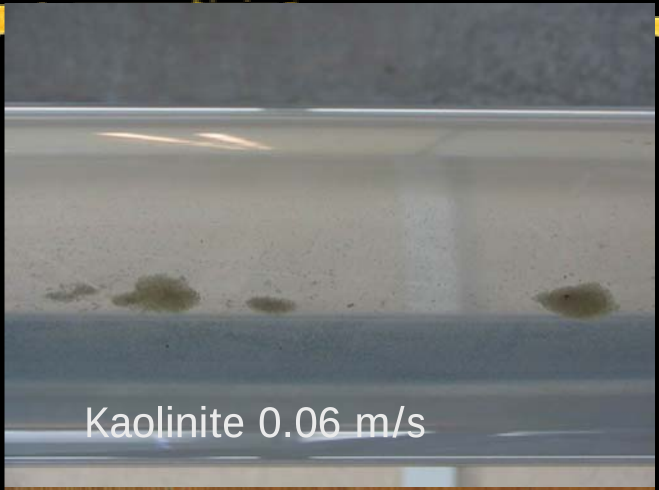


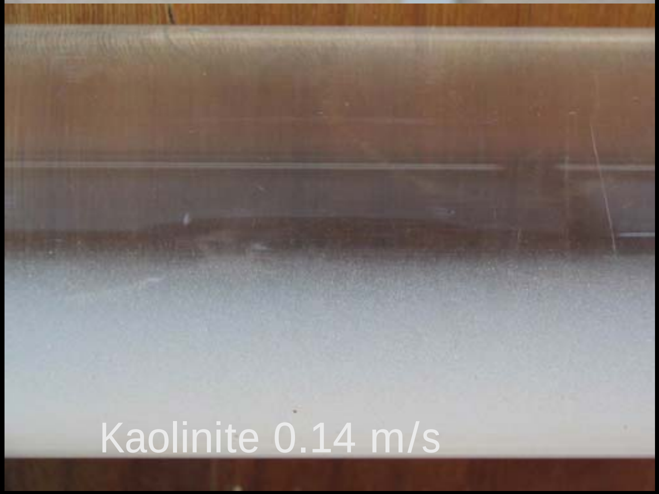
First observations



Some more observations







Drinking water quality aspects: Remove the sediment

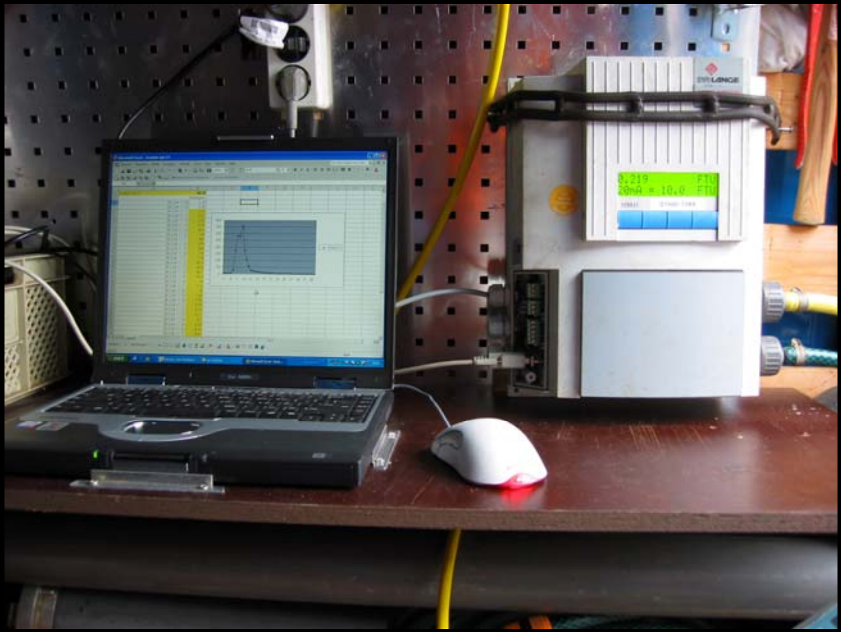
Remove the sediment

- Water flushing is effective if:
  - 1,5 m/s is reached
  - Flush volume is 3 times the pipe content
  - Clear water front
- Alternative methods as water/air scouring and pigging only when water flushing boundaries are not met

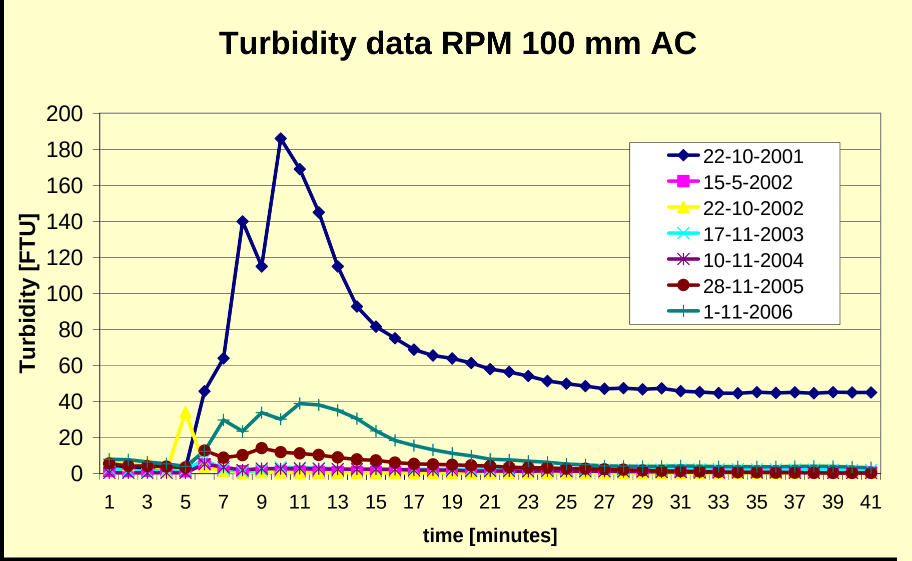
Results of cleaning program

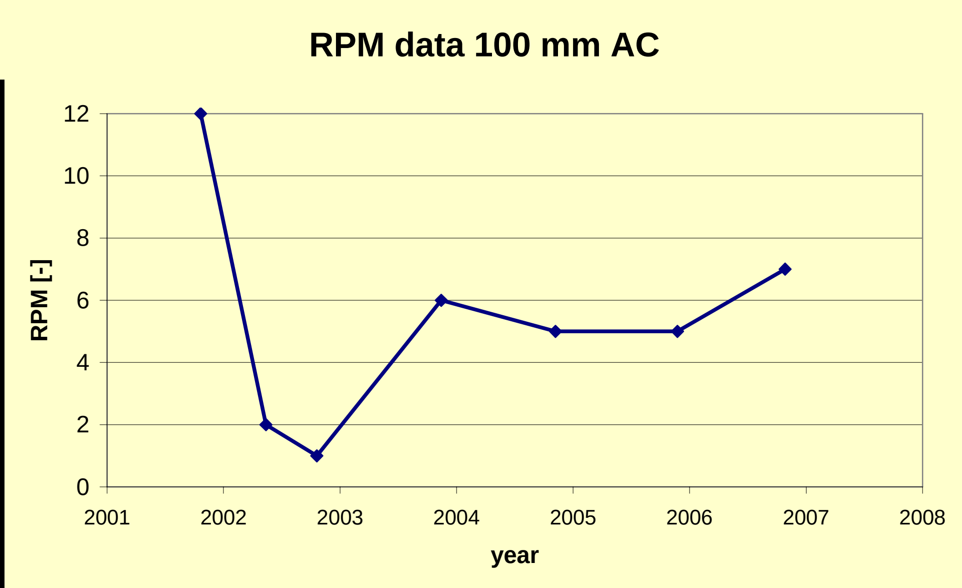
- City of Venlo
- Red line are CI
- Rest is PVC/AC

Measuring equipment

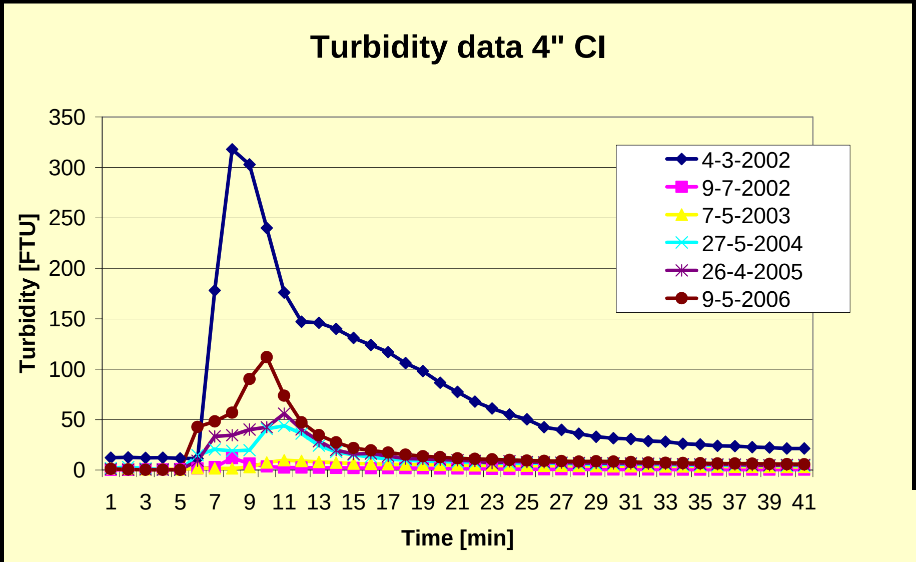


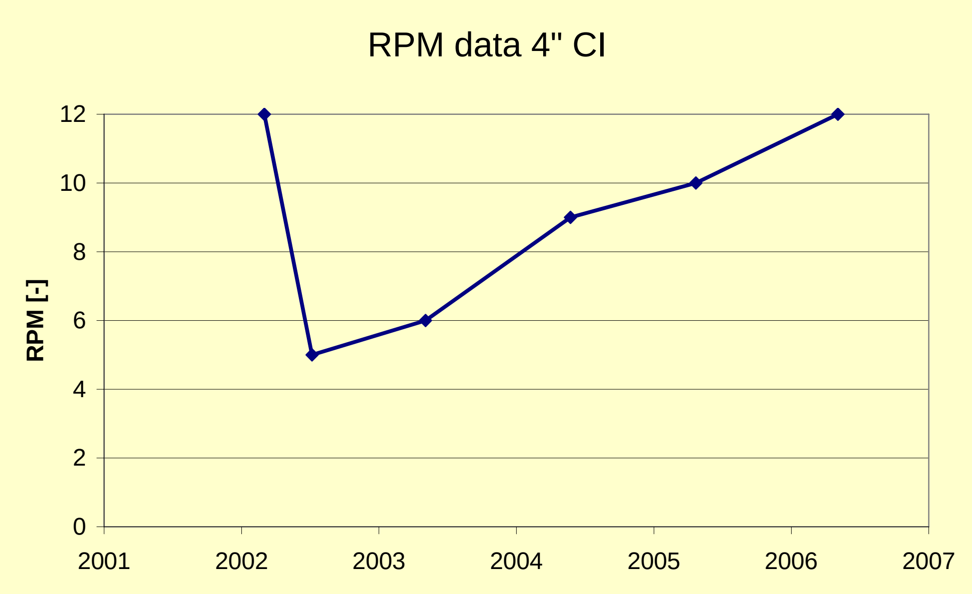
RPM results individual location



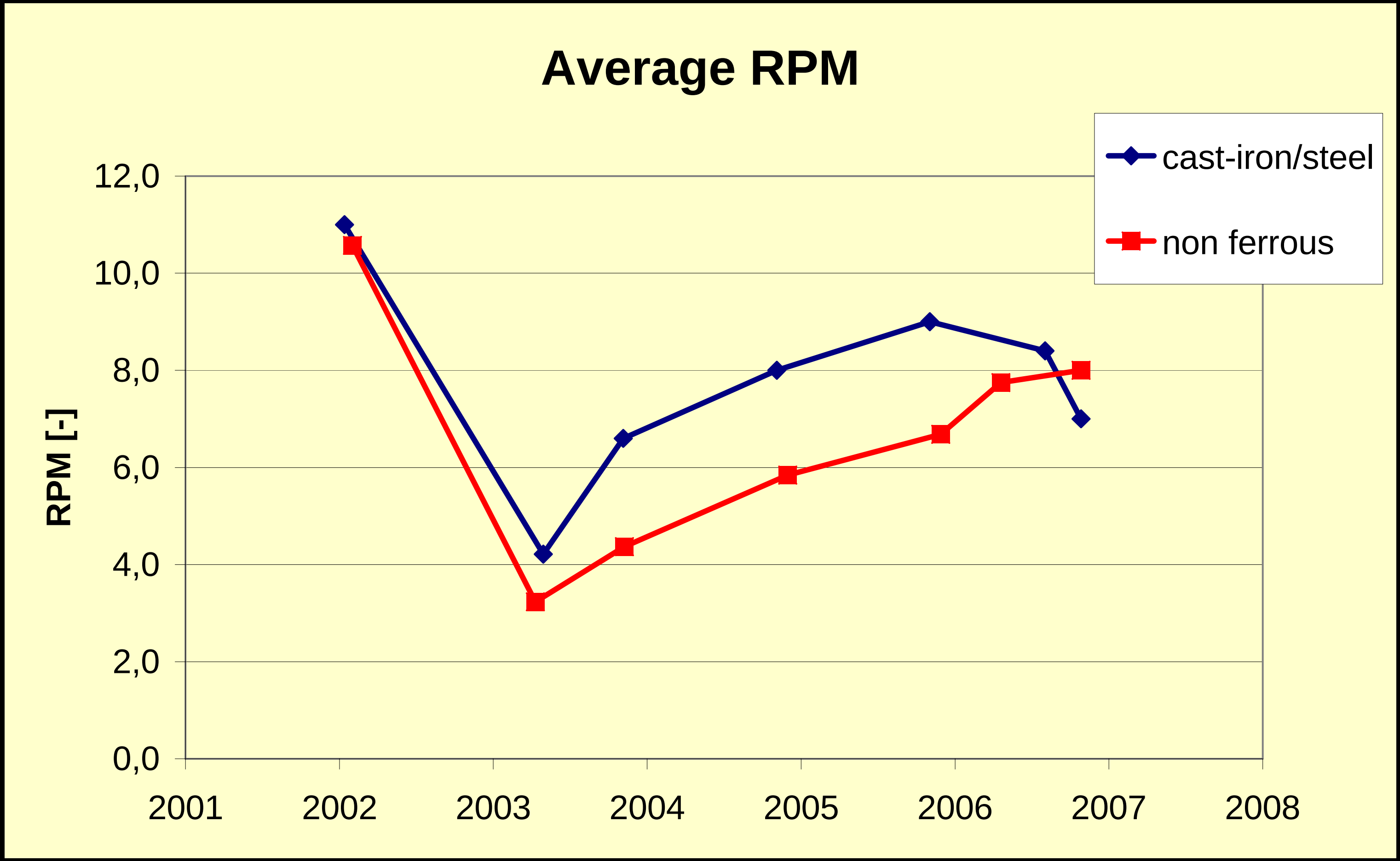


RPM results CI-location

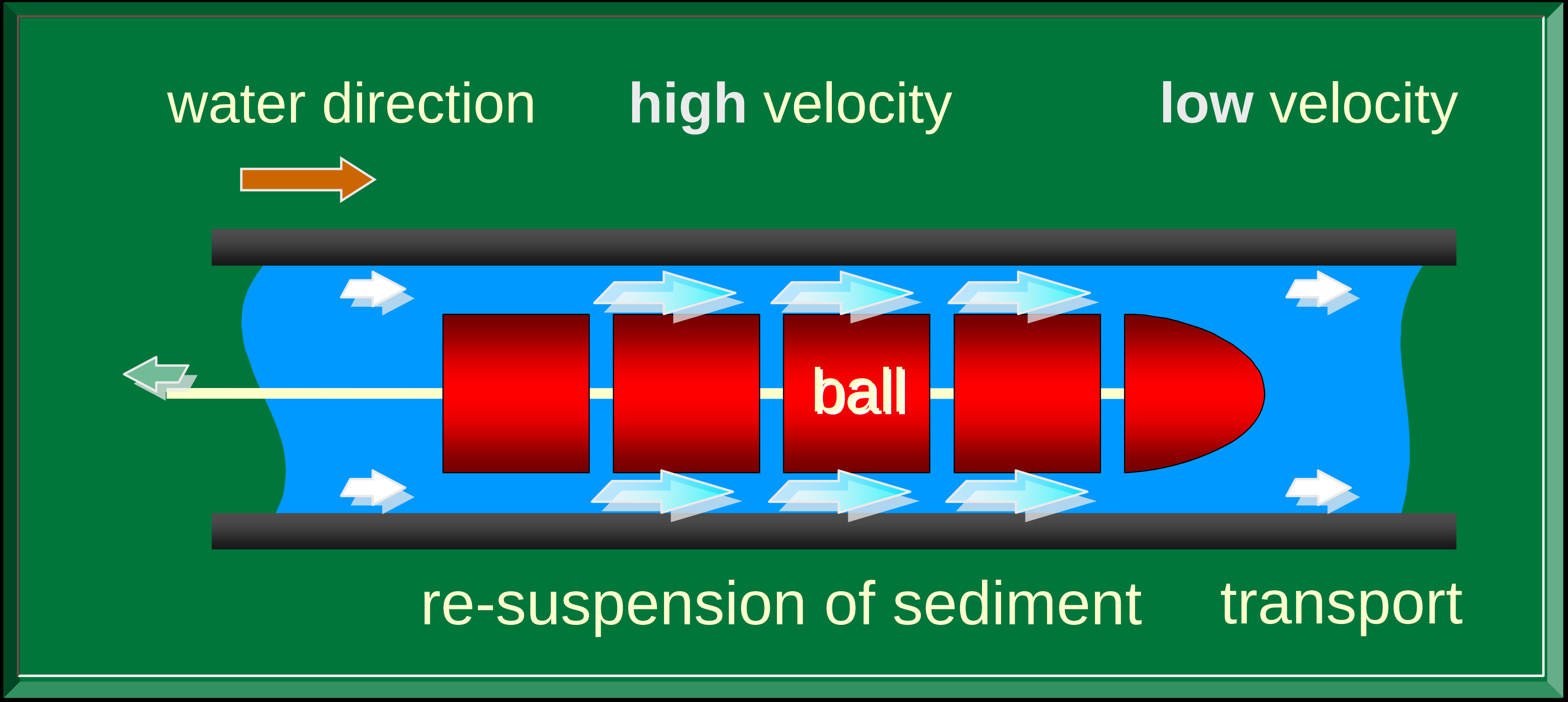




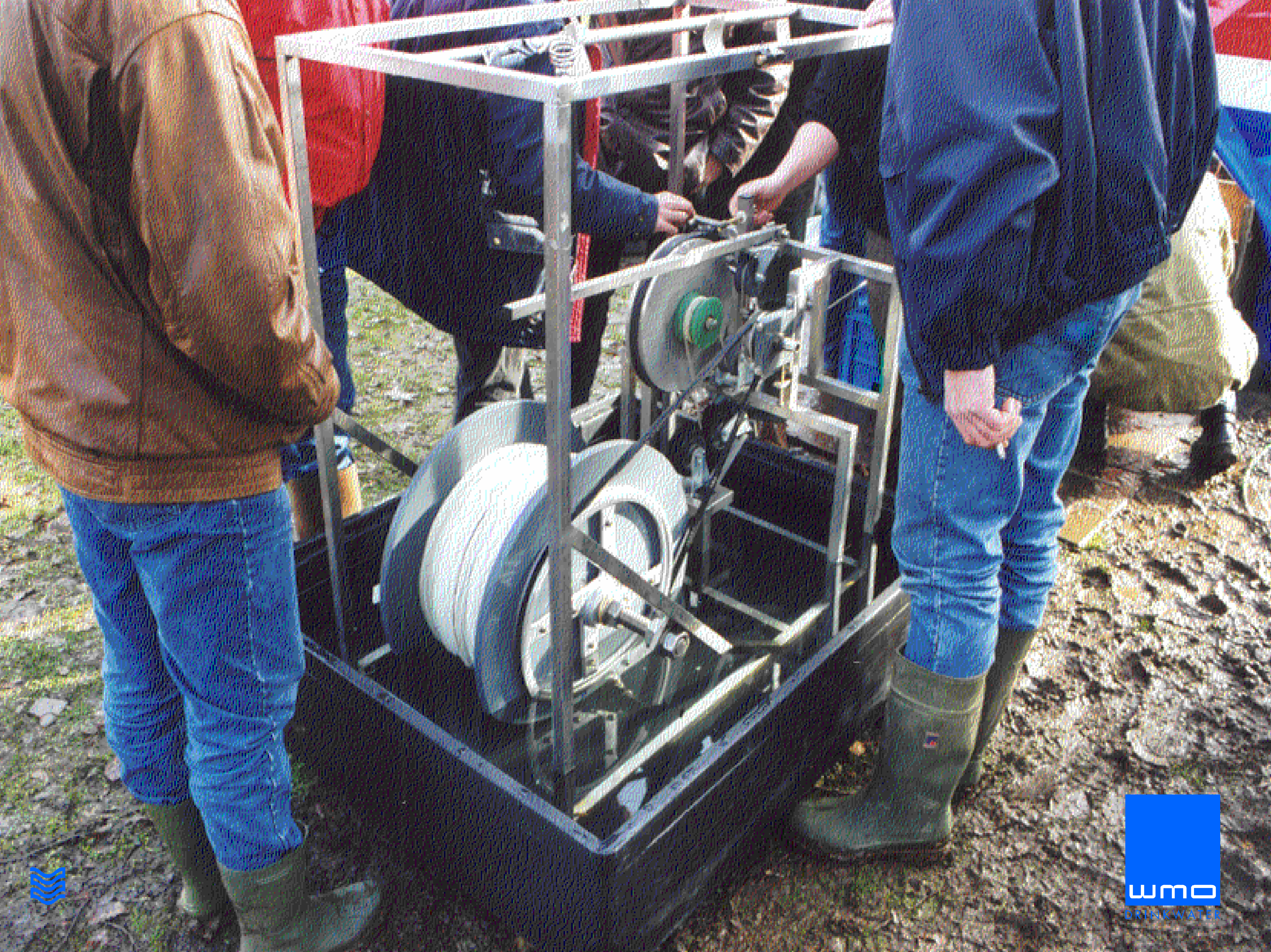
Overall results



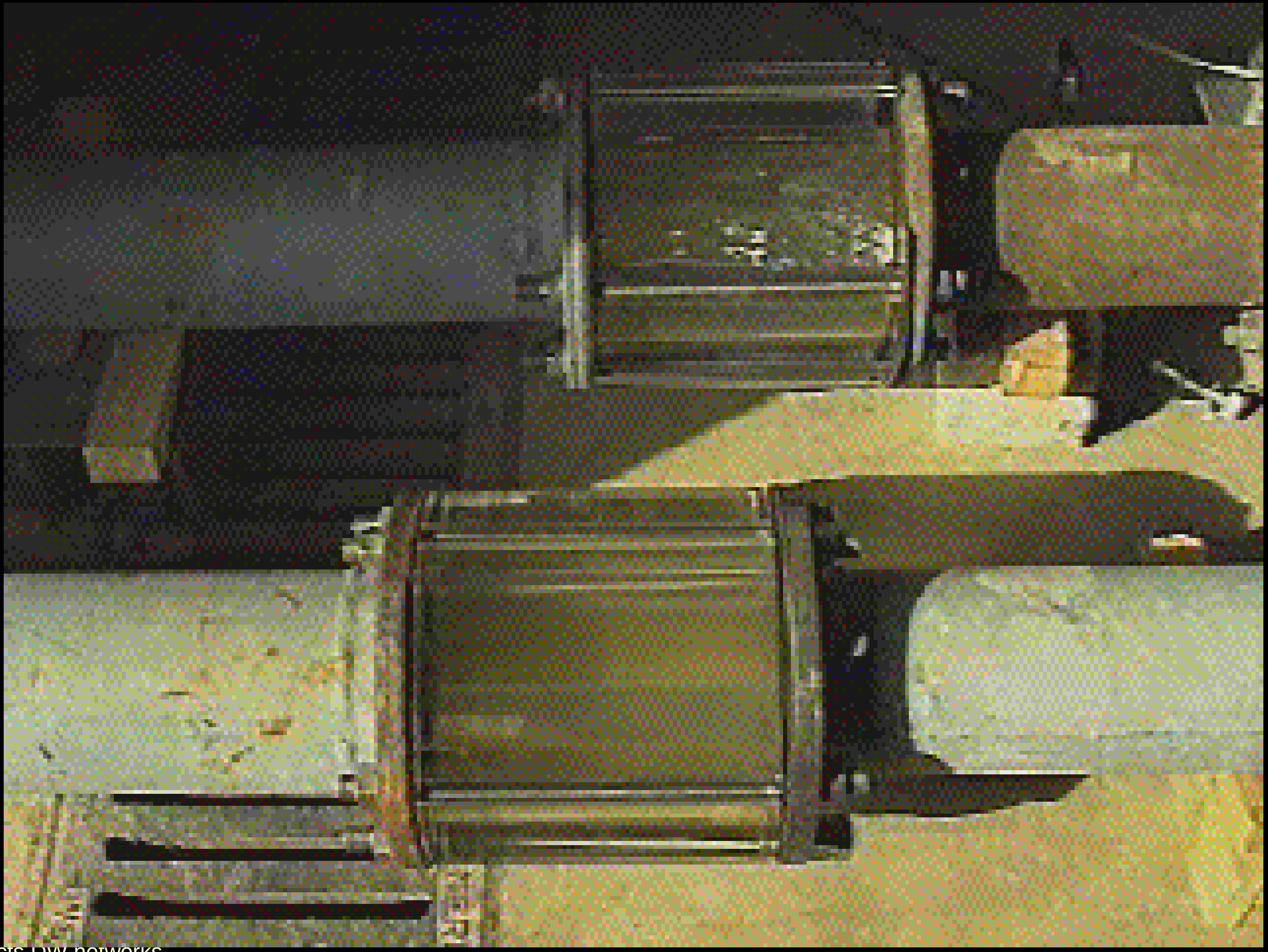
Innovative cleaning methods




wmo
DRINKWATER

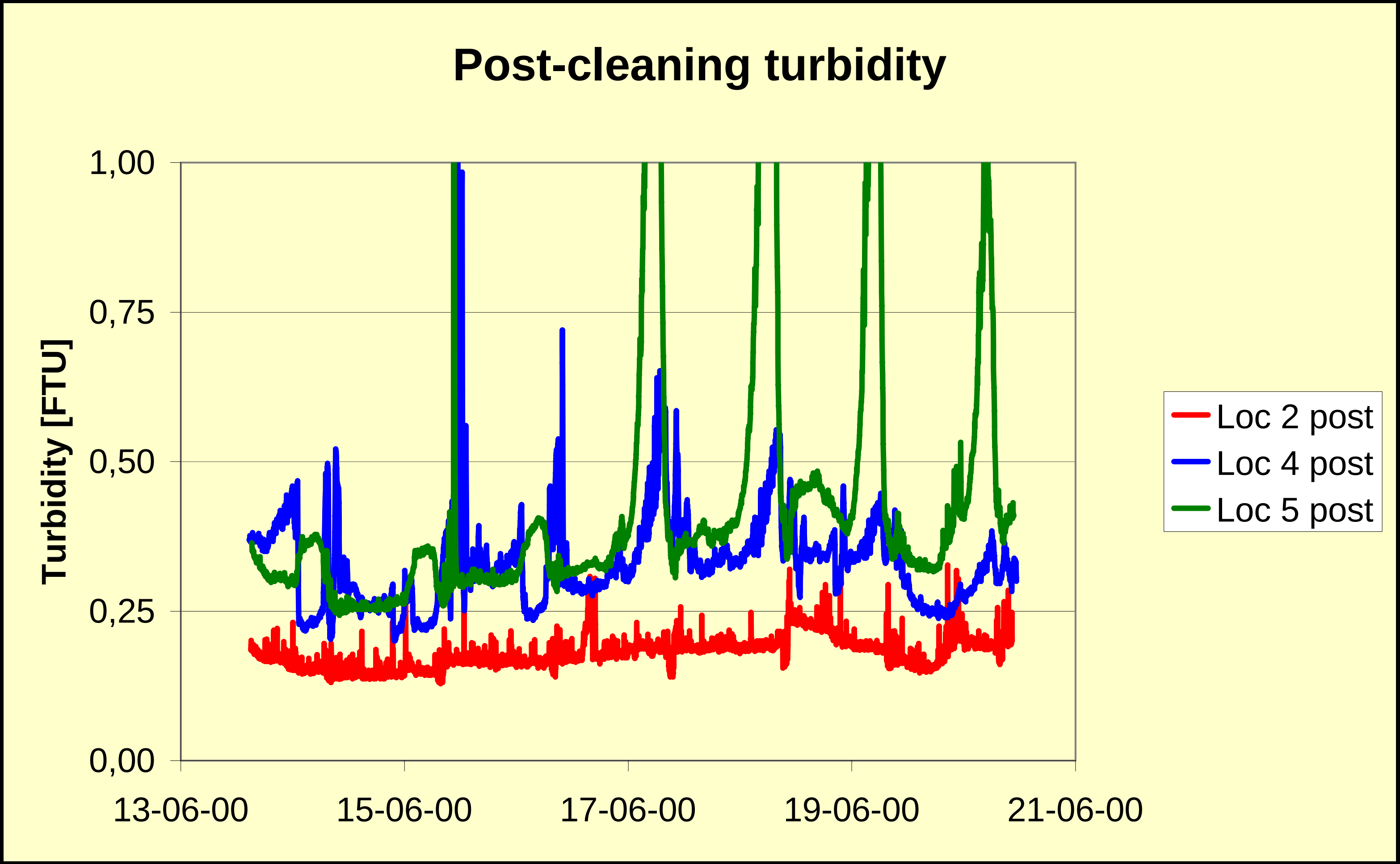

wmo
DRINKWATER

Water/air scouring



Pigging

Result of aggressive cleaning cast iron (pigging or W/A scouring)



Third stage: prevent sedimentation

- Design drinking water networks instead of fire fighting networks
- Main characteristics of drinking water network
  - Looped transport network
  - Branched district areas with up to 200 connections
  - Velocity in branches 0,4 m/s once a day
- Result: ‘self cleaning’ network

- Large draw back: less fire fighting capacity

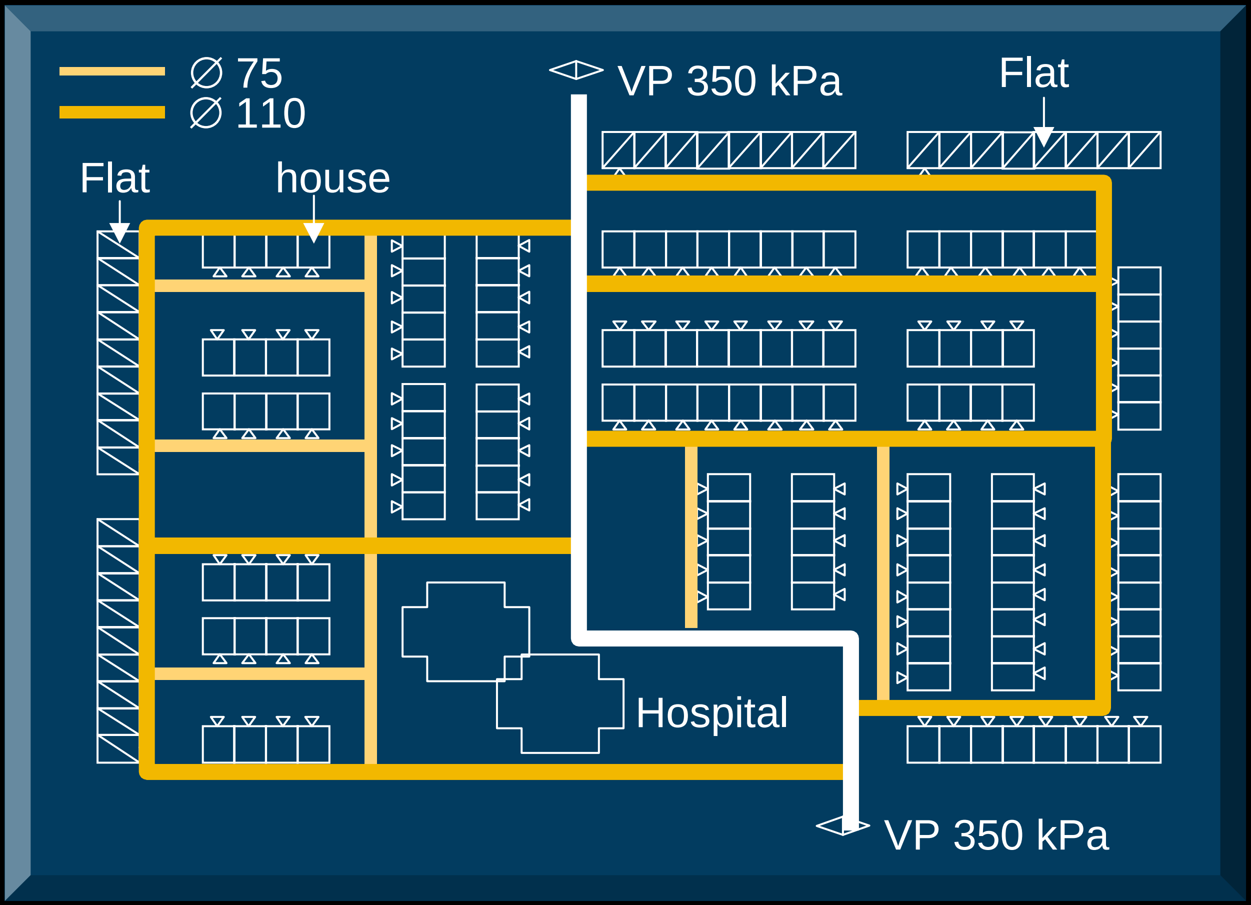
‘Self cleaning’ network

Looped network
V = 0,07 m/sec

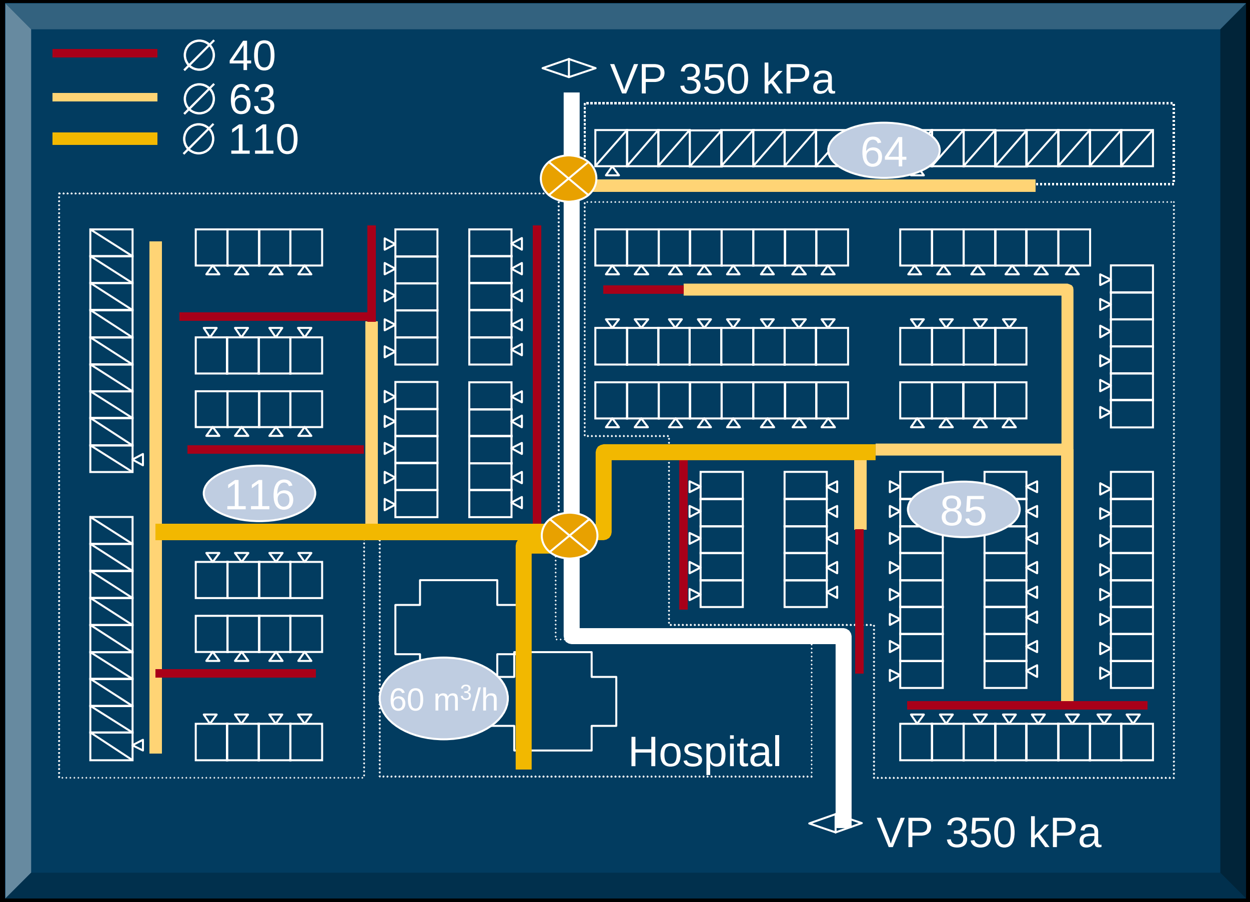
Looped network (disturbed)
V = > 0,4 m/sec

Drinking water network (self cleaning)
V = > 0,4 m/sec

Conventional network



‘New’ network



Pumping stations and water transport

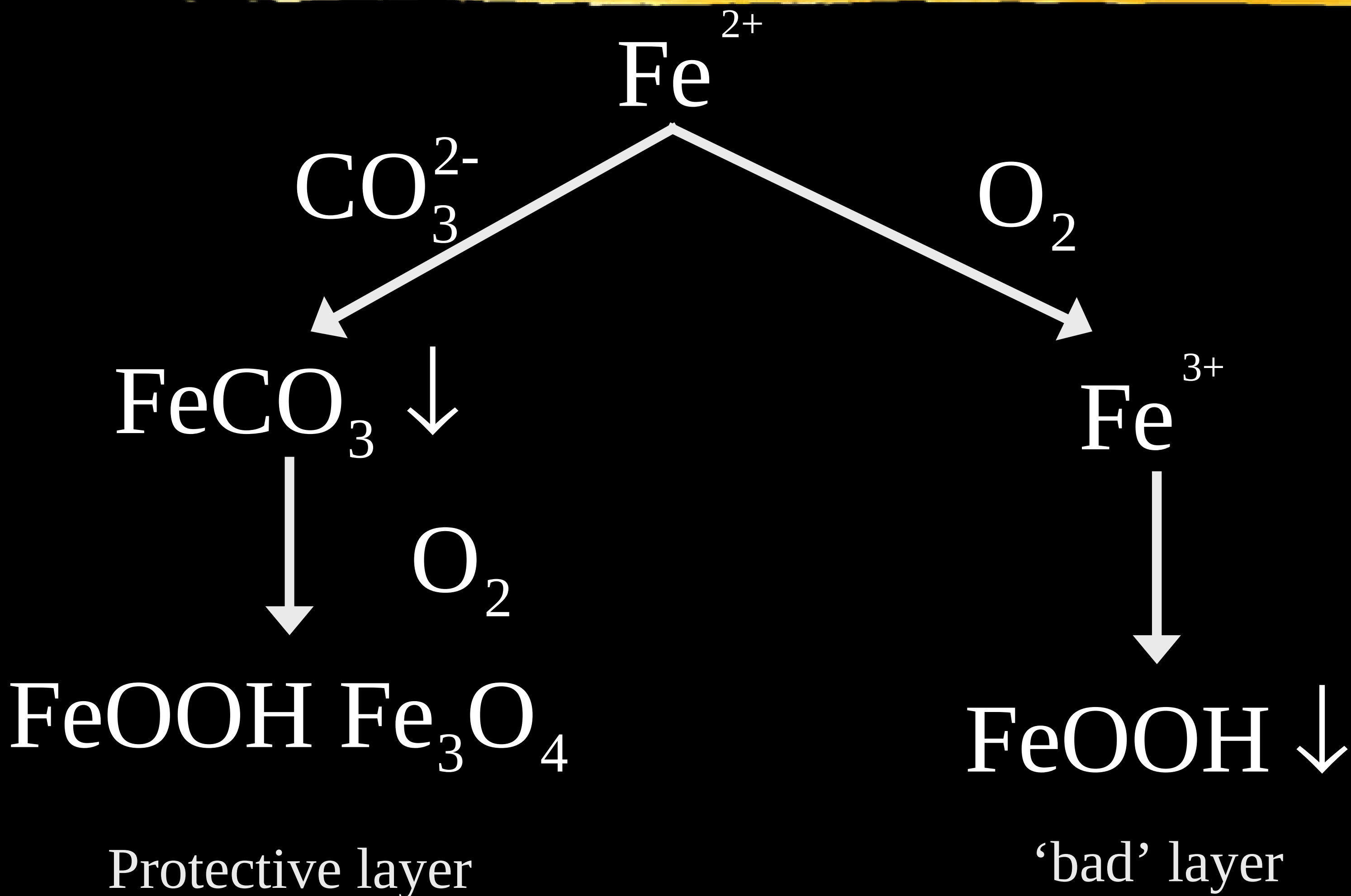
Water quality aspects of drinking water networks

ct5550

Chemical processes

- Materials used in drinking water transport and distribution
  - Cast Iron
  - Asbestos Cement
  - Plastics as PVC and PE
- Materials used in house plumbing
  - Lead
  - Copper
  - Plastics, mainly PE
- Other materials as concrete, (galvanised) steel, GRP act chemically in similar ways

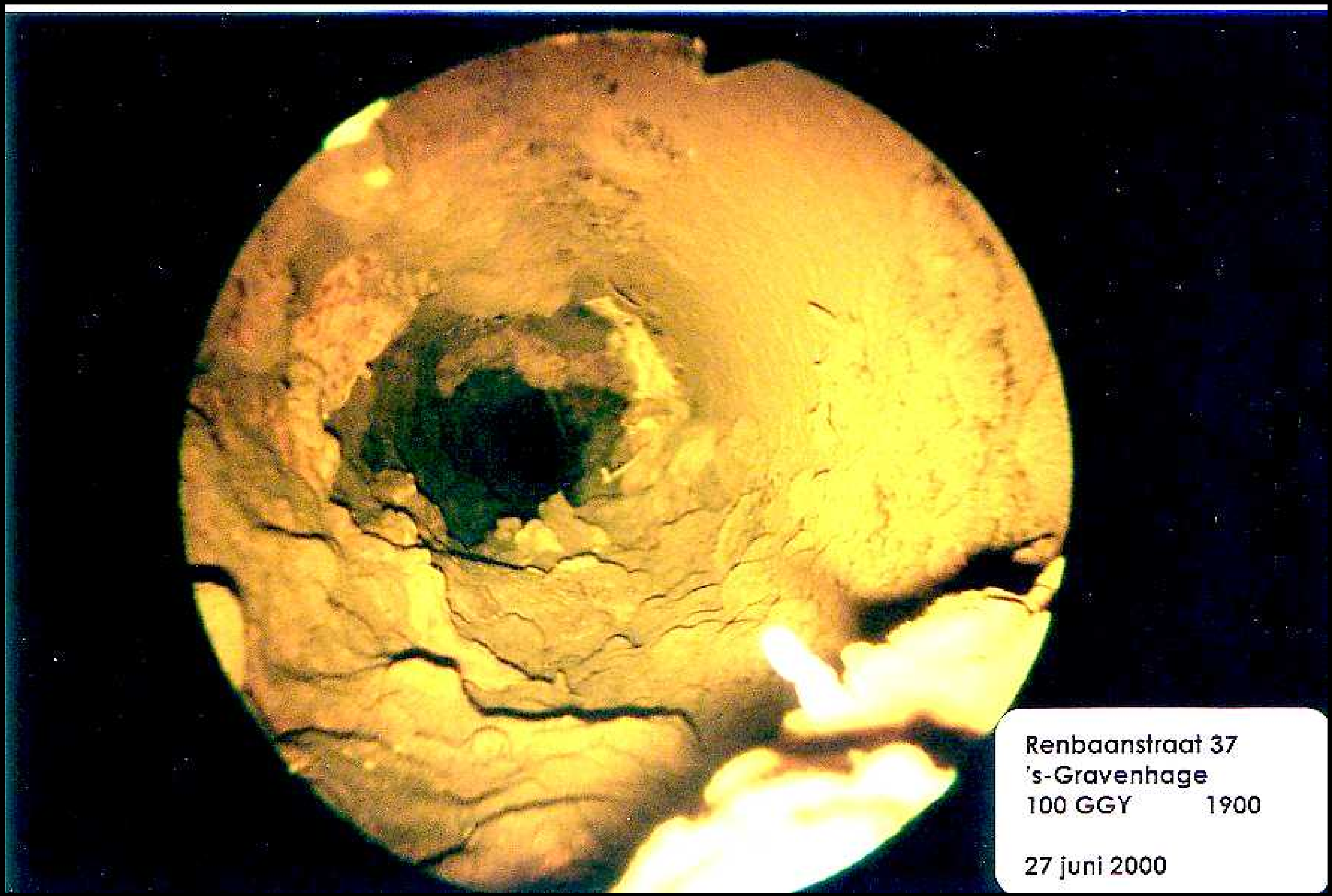
Cast Iron: corrosion products



Cast Iron: corrosion problems

- Graphitisation: weakening of pipe material and strength
- Loss of hydraulic capacity due to voluminous corrosion products
- Deterioration of water quality
  - Discolouration
  - Biofilm formation

Ø100 Cast Iron (1900)



Cast Iron: prevention of corrosion

- Water composition at pumping station
  - pH > 7,5
  - TIC > 2 mmol/l
    (Total Inorganic Carbon ≅ $[HCO_3^-]$)
  - $(Cl^- + 2SO_4)/TIC < 1$
- Coatings
  - Cement mortar lining
  - PE-sleeves

Asbestos Cement

- Corrosion process: Leaching of Calcium Hydroxide
- Corrosion problems:
  - Loss of strength
  - Increase of pH
  - Release of asbestos fibres
  - Precipitation of calcium carbonate

Prevention AC corrosion problems

- Water composition
  - -0,2 < SI < 0,3
  - TIC > 2 mmol/l

$$SI = \log \frac{\left[Ca^{2+}\right]\left[CO_3^{2-}\right]}{\left[Ca^{2+}\right]_{eq}\left[CO_3^{2-}\right]_{eq}} = pH - pH_{eq}$$

Plastics

- No chemical processes known at the moment
- (limited) Lead destabilisation at the start of the life time

Lead and copper

- Corrosion process: release of lead
- Corrosion problem: public health
- Prevention
  - Water composition: pH > 7,8
  - Coating
  - replacement

Optimal composition of drinking water

- 7.8 and (0,38 TIC + 1.5$\left[SO_4^{2-}\right] + 5.3) < pH < 8.3$
- $TIC > 2$
- $-0.2 < SI < 0,3$
- $\dfrac{\left[Cl^{-}\right] + 2\left[SO_4^{2-}\right]}{TIC} < 1$

$TIC = \left[HCO_3^{-}\right]$ (if 7.8 < pH < 8.3)

Chemical en biological processes

- The following slides are optional and can be put in an appendix.

Biological processes

- Biological water quality will change in the distribution system
- Changes are governed by:
  - initial water quality
  - chemical and biological processes
  - hydraulics
  - pipe material
  - system integrity

Goal in-pipe water quality control

- Hygienic water safety control
  - limitation of regrowth
  - prevention of recontamination
- Controlling chemical and physical composition

Hygienic water safety control: limitation of regrowth

- Disinfectant residual
  - May have some effect
  - Not applied because of adverse effects (disinfection by-products, taste, odour)
- Controlling the source of regrowth problems
  - biologically unstable water
  - biologically unstable pipe materials

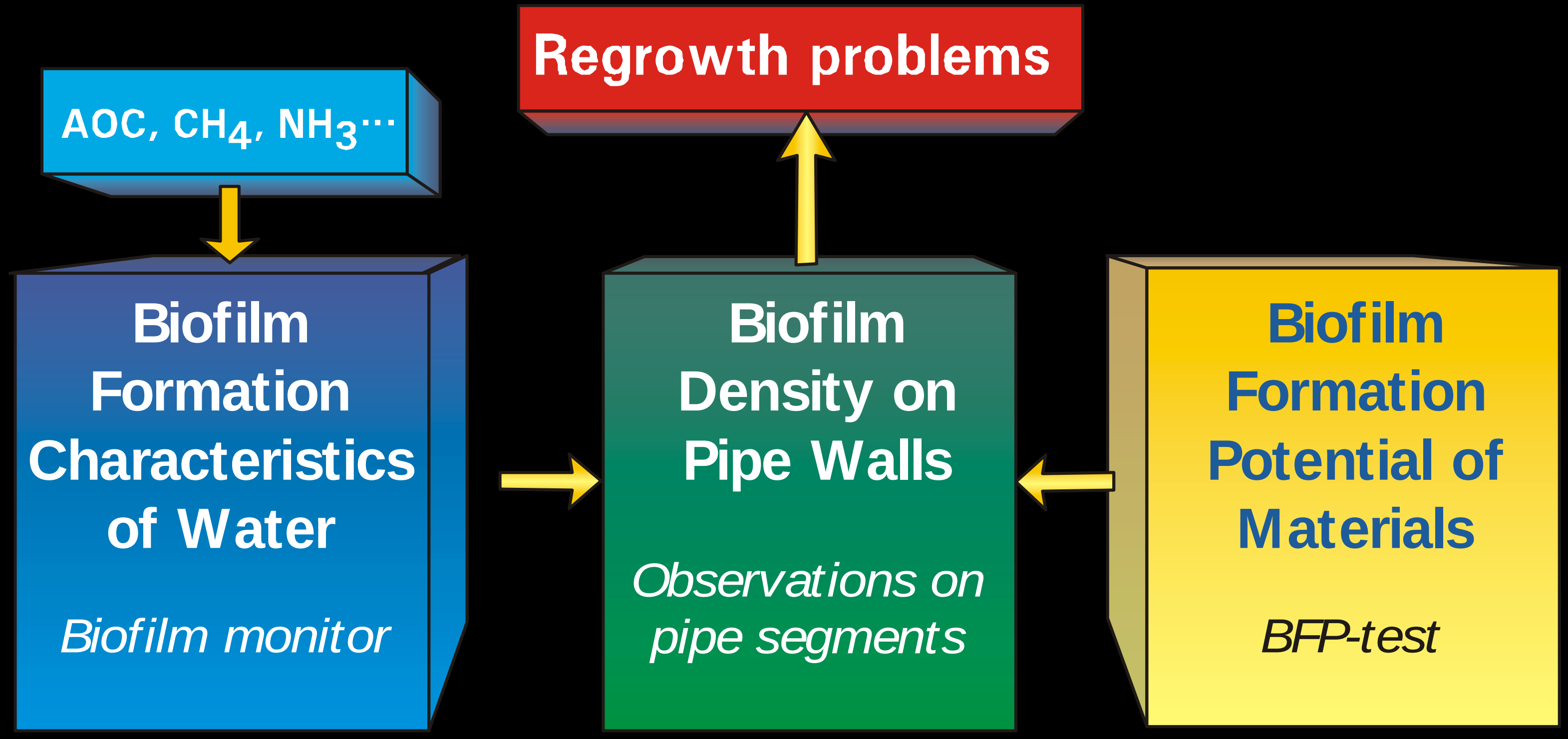
Causes for degradation of the microbial in-pipe water quality

- biofilm formation
  - attachment and growth of micro-organisms onto surfaces exposed to drinking water
  - entrapment of (inorganic) particles in biofilm
- sediment accumulation
  - environment for multiplication of micro-organisms (Aeromonads, invertebrates)

Biofilm formation

- Biofilm formation is promoted by microbial utilisation of biodegradable compounds
- Sources for biodegradable compounds:
  - treated water
  - pipe material in contact with drinking water

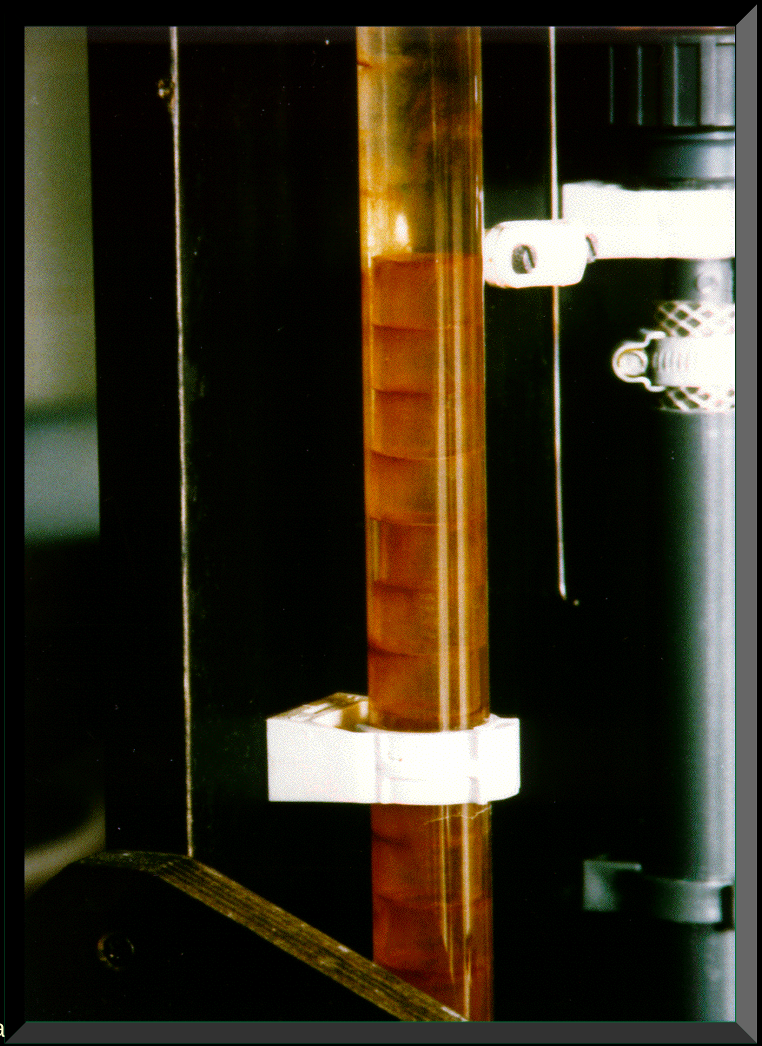
The Unified Biofilm Approach

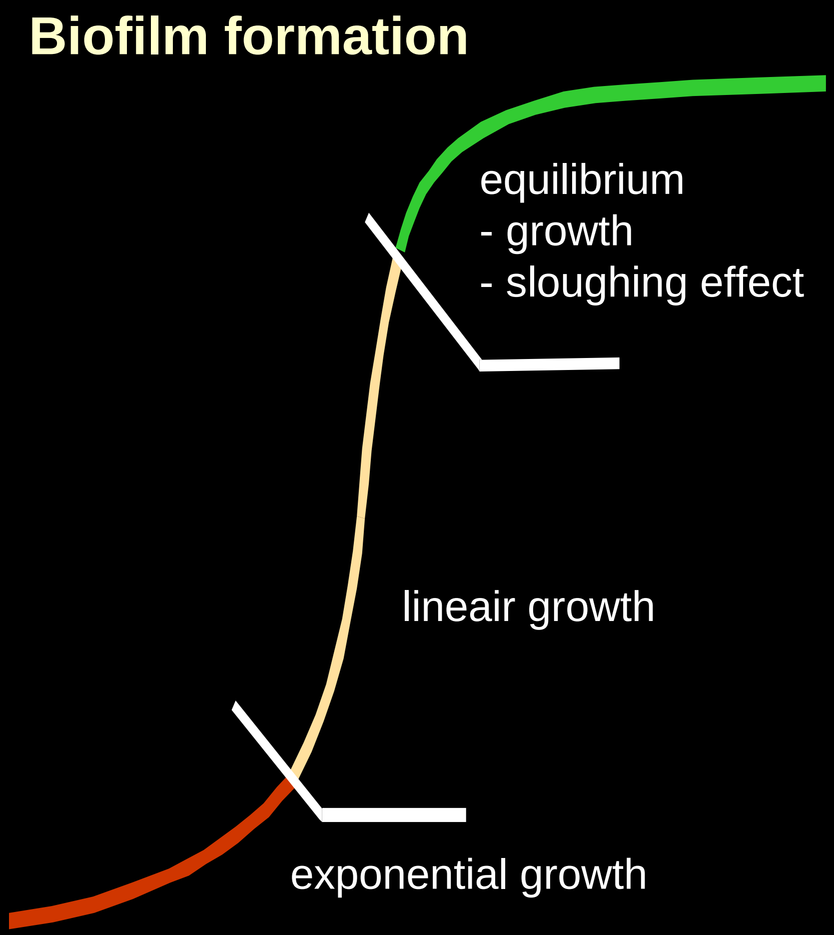


Assessing biofilm formation

- Kiwa Biofilm Monitor
  - assessment of rate (BFR) and extent (BFP) of biofilm formation on surfaces exposed to water under test
    - BFR = Biofilm Formation Rate (pg ATP/cm^2.d)
    - BFP = Biofilm Formation Potential (pg ATP/ cm^2)
  - provides information on the biostability of the water
- Biomass Production Potential (BPP) test
  - assessment of the growth promoting characteristics of materials in slow sand filtrate
  - BPP = BFP + Suspended Biomass Production (SBP)

Biofilm Formation Rate (BFR) in water:Kiwa Biofilm Monitor

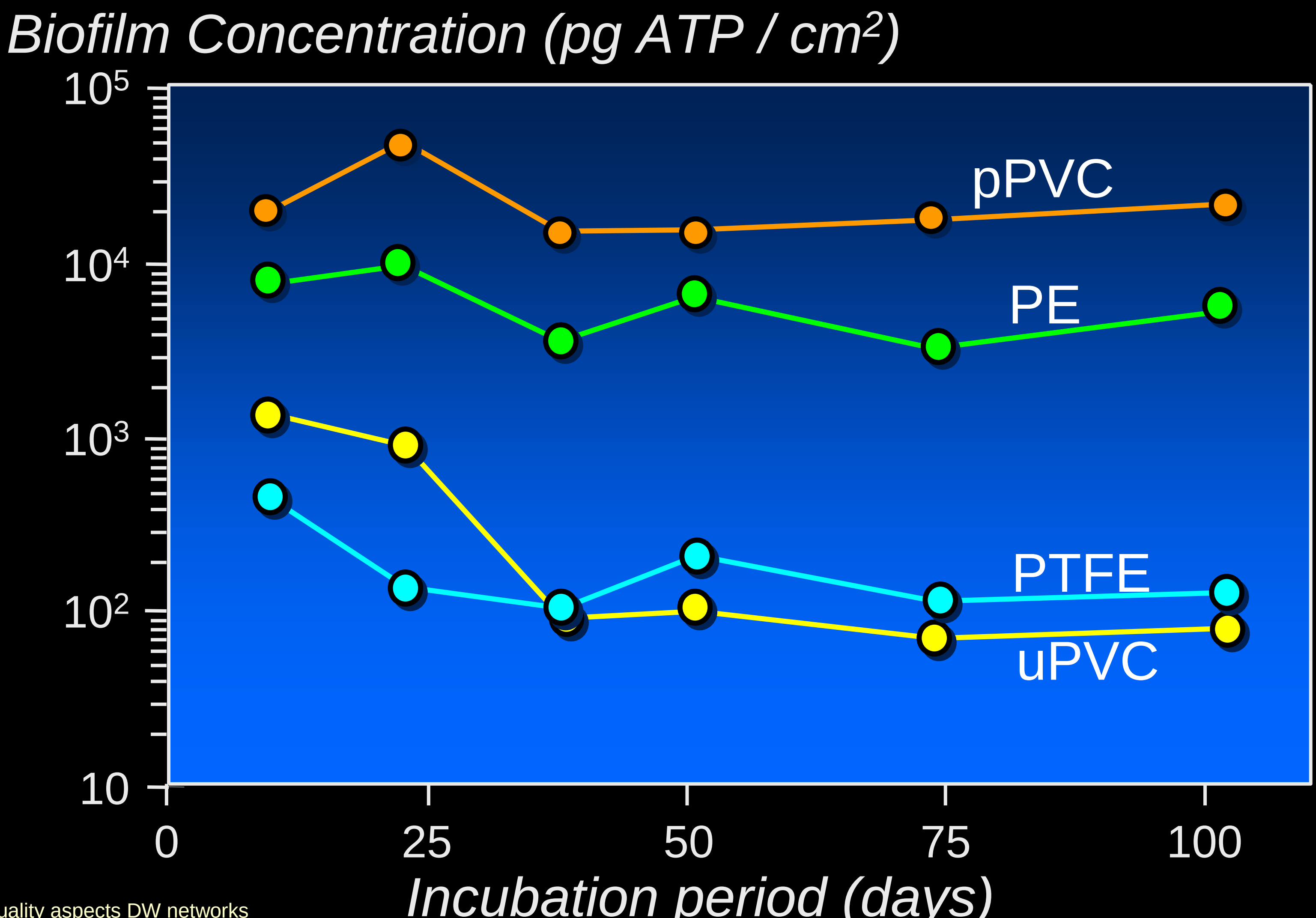




Biomass Production Potential (BPP)

- BPP of materials in contact with (tap) water
- BPP/BFP test
  - Slow sand filtrate (600 ml)
  - 12 pieces of material
  - S/V = 0.15 cm2/cm3
  - Duplicate flasks
  - Incubation at 25 °C
  - Period: 16 weeks
  - Biomass parameters:
  - - ATP
  - - HPC
  - - Legionella, ..

Biofilm Formation on materials in slow sand filtrate (BFP-test)



The Unified Biofilm Approach: a framework for evaluation