Sensors and Monitors Used by the Global Water Industry

Thursday, September 4th, 2014

11:00 am – 1:00 pm Eastern

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Global Water Research Coalition

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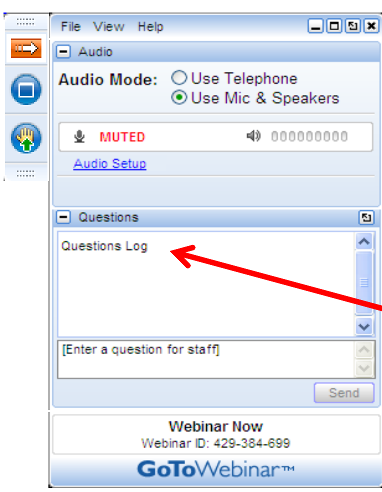
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

Amit Pramanik, PhD, BCEEM
Acting Director of Research,
WERF

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Today's Schedule

- Joep van den Broeke, Benten Water Solutions – Project Introduction
- Leo Carswell, WRc – The Compendium
- Jorgen Jonsson, WRc - Compendium Demonstration
- Presentation of Case Studies
- Questions & Answers

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The Global Water Industry's Experience with Sensors

Compendium of Sensors and Monitors and their Use in the Global Water Industry

WERF Project SENG1C11

The Global Water Industry's Experience with Sensors

Joep van den Broeke

Benten water solutions

Sampling and Analysis

Source: Het Waterlaboratorium

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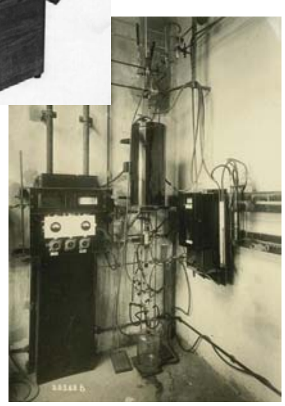
Generations of Online Instruments



Source: Hach Lange

Source: BlueLeg Monitoring

Source: Optiqua Technologies

Source: scan Messtechnik

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Permeation through the Entire Water Cycle

Source: bbe Moldaenke

Source: YSI

Source: Analytical Technology Inc.

Source: DCM Process Measurement

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But still…

- Prevailing image of online water quality sensors:

Source: Analytical Technology Inc.

- Operation is problematic:
  - Unreliable
  - Laborious to maintain
  - Overly complicated

⇩

  - Lack of trust in instruments

- Value is limited:
  - Unclear what is can be used for / what instrumentation can achieve
  - What to do with the data?

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Changing Face of the Water Industry

- Challenges: management of water and wastewater networks is becoming increasingly challenging:
  - Meet operational demands
  - Regulatory compliance
  - Improving economics
- Opportunities: real-time control allows more flexible and efficient use of existing assets. To maximize benefits, greater system knowledge is required. This includes online water quality information.
- But... potential of sensors and monitors not (yet) generally embraced:
  - Paradigm shift to real-time-control supported flexible operations has not (yet) taken place

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Why does this not change?

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Why does this not change?

- Successes: there are many examples of the successful use of water quality sensors and the associated benefits, however...
  - Such information often not (easily) available
  - Often not or only locally disseminated
  - There is no well-recognised, unbiased, open, global tool available to share information and experience
- What is available:
  - (too) Scientific materials – not relevant for daily operations
  - Commercial materials – not objective
  - National publications & conference proceedings – difficult to find
  - Reports from organisations such as WQTC, WERF, KWR, UKWIR, WRF/AwwaRF, ... – in many cases have to be purchased, contain excessive background information and little practical information.

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A Compendium

- WERF project SENG1C11 was commissioned by GWRC to
  "Identify and document information on the types, costs (capital and operating), and real-world experiences with the use of sensors in the water/wastewater industry in each of the participating GWRC member countries."
  - What works?
  - What is needed to keep it working?
  - What is it used for?
  - What benefits can be achieved by the appropriate use of sensors?
- To create an online ***Compendium*** that will provide unbiased sensor performance information, best practice guidelines & case studies
- To allow user to ***learn from the experience*** of existing users and facilitate communication between stakeholders

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Members Involved

Global Water Research Coalition

- Water Environment Research Foundation (WERF, USA)
- Water Research Foundation (WRF, USA)
- US Environment Protection Agency (US EPA, USA)
- UK Water Industry Research (UKWIR, UK)
- KWR Watercycle Research Institute (NL)
- STOWA (NL)
- DVGW Technologiezentrum Wasser (TZW, Ger.)
- SUEZ Environnement – Cirsee (F)
- Water Research Commission (SA)
- Public Utility Board (PUB, SG)
- Water Services Association Australia (AU)
- Water Research Australia (WRA)

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The Project Team

- **Benten Water Solutions (the Netherlands)**
  Experts on sensors for water quality monitoring (DW)
- **WRc plc (UK)**
  Experts on sensors for water quality monitoring (WW)
- **Tetra Tech (USA)**
  Data collection and case studies for USA
- **AECOM (Australia)**
  Data collection and case studies for Australia and Singapore
- **Chris Swartz Water Utilization Engineers (South Africa)**
  Data collection and case studies for South Africa

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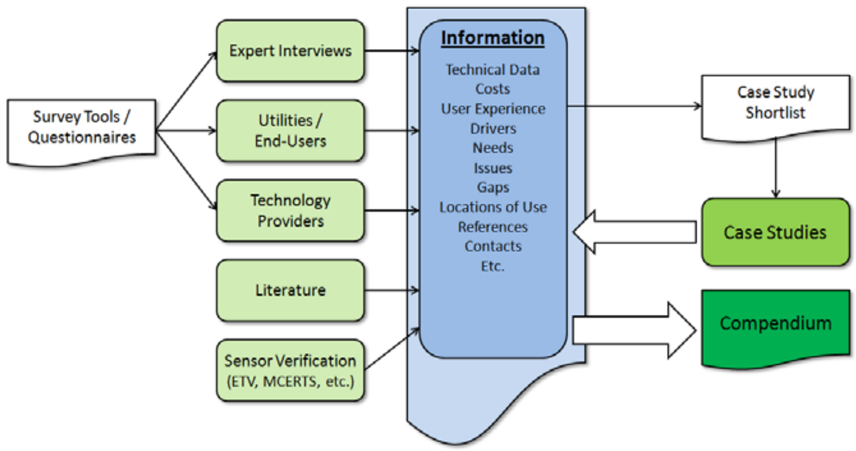
A Compendium of Sensors and Monitors and their Use in the Global Water Industry

- Timeline: October 2012 – December 2013
- Approach:



Overview of Results

- Questionnaires developed
  - Level 1
  - Level 2
  - 80+ responses from 8 countries received
- Review of > 250 papers, reports and books
- Inventory of > 250 manufacturers + their technologies
- 6+ regional workshops
- 21+ Case Studies

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Critical Issues Identified

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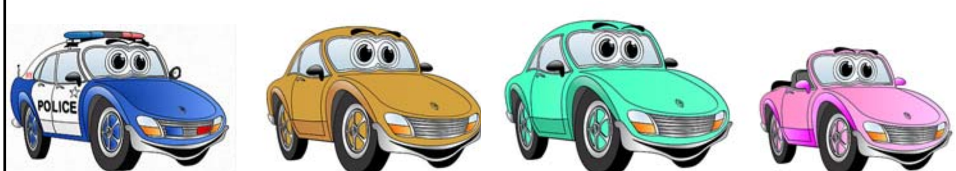
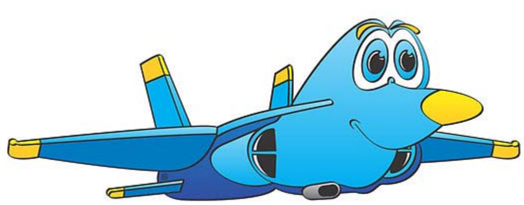
Just consider this...





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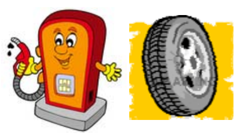

Case Studies & User Cases

- Drinking Water – Source Protection & Intake Protection
- Drinking Water Treatment – automated operation
- Pollution Load Control in Wastewater Collection and Treatment
- Feed-forward control of coagulation
- Process Control in WWTP (e.g. aeration, nitrification/denitrification)
- Ensuring effective disinfection under changeable water composition
- Trade Waste / Consent Monitoring

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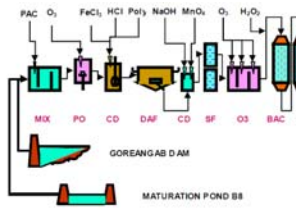
Exemplary Examples

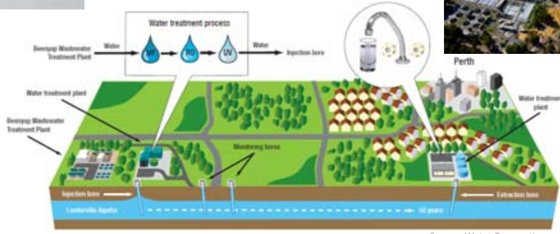
PUB
Water for All: Conserve, Value, Enjoy

Source: PUB

Source: Wingoc



wingoc



WATER CORPORATION

Source: Water Corporation

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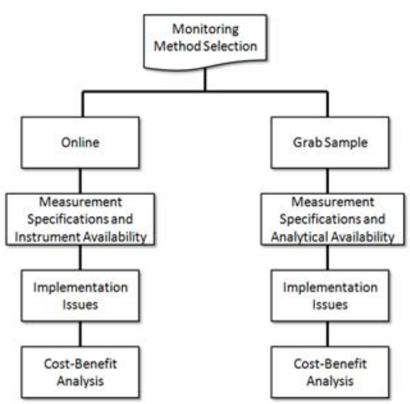
Best Practice Guidelines



Factor	Grab Sampling	Online Monitoring
Parameter Measurement		
Water Quality and Environmental Regulations		
Real-time Decisions with Automatic or Manual Control		
Sample Subject to Water Quality Deterioration		
Variability of the Parameters		
Frequency of Analysis		
Accessibility of Sampling Locations		
Process Optimisation for Water Quality and/or Economic Factors		
Offline Model Calibration		

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What have we learned?

- Carefully consider what to monitor and how
- Expectations need to be realistic
  - Maintenance & Calibration 1x month – great ?
  - Maintenance & Calibration 1x month – awful ?

or

- Rating of instrumentation differs widely between utilities
- Purpose of the monitoring plays a role in how technology is embedded in organisation which reflects on appreciation
  - RTC -> instruments have clear purpose, maintenance is part of the deal
  - Compliance -> instruments are imposed, maintenance burden
  - Informative -> often not clear what to do with data, sometimes burden
- Utilities with dedicated personnel which is well trained appreciate instruments more / have less difficulty with operations. Often mid-sized utilities.

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Identified Drivers for Online Monitoring

- Cost (sampling – transport – analysis is expensive)
- Speed
- Measurement frequency

- Business drivers
  - Process control / optimisation
  - Regulatory (health and safety)
  - Event detection / response
  - Safety
  - Asset protection
  - Planning
  - Maintenance

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Considerations

- Even the simplest parameter is complex
- Implementation is a technical process as well as an educational and cultural one
- Successful application of online monitoring requires organisation-wide effort and support
- Dedicated and well-trained maintenance personnel are required
- Maintenance requirements depend on type of use (RTC vs. Informative)
- Consider that the lifespan of the instrument is limited -> budget for spares/replacement

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Issues

- Lack of skilled personnel & overall lack of personnel
- Current generation of sensors is capable but not fit for large scale use (CAPEX and OPEX too high)
- Need to organize QA/QC, including standard operating procedures, often ignored.
- Data Management:
  - Handling and interpretation needs specific skills which are often lacking amongst traditional utility personnel
  - Effective tools for data management lacking

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Issues

- Cost effectiveness of sensors is difficult to quantify
- Legislation can be a driver but often is a barrier
- Distribution of knowledge is problematic, even within an organisation (often different sections do not talk to each other)
- Research is very ad-hoc and un-coordinated. Mainly on national level, although the demand is global. Little cooperation between sectors.
- Market dynamics can be hindrance:
  - Need to tender contracts -> no continuity, different systems

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Summary

- Carefully determine the needs and the best solution for these needs, considering available skills, resources and budgets
- Embed online monitoring in the organisation
  - Understanding of what data is used for
  - Well designed and managed effort
  - Regular maintenance
  - Attention to apparent failures
  - Regular reassessment of the monitoring programme
- **Realistic expectations prevent disillusionment**
- **Compendium is a tool to assist with understanding, need identification, selection of solutions, learning from experience**

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A Compendium of Sensors and Monitors and their Use in the Global Water Industry

Thank you for your attention

For more information:

www.wqsmc.org

Water Environment Research Foundation

werf@werf.org

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The Compendium

Leo Carswell

WRc

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The purpose of the compendium

Utilise the experience of current users to help the wider water industry use on-line water quality monitoring instrumentation more effectively.

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Why an on-line compendium?

Easy access and searching

Retrieve of data

boston.lti.cs.cmu.edu

The potential to keep it up-to-date

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What is the compendium?

- An on-line database that can be queried through a web based interface.
- A source of information to help in the process of selecting the monitor that best fits an application.
- A source of contact details to facilitate procurement and implementation of sensor and monitoring systems.

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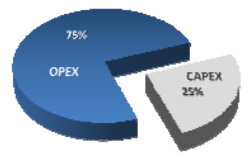
What it's not

A comprehensive reference database

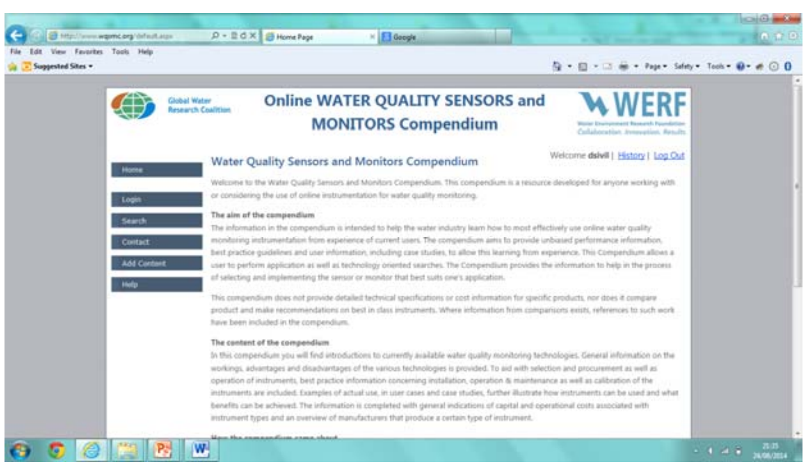
A Detailed cost database



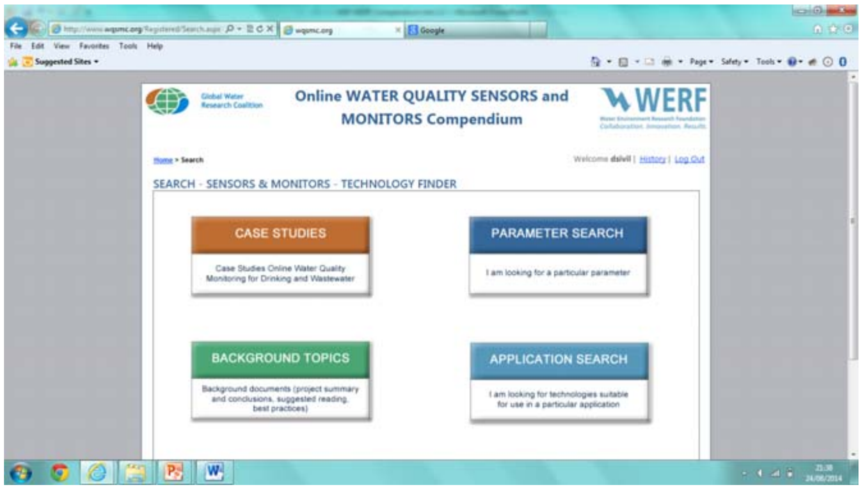
A compilation of all evaluation data

It will not tell you exactly which instrument/model you should purchase

http://www.wqsmc.org



What can the compendium tell me?



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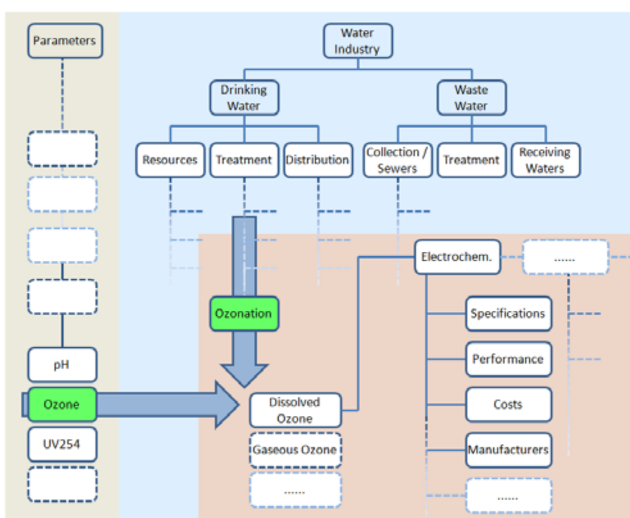
Data structure



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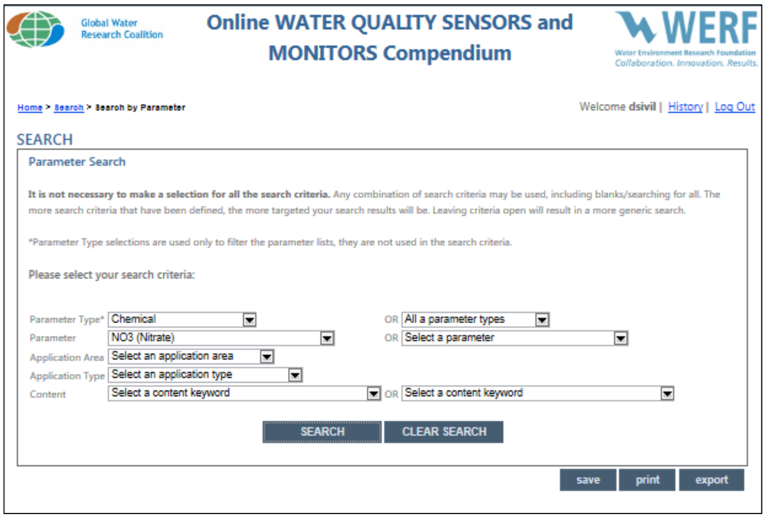
Searching



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Search results

Search criteria

Search result

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Contents

General Summary Introduction to the described parameter

Technical description of the measurement method

Advantages and disadvantages of the described technology

Key operational aspects of the described technology.

Instrument Cost (Capex and Opex)

Installation best-practice information

Technical data, e.g. known cross sensitivities.

Information on **calibration requirements**

List of **manufacturers** that provide the described type of technology

References to documents for further reading and available performance verification/validation reports.

List of **user cases**

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Access to the compendium

- The Compendium is accessible at www.wqsmc.org.
- User log-in and passwords

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Summary

- The compendium consists of an on-line database that can be queried through a web based interface.
- Users can perform application as well as technology oriented searches.
- The compendium provides information to help in the process of selecting and implementing the monitor that best the application.

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Compendium Demonstration

Jorgen Jonsson

WRc

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A Selection of Case Studies

Joep van den Broeke

Benten water solutions

Case Studies & User Cases

- Drinking Water – Source Protection & Intake Protection
- Drinking Water Treatment – automated operation
- Pollution Load Control in Wastewater Collection and Treatment
- Feed-forward control of coagulation
- Process Control in WWTP
- Ensuring effective disinfection under changeable water composition
- Trade Waste / Consent Monitoring

A Selection of Case Studies

- A total of 22 case studies performed, including:
  - DW-A (USA)
  - Waternet (the Netherlands)
  - SA Water (AU)
  - De Dommel (the Netherlands)
  - WW-A (USA)
  - NEWater (SG)
  - Eastman Chemical Company (USA)

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DW-A (USA) Case Studies

- The case describes the experience of a large US East Coast utility
- Drinking water sources – primarily surface water in highly urbanized area
- Challenges include water quality issues, mature distribution system with zones that have to deal with demographic and business changes, network age.

- Consequences: frequent turbidity spikes, nitrification and need for active corrosion control
- Utility received Water Security Initiative grant to develop an early warning system for contamination warning.
- Other uses for monitoring includes: operational control, chlorine residual monitoring, understanding hydraulics, research.

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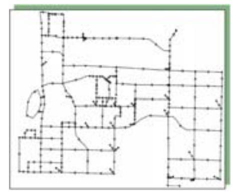
DW-A (USA) Case Studies



- Successes and Limitations
  - Monitoring chlorine helps identify areas where flushing is needed
  - OWQM used to develop a continuous snap shot of water quality at key locations
  - Difficulty in hiring and retaining trained staff, due to better earning potential in other industries
- Lessons Learned
  - Need for right personnel and support
  - Selection of system integrator was crucial in achieving goals
  - Operation of a monitoring system of this complexity is a team effort which includes staff and contractor support

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- Drinking water for > 1 million in Amsterdam
- Mix of high quality ground water and river water
- Recently established from various smaller organisations
- Company goal: High level of plant automation
  - Recent switch from manual operation to sensor based unmanned operation

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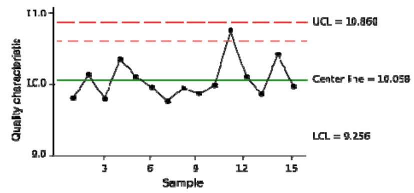
- Step 1: rationalisation
- Step 2: Approach
  - Take one example
  - Develop procedures
  - Embed in organisation
- Step 3: Developing the Procedure
- Step 4: Control and Reporting
  - Detection of patterns and bottlenecks
  - Evaluation of performance
  - Evaluation of maintenance quality
  - Management support
- Step 5: Improving the procedure



Management rapportage funtioneren online kwaliteits monitoren: Weesperkarspel

	2009				2010				2011			
	1e kw	2e kw	3e kw	4e kw	1e kw	2e kw	3e kw	4e kw	1e kw	2e kw	3e kw	4e kw
Totaal indruk funtioneren monitoren	79	91	92	91	89	92	92	90	91	93	95	92
aantal monitoren	29	29	27	27	28	37	36	38	38	38	30	28
	1e kw	2e kw	3e kw	4e kw	1e kw	2e kw	3e kw	4e kw	1e kw	2e kw	3e kw	4e kw
1. Zuurstof	70	87	90	80	83	93	94	93	83	97	93	100
2. Troebelheid	76	94	93	92	84	94	97	91	89	97	97	87
3. Zuurgraad	84	91	95	92	95	91	88	89	95	90	95	92
4. Temperatuur	67	100	100	100	83	83	100	100	100	100	100	100
5. Hardheid	87	88	84	85	86	89	80	78	80	79	85	84
6. Ozon in gas	79	68	83	74	100	100	#####	#####	100	94	95	61

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Benefits

- Savings on operation
  - Monitoring budget (excl. hardware costs) decreased from 600.000 to 400.000 € yearly
  - Reduced consumption of acid and caustic
  - Longer run times of carbon filters + higher regeneration efficiency
- More stabile water quality
  - Saturation Index (main quality indicator)
  - pH used as operational indicator for reporting at management level / benchmarking

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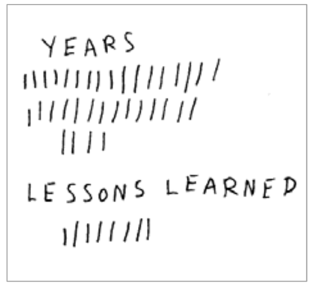
Lessons Learned



- Even the most basic parameter is complex
- More intensive maintenance and performance verification reduces overall time spent on instrumentation
- Successful application of online requires organisation-wide effort and support
- Implementation requires a dedicated manager
- Implementation is a technical process as well as an educational and cultural
- Periodical audits help in keeping everyone sharp and keeping up quality

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SA Water (AU) Case Study

Source: SA Water

- SA Water provides water and wastewater services to 1.5M in Adelaide region
- Case study deals with Happy Valley water treatment plant, largest of SA Adelaide plants
- HaV has a capacity of 850 ML / day
- Plant combines treated surface water and desalinated water from Adelaide desalination plant. Ratio between the waters is variable.
- These two very different waters are blended before distribution
- Blending has impact on characteristics such as chlorine demand. Consistent water quality is challenging due to source variability.

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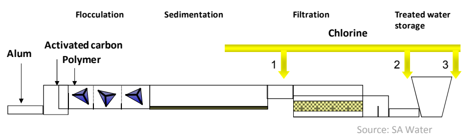
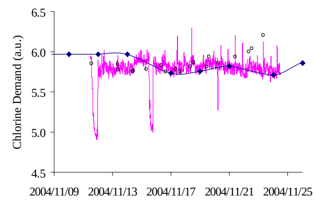
SA Water (AU) Case Study

- SA Water project to investigate use of online monitoring to predict chlorine demand due to desal. water blending
- SA Water investigated online chlorine demand prediction using UV absorbance measurements with a submersible spectrometer probe.

Source: scan Messtechnik



Source: SA Water



- Findings include UV spectroscopy has potential in feed-forward control of chlorine dosing. Technology use is highly site specific, and needs to be optimised at each location.

De Dommel Case Study

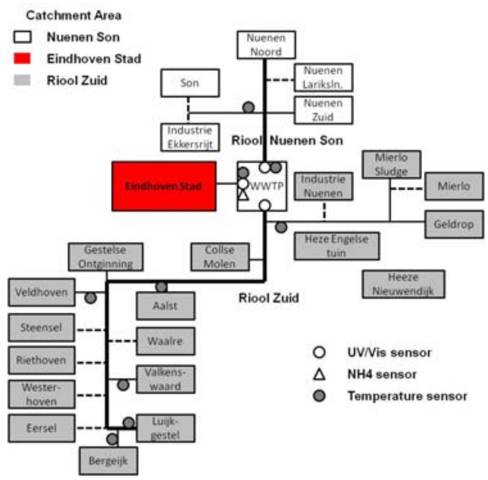
Source: De Dommel

- Waterboard with responsibility for WW collection and treatment
- Case study describes modernisation project at Eindhoven WWTP, with 750000 person equivalents
- WWTP discharges into small river (dry weather 50% is WW), which has to meet EU Water Framework Directive water quality targets
- Prime problem is high nutrients load and high COD (low DO in river), primarily due to CSO
- Project evaluated options to improve plant performance, reduce CSOs and increase ecological quality of river Dommel.

Source: De Dommel

De Dommel Case Study

- Kallisto project launched to identify most cost effective measures
- Extensive modelling of hydraulics and water quality in the collection system as well as the WWTP
- WQ sensors used include UV, turbidity, EC and NH4
- Many lessons learned on instrument selection, installation, operation.
- Solutions:
  - Use additional buffer capacity of sewer system
  - Build wet storage
  - Aeration of river



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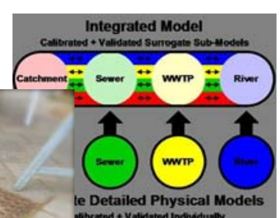
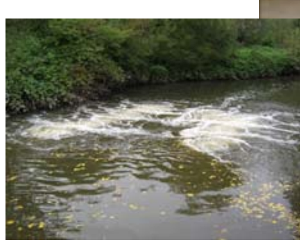
De Dommel Case Study

- Traditional upgrade to treatment would have cost 160M€
- Solutions:
  - Use additional buffer capacity of sewer system
  - Build wet storage
  - Aeration of river



Source: De Dommel

Source: De Dommel



Source: De Dommel

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WW-A (USA) Case Study

- US West Coast wastewater utility, treating 200MGD (municipal and industrial)
- Obligation to monitor water quality at intake, effluent and of receiving waters
- Part of water undergoes tertiary treatment for re-use. Aim is to achieve zero discharge in 10-15 years.
- Public pressure to improve water treatment, but pressure from utility management to prevent rate increases.
- New processes and improving service levels and regulatory compliance necessitated installation of online monitoring.
- Focus is on bio-solids as digesters are near capacity.

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WW-A (USA) Case Study

- Sensors trialed / used include:
  - Optical DO sensors
  - H_2S sensors
- Teams involved including operations, laboratory, instrument technology
- Instrumentation group is responsible for installation, maintenance and QA/QC. Total costs instrumentation: 4M USD personnel costs (20 staff) and 1.4M USD maintenance and repair.
- Results are used to evaluate processes. Automation of process control is pursued but not implemented.
- Successes:
  - Instrumentation useful in improving treatment

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WW-A (USA) Case Study

- Limitations/lessons learned
  - Barriers within organisation hamper communication and effective use of sensors
  - Sensor selection as part of capital programmes leads to fragemented instrumentation pools, with various instruments for same parameter
  - Most data never used in decision making, neither real-time nor retrospective
  - Important to consider how data will be managed, stored and accessed.
  - Operators tend to turn off sensor that give incorrect information.
  - Choice of instruments (including maintenance requirements) and proper embedding in organisation as well as maintenance crucial to make online monitoring successful.

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PUB Singapore Case Study
Indirect Potable Reuse

- NEWater Reuse Program
  - 4 NEWater WTPs
  - Indirect potable use
  - Currently 30% water supply
  - 50% supply by 2060
- Multi Barrier Treatment
  - Dual-membrane Microfiltration
  - Reverse Osmosis
  - Ultraviolet Disinfection

Source: PUB

- On-Line TOC Analyser Monitoring of Membrane Integrity Case study on its way…..

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NEWater Case Study


Source: GE / Sievers

- Use of TOC analysers to monitor treated water
- TOC analyser perform automated analyses every few minutes instead of tedious lab procedure
- Online instruments serve as EWS of operational problems, such as RO membrane integrity breach
- TOC analysers are delicate instruments that suffered from various operational issues which caused deteriorated data quality and leads to high maintenance requirements:
  - Small tubings and pumps which trap air bubbles
  - In-line filters used clog and affect sample flow
  - Instrument spikes

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Eastman Chemical Company Case Study

- Industrial biological activated sludge wastewater treatment. Similar to municipal WWTP, but influent 100% industrial
- Use for monitoring primarily in control of aeration.
- Real time control is computerised with manual override. Based on input from DO sensors.
- Duplication of DO sensors QA measure. If inconsistency is observed, maintenance is performed.
- Instruments used: Hach LDO probe


Source: Hach Lange

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Eastman Chemical Company Case Study

- Successes:
  - DO sensors have worked well
- Lessons learned:
  - Sensors have their place
  - When they work well they are an integral part of the system
  - Require fair amount of attention
  - Organisation must have right personnel involved in selection, maintenance and review of instruments and data
  - Online sensors make sense if there is a need for real-time control.
  - Sensors slightly more expensive than grab sampling, but more useful for process control.

Source: Eastman Chemical Company

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Summary and Conclusions

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A Compendium of Sensors and Monitors and their Use in the Global Water Industry

Thank you for your attention

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UK Case Studies

Leo Carswell

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Two case studies

- UK approach to Process Automation in Wastewater Treatment Plants
- UK Approach to Intake Protection at Water Treatment Plants

Why selected

- Areas of development and interest in the UK.
- Recent work in this area by WRc, UKWIR and others.
- Still some challenges.
- Information gathered from existing work and discussion with water company experts.

UK approach to Process Automation in Wastewater Treatment Plants

Introduction

- Potential for significant savings of energy, chemicals and carbon.
- Advanced Process Control (APC) technology trials.
- This cases study looks at activated sludge treatment plants where most work has been completed.

£175,000 typical aeration costs per year

UK approach to APC

Three different approaches currently employed in the UK for APC:

1. Combined conventional **feed-forward and feed-back control** incorporating a process model based upon an established IWAPRC model;
2. Control which utilises a **predictive model** of the plant built from actual observation of the plant behaviour over a representative period;
3. An **empirical rule-based system** of control, which adjusts the DO set point according to the ammonia load using a look-up table.

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WERF Water Environment Research Foundation Collaboration. Innovation. Results.

Sensors – Dissolved oxygen

- Reliable and robust dissolved oxygen measurement is fundamental to aeration control.
- Genuine advance in technology in the past 10 years.
- Commonly issue - sensor fouling.
- UK trial of on-line dissolved oxygen probes.

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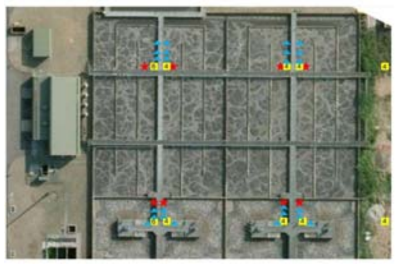
Sensors – Ammonia

- Ammonia monitors used as part of feed-back control to adjust the dissolved oxygen set-point and hence the rate of aeration.
- As with all wet chemical analysers correct installation of ammonia sensors in wastewater is crucial.
- Mixed views on the benefits of the simplicity of the electrochemical probes versus the use of more complex analysers.
- UK undertaking a 6 month trial of wastewater ammonia and nitrate monitors.



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Conclusions

- There is considerable potential for the use of sensors with more advanced control of ASP in the UK.
- The performance achieved using on-line sensors is linked to the correct installation and suitable maintenance. These two issues remain a challenge for UK water companies.
- The UK is building information on the real performance and maintenance requirements of on-line monitors through a series of collaborative trials.

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UK Approach to Intake Protection at WTW

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Introduction

Wide variety of water sources in the UK

Risk

Infrequent events

No one monitoring solution

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Current monitoring

Parameter	On-line	Laboratory
Temperature	Yes	
pH	Yes	Yes
Colour	Yes	Yes
Ammonia	Yes	
Solids/turbidity	Yes	Yes
Oil/VOCs	Yes	
Conductivity	Yes	Yes
Dissolved oxygen	Yes	
Toxicity	Yes	
Pesticides	Yes	Yes
Bacteria		Yes
Fe, Al, Mn		Yes
Chlorophyll A		Yes
Geosmin, MIB		Yes

Note: Not all parameters are monitored at all sites.

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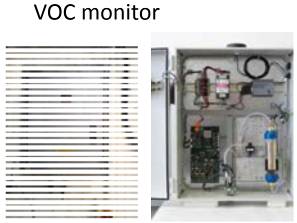
On-line monitors

Endress+Hauser MemoSense pH electrodes

S::CAN Color::lyser

ATi Q45N Ammonia

Modern Water VOC monitor



Hach-Lange Cosmos

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Sample introduction

- Some UK water companies have moved away from individual sampling systems, pipework and analysers to the use of open baffled trough type arrangements.
- Installing a new trough with a new sensor suite costs in the region of $100k

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Future challenges and needs

Compounds of concern in raw water:

- **Endocrine disruptors**
- **Geosmin, MIB**
- **Pesticides**
- **Solvents, VOCs**
- **Metals**

Some of the compounds can be analysed using on-line instrumentations that are available today:

- ASV (anodic stripping voltammetry) for metals
- GC-MS for pesticides

But these are expensive and require substantial maintenance.

- Solvents and VOC can be detected by the VOC monitor and the Lonestar IMS but neither instrument is widely used.

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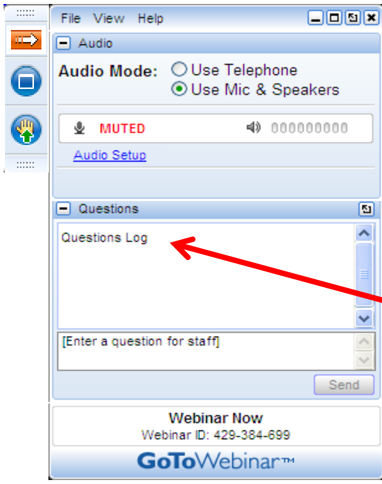
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

Questions?