

The new first responders:
Automated on-line systems for detection of
microbial water contamination

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The value of clean water

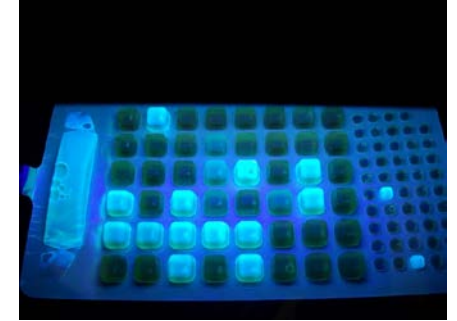


cultural – recreational – economic - food source – raw water

- waters are swimmable
- suitable for cultural use
- Aquaculture
- Fishing and shellfish harvest
- Raw water source for drinking water

The presence of microbial pathogens in water can cause serious illness in people.

Standard microbial water quality testing ...



Sampling – transport – lab analysis – results – alert to the public ...

24 – 48h



or



... safe/not safe – delay of up to *two days*

Sensors

- Turbidity
- pH
- SAC254
- Nitrate
- Oil / PAH
- ...



on-line
analyzers



Water Quality



Current state-of-the-art
lab methods

sampling transport processing analysis



Time to Result
[hours]

15 min

> 24 hours

Knowledge about microbial water quality is crucial. Fast on-line detection systems are needed!

new technologies overview



Semi-automated lab system

(Veolia Tecta)

Faster, higher throughput

Manual sampling & sample transport



Fully automated on-line-automated systems

(VWM-ColiMinder
ColiFast ALARM & CALM)

15min – several h to result

Continuous or interval measurements

Automatic alerts & process control



Optical Tryptophan Sensors

(TriOS, CTG, Turner Design)

Instant result, no consumables, rel. cheap

Automatic alerts & process control

- Not fully market ready
- Measure a proxy of a proxy



Mobile Molecular Assays

(Biomeme)

Real-time PCR
Highly specific

Fast results, mobile

- Not automated
- Expensive consumables

enzymatic substrate hydrolyzation

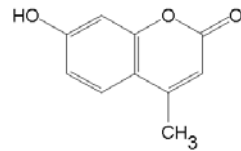
(COLIFORM) BACTERIA COLIFAST REAGENT(s)



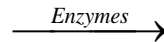
Coliforms bacteria
With faecal origin

Coliform bacteria
with specific enzymes

TC/TtC: β -D-galactosidase
E. coli: β -glucuronidase



MU-substrate



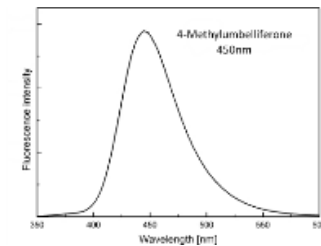
REACTION



substrate + MU

Bacterial enzyme
hydrolyze the
substrate, the product
is fluorescent (4-
Methylumbelliferone)

DETECTION



Fluorescence indicates
presence of bacteria in the
sample

Excitation = 365 nm
Fluorescence = 430 nm

Example automated P/A detection system

Fully automated on-line detection of thermo-tolerant and total coliform bacteria

- 1 cfu / 100 mL
- results 6-15h
- alerts via network
- 21 days unattended operation

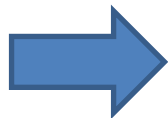
- widely used for raw water intake monitoring in northern Europe
- US-EPA and EU-ETV approved systems



Raw (ground-) water monitoring (GIVAS, Norway)



- GIVAS: 30.000 consumers, 9 WTP, 13 WWTP, 47 employees, area: 30.000 km²
(1.4 x Waikato)
- generally the groundwater is of excellent hygienic quality (requiring simple treatment with only an aeration step and no disinfection)
- Water quality can deteriorate when the nearby river (Glomma) is flooding and water infiltrates the aquifer
- Chlorination is initiated when the water level in the river reaches a certain level and is terminated when automated P/A testing reports negative results



- + more accurate chlorination duration
- + cost optimization
- + improved water quality for consumers

fully automated on-line monitoring system

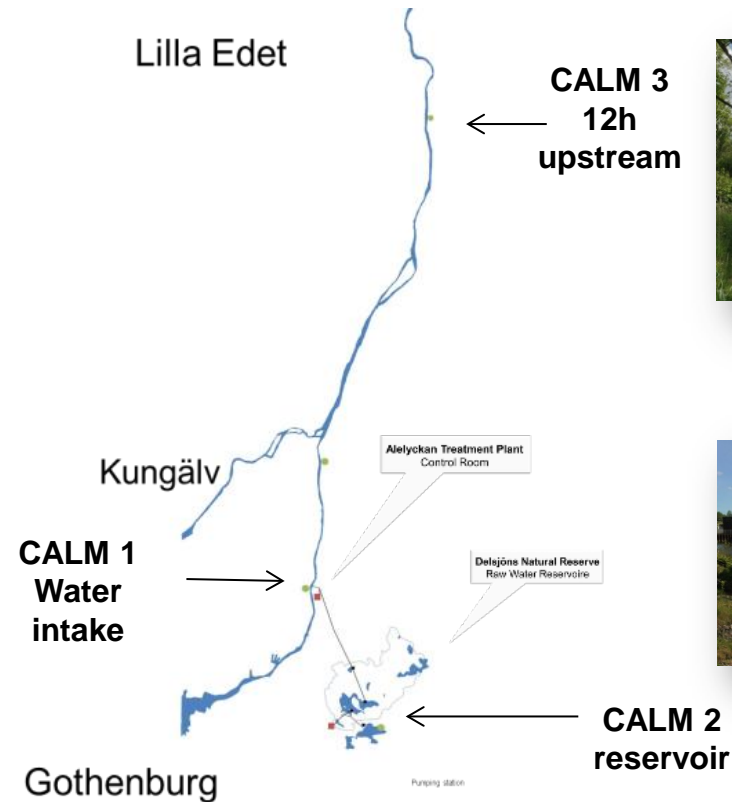
- Fully automated, up to 76 samples/run, 0.1 – 50 mL sample volume, simultaneous tests for two target organisms possible
- Multiple protocols
- Fast **enzymatic methods**: suitable for higher *E. coli*-levels
 - results 90 – 120 min
 - up to 8 analyses / day
- **MPN** (Most Probable Number): generally 2 analyses / day
- **P/A** (Presence/Absence)
- Results are directly transmitted to the treatment plant
- Tested/verified in EU-project DEMOWATERCOLI and verified by four research institutes in Europe



Continuous on-line raw water monitoring Gothenburg / Sweden

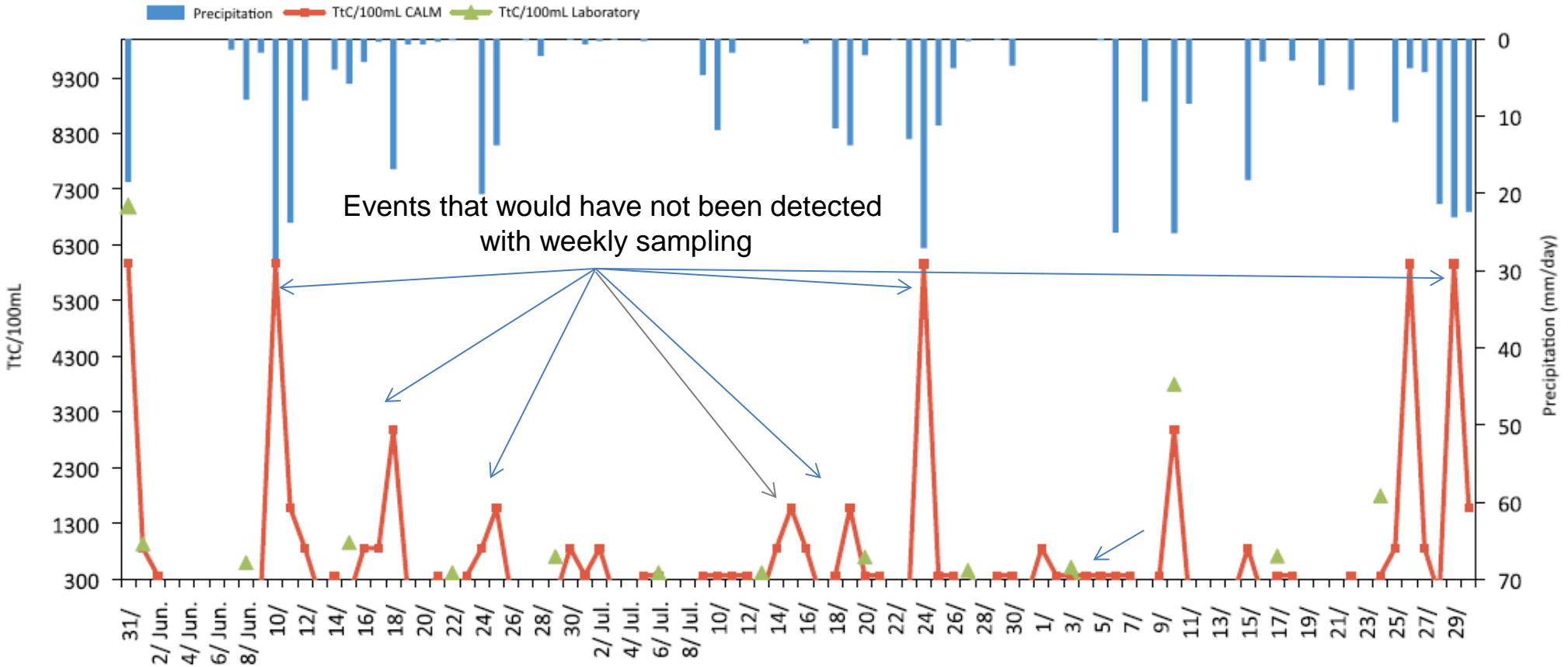


- Drinking water source for Gothenburgs 600 000 inhabitants
- 2 WTPs
 - Alelyckan – Gota river
 - Lackarebäck – reservoir
- 3 fully automated systems monitor the river and reservoir since 2003
- 8 WWTPs and intense land use upstream of water intake

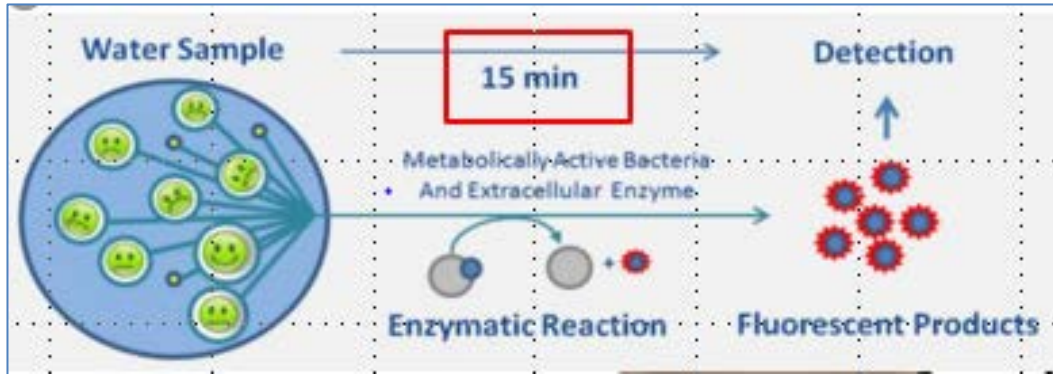


daily on-line raw water monitoring (MPN)

Gothenburg / Sweden



Fully automated on-line monitoring system - ColiMinder



Measurement of metabolic activity

- Measures specific enzymatic activity of target microorganisms
- Detects viable (including non-culturable)
- + up to 48 measurements/day
- + Results within 15 min
- + fully automated
- + remote and on-line
- + 2 sampling ports
- MFU/100mL
[modified Fishman units]

we are testing this in NZ waters for calibration against our traditional methods

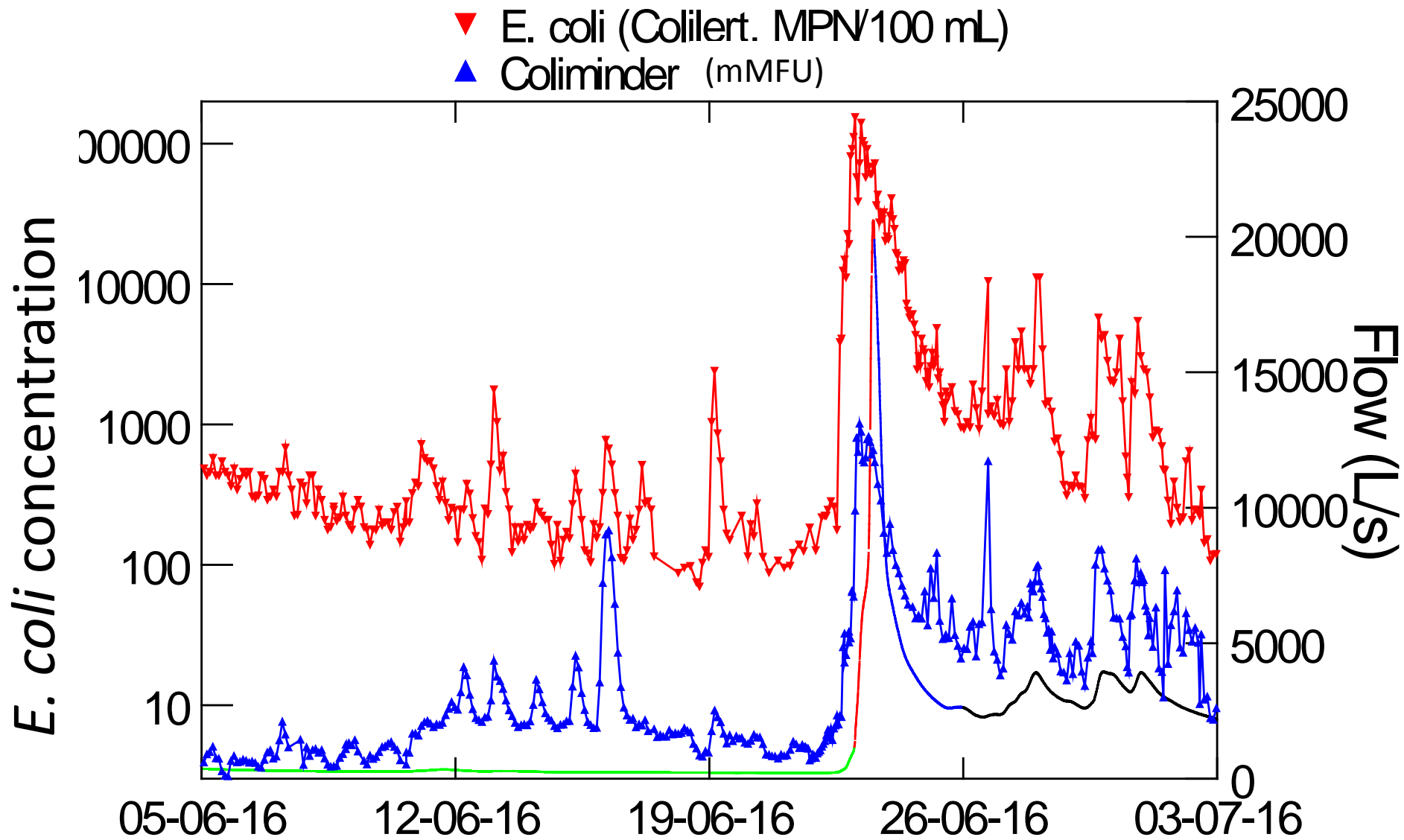
NIWA - surface water Field testing: Porirua Stream, Wellington & Piako River, Waikato



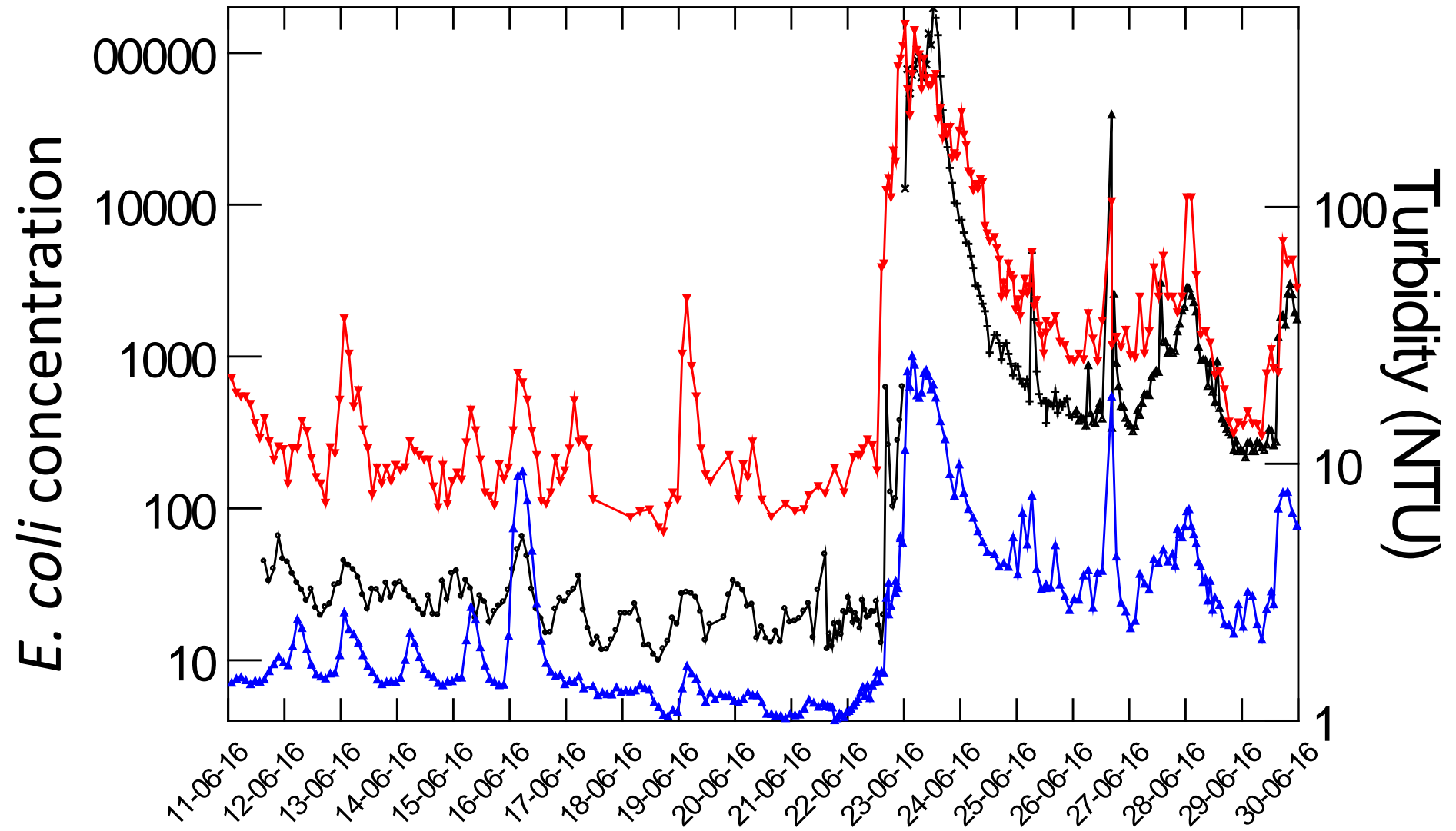
Porirua Stream, Wellington



Piako River, Waikato



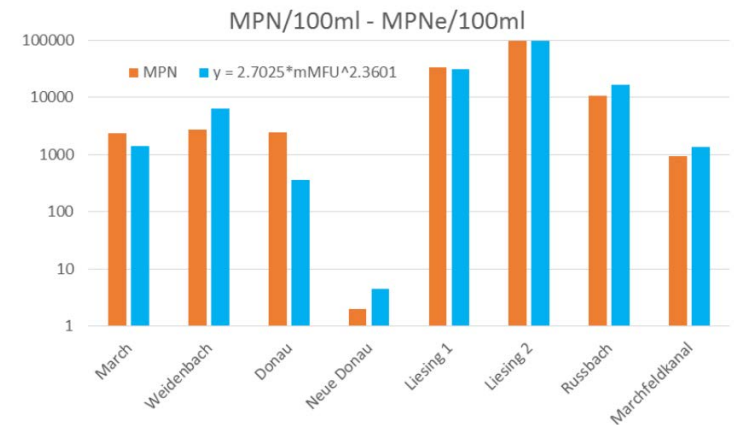
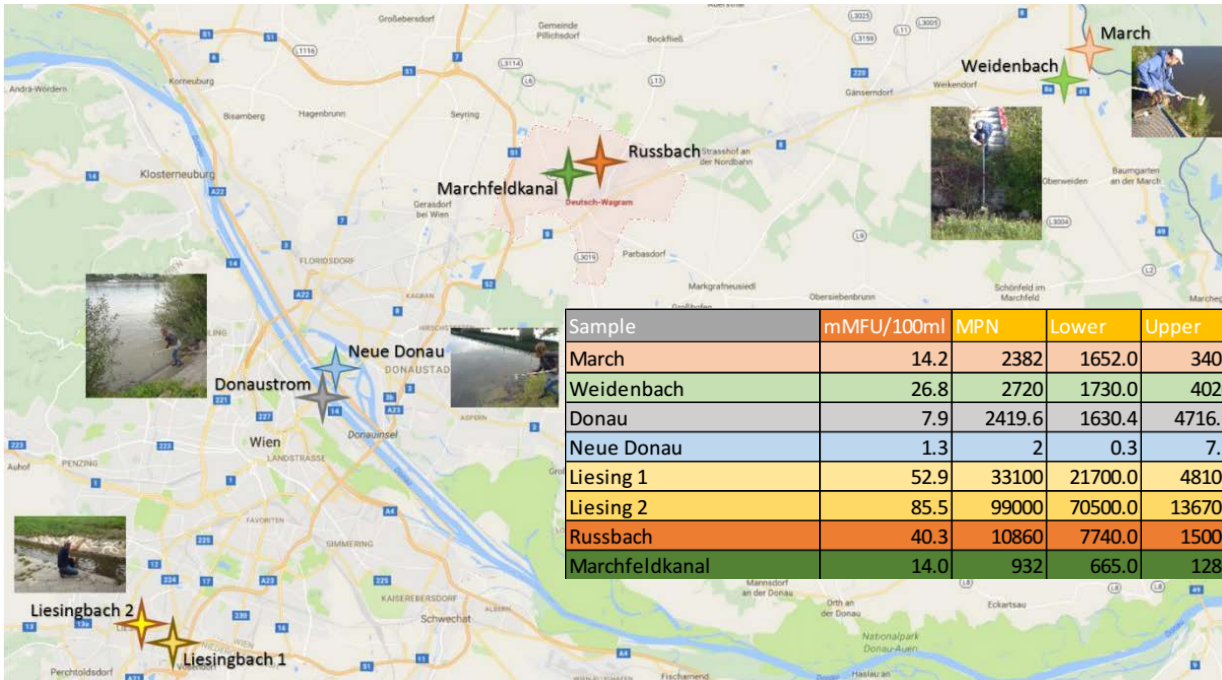
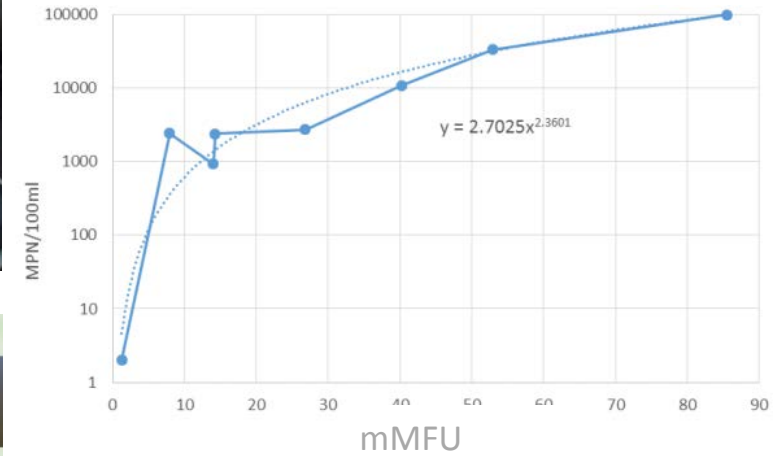
▼ E. coli (Colilert. MPN/100 mL)
▲ Coliminder (mMFU)



mobile monitoring



- * ½ day sampling campaign
- * 8 locations over approx. 60 km



NIWA – (surface) water field testing: what next ...

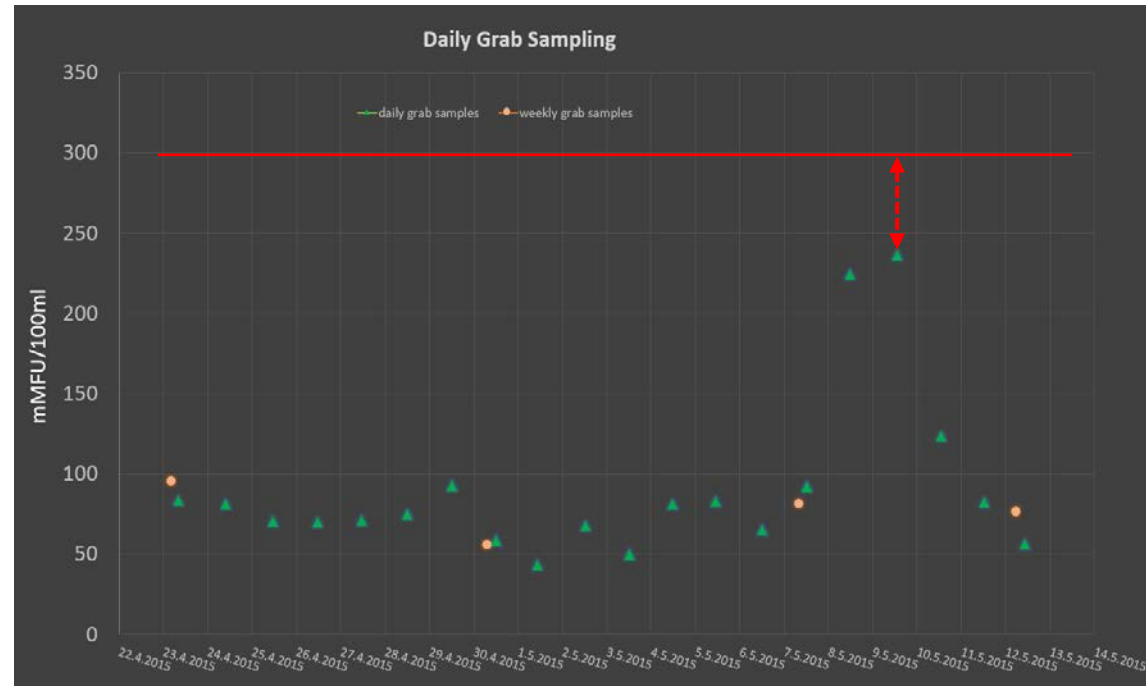
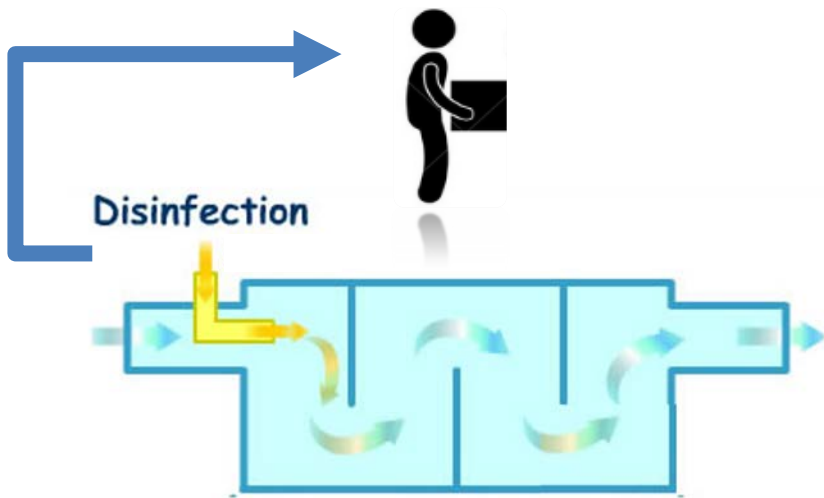
- Calibrate ColiMinder® to culture-based assays (Colilert®, membrane filtration)
- Future surface water testing
 - Additional freshwater testing + multi sensors (Hutt River, Wellington, on-line laboratory)
 - Event triggered sampling
 - FW suitability for swimming
 - Extension to saline water
- Real-time assessment and forecasting
- Collaboration Montréal Polytechnique (Drinking water process control)



Continuous on-line monitoring – process control

Weekly Sampling (raw water)

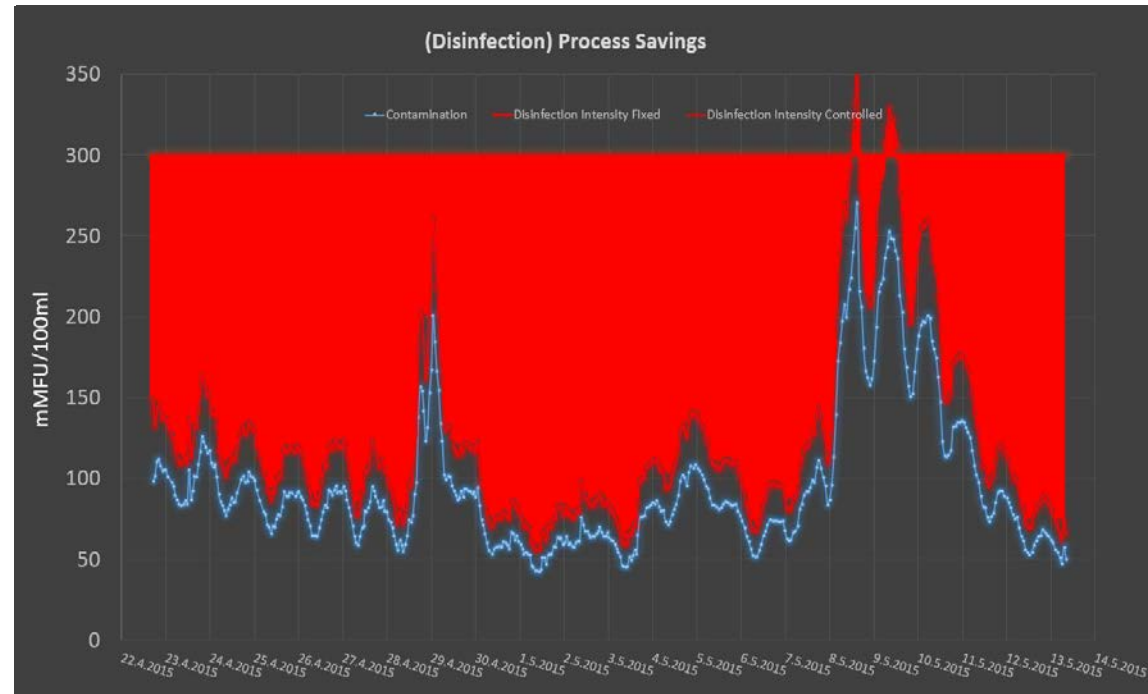
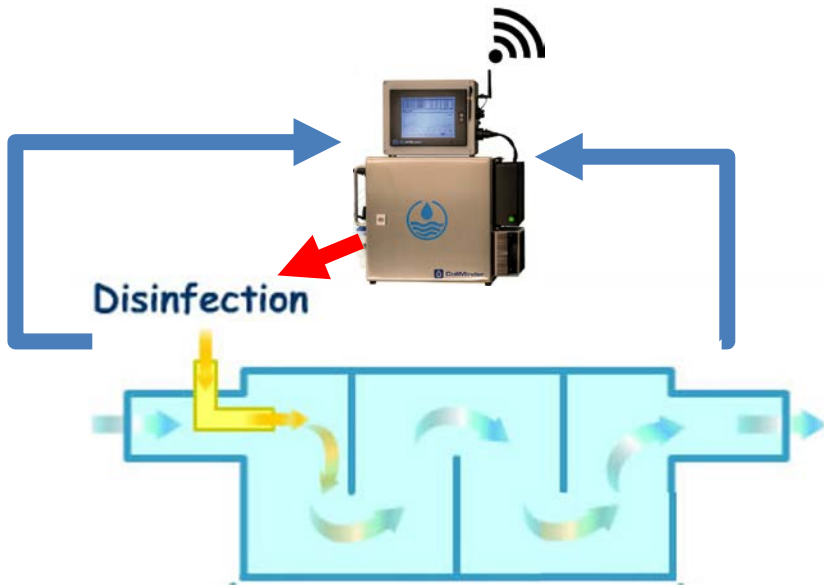
Daily Sampling (raw water)



Standard treatment process

Continuous on-line monitoring – process control

Automatic on-line monitoring (raw water)



knowledge for controlled treatment process

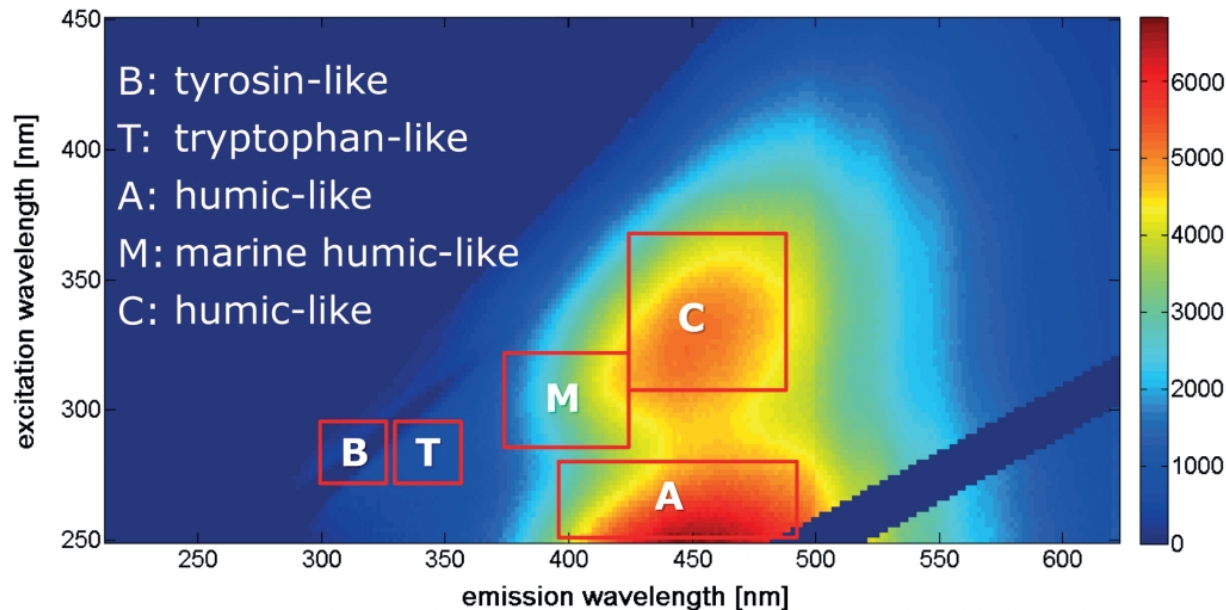
process optimization

significant cost savings

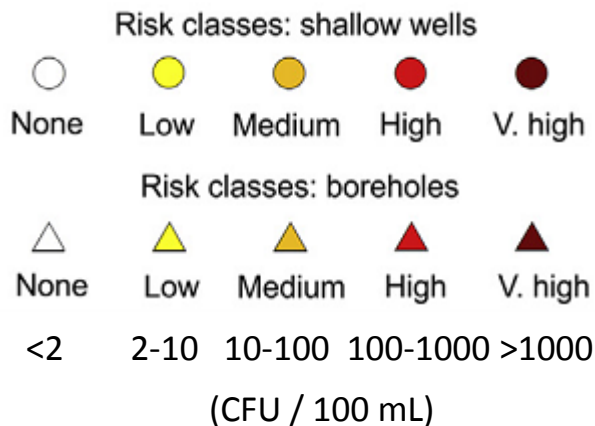
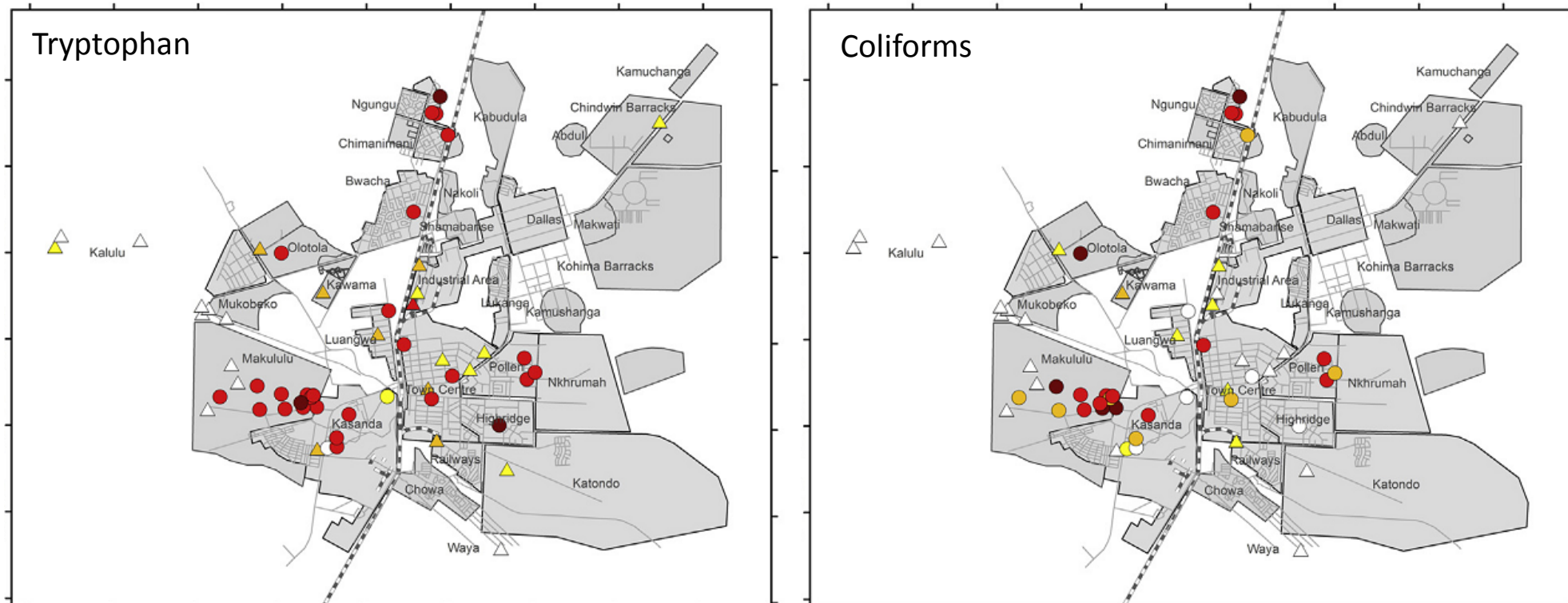
increased safety

Future outlook – optical tryptophan sensors

- Fluorescence measurement
- Tryptophan is an aminoacidic – presence in water correlates well with fecal bacteria
- Interferences by temperature, CDOM, turbidity, ... pH?
- No consumables
- Several tests in UK and by British Geological Survey in Zambia
- Real-time assessment and forecasting



In-situ tryptophan-like fluorescence tested as a real-time indicator of fecal contamination in drinking water supplies – Kabwe, Zambia



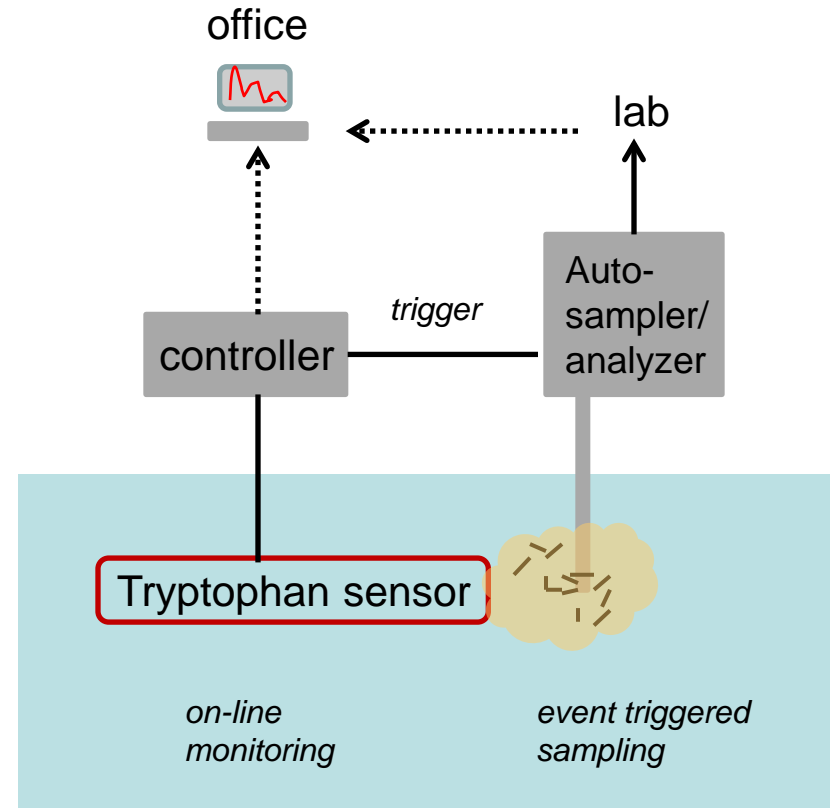
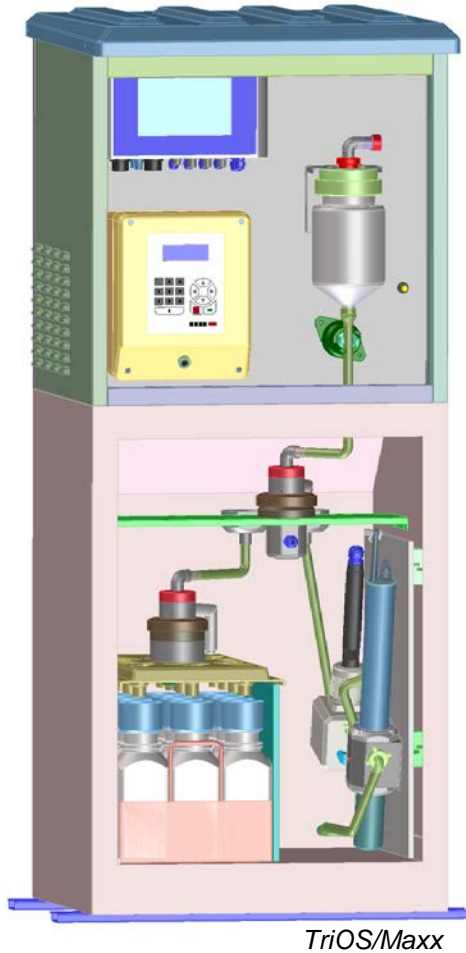
Sorensen et al. 2015. Water Research 81: 38-46.



British Geological Survey

vision

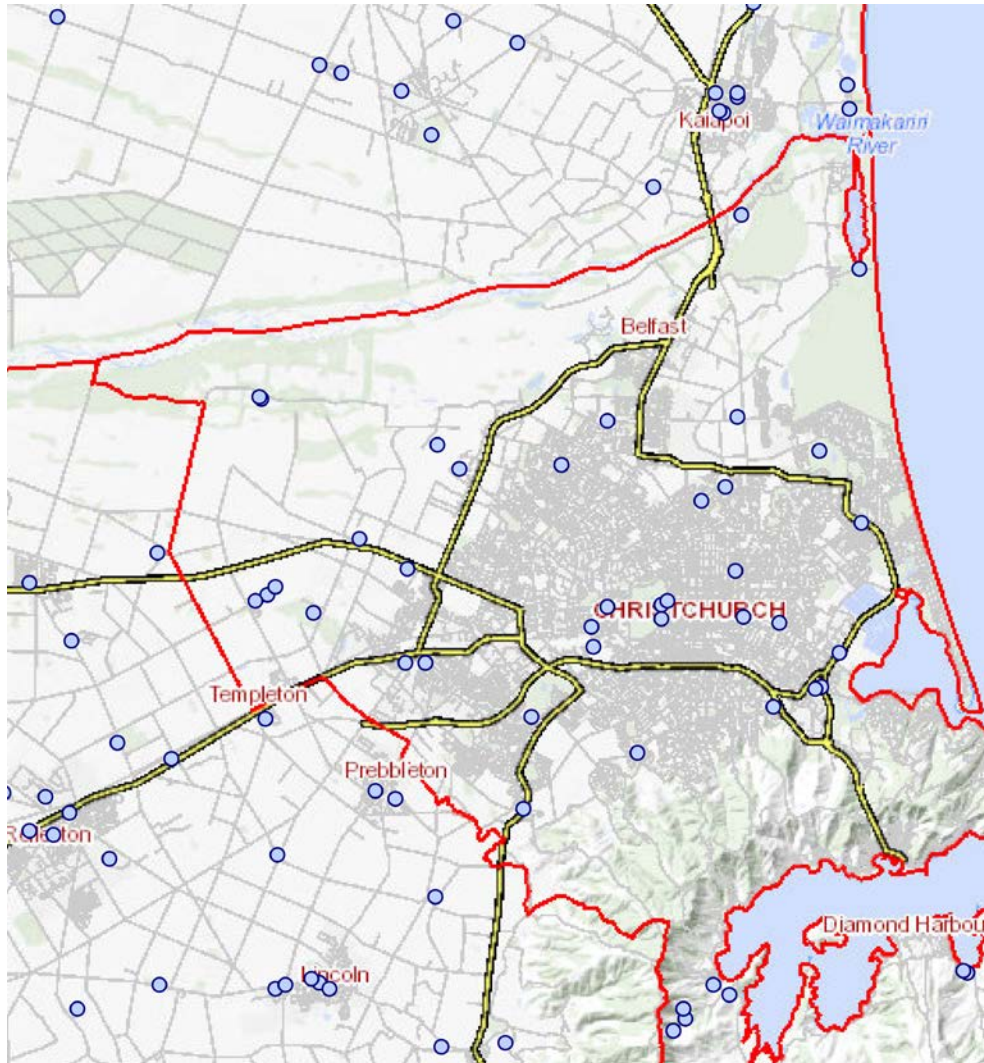
Real-time coliform bacteria monitoring Tryptophan sensor and autosampler



➔ Continuous on-line control with discrete sample validation / analysis for further parameters!

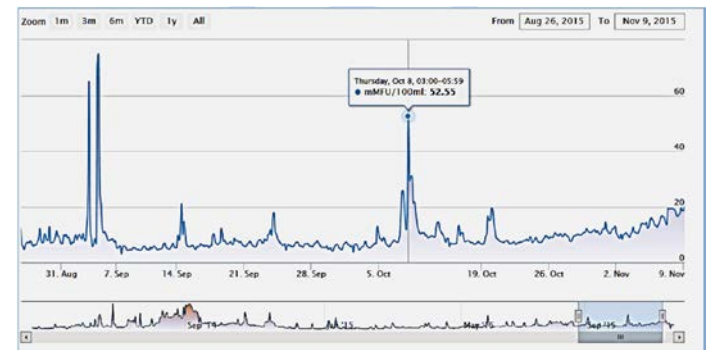
vision

Sensor network with on-line analyzers at critical nodes



Example: Christchurch drinking water sources

Continuous on-line monitoring to safeguard drinking water



Allows for fast responses ...

Smart city networks ...

advantages of automatic high frequency analysis

- Real time detection at high temporal resolution
- Remote on-line monitoring
- Early warning systems – allow for rapid response to threats and events, water integrity
- Leads to
 - Improved process control and cost optimization
 - Improved drinking water safety
 - improved understanding of water quality trends at local catchment and regional scale

Thank you for your attention

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