RESIWATER

INNOVATIVE SECURE SENSOR NETWORKS AND MODEL-BASED ASSESSMENT TOOLS FOR INCREASED RESILIENCE OF WATER INFRASTRUCTURES

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Fully automated and long term stable biological Toxicity Sensor

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MOTIVATION AND AIMS

§ **Aim: Enhancement of the biosensor prototype *AquaBioTox* for broadband detection of chemical contaminants**

à from a laboratory device with high maintenance effort to a fully automated prototype (targeted maintenance effort ~ 4 weeks)

§ **Fraunhofer IGB:**
biological part

Fraunhofer IOSB:
low cost fluorescence sensor;
automation and integration

AquaBioTox prototype (Fraunhofer IGB + IOSB, 2010)

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MOTIVATION AND AIMS

Motivation

§ Online monitoring of water quality by measuring fluorescence from genetic engineered bacteria (e.g. *Ecoli* and *Caulo bacter)*

§ Industrial Fluorescence measurement systems are very costly (8 – 14 k€, e.g. Algaetorch, bbe Moldenke or FP 360, Hach Lange)

§ Targeted costs for online water toxin meters are < 7.000€ for the complete system

Principle of AquaBioTox biosensor:

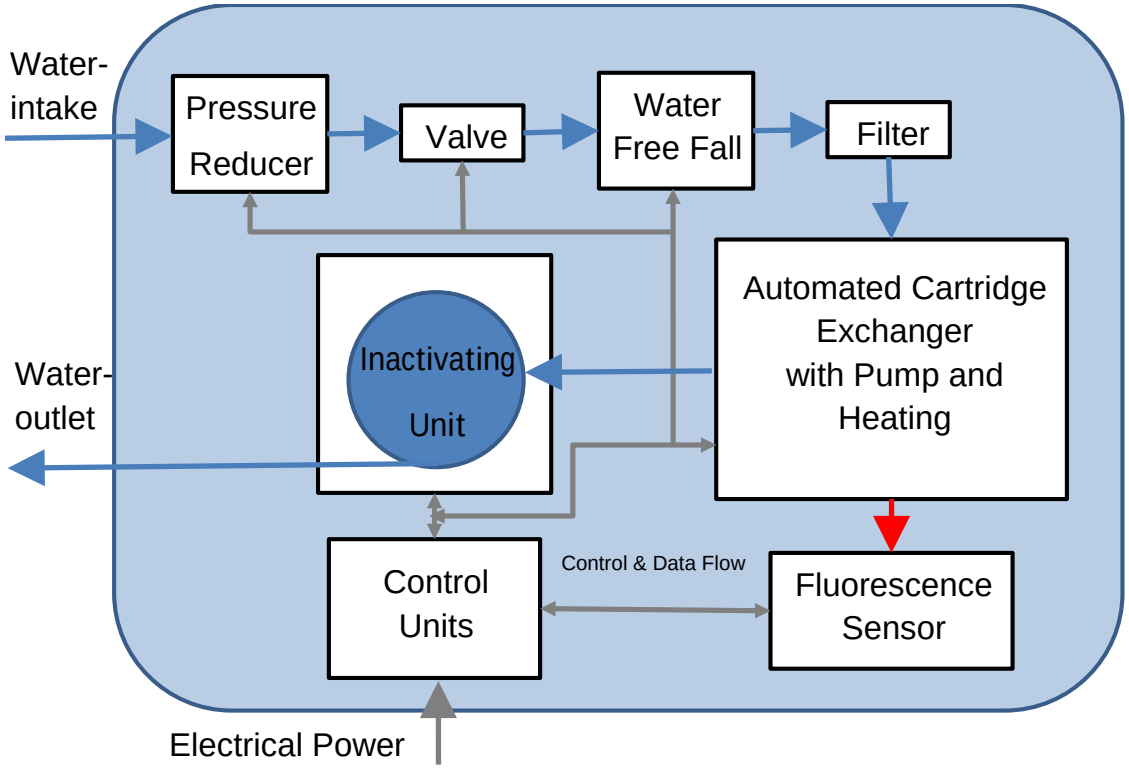
§ Genetically constructed strains of Escherichia coli and Caulobacter vibrioides

§ Non pathogenic bacteria (risk group 1)

§ Adapted to the normal conditions in water

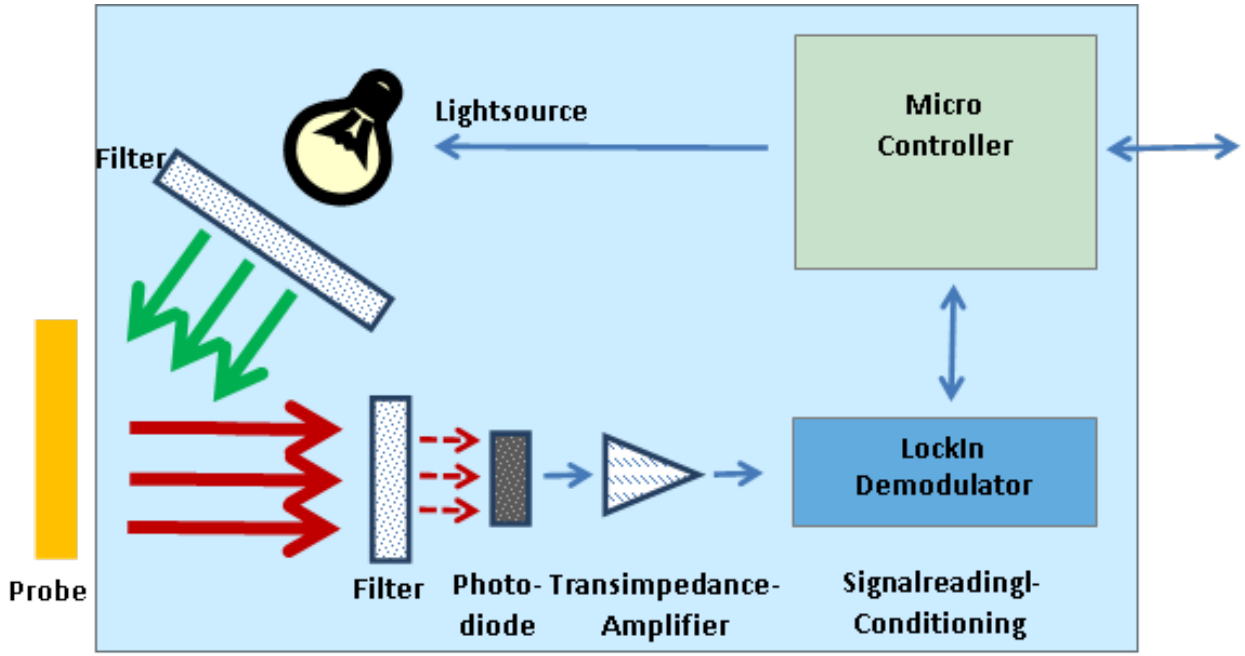
SENSOR SYSTEM - OVERVIEW

Main components of the automated sensor system:



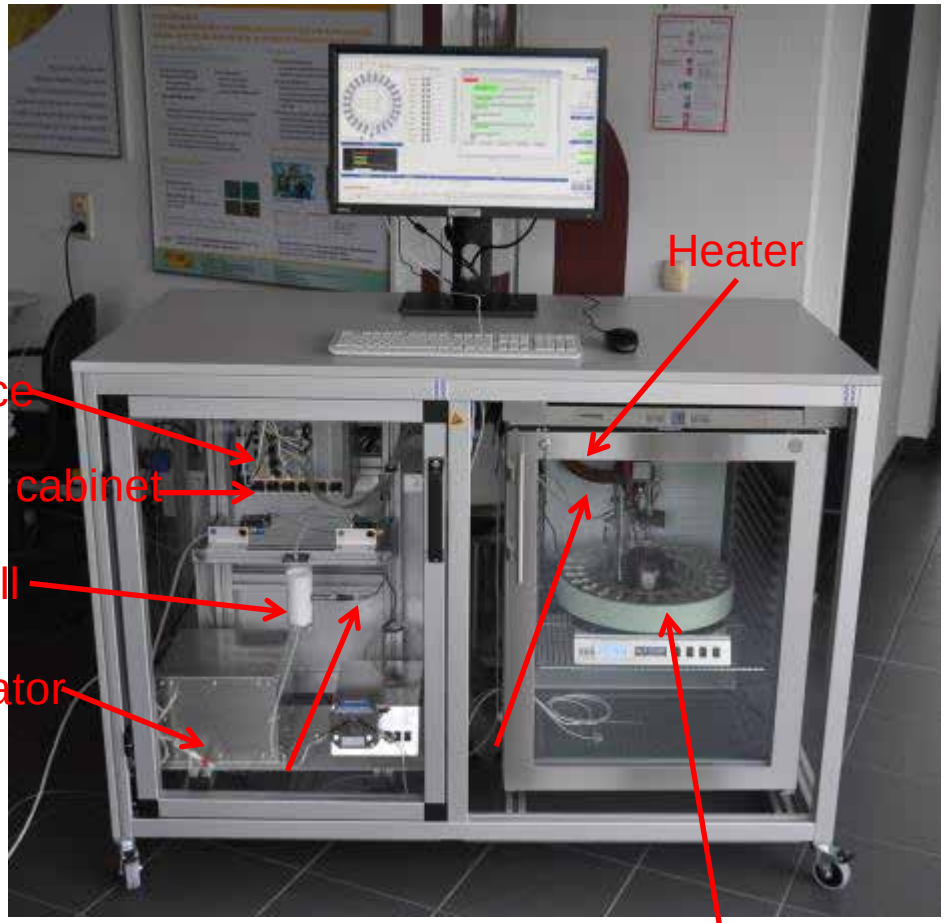
LOW-COST FLUORESCENCE SENSOR

Principle of the low-cost Fluorescence Sensor

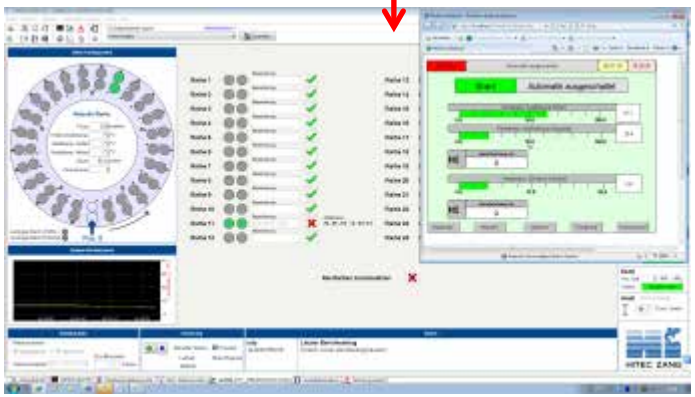


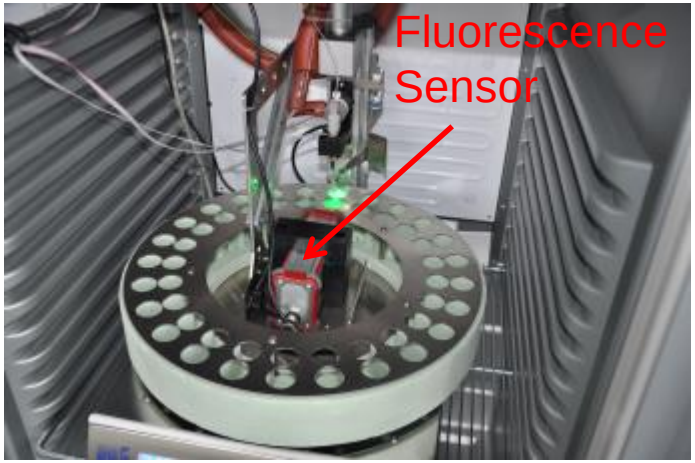
- Robust rugged case IP65
- 2 versions of the optical unit
  - Coaxial setup with dichroitic filter
  - 20 ° Angle setup
- stable long term behavior

FINAL DEMONSTRATOR



HMI





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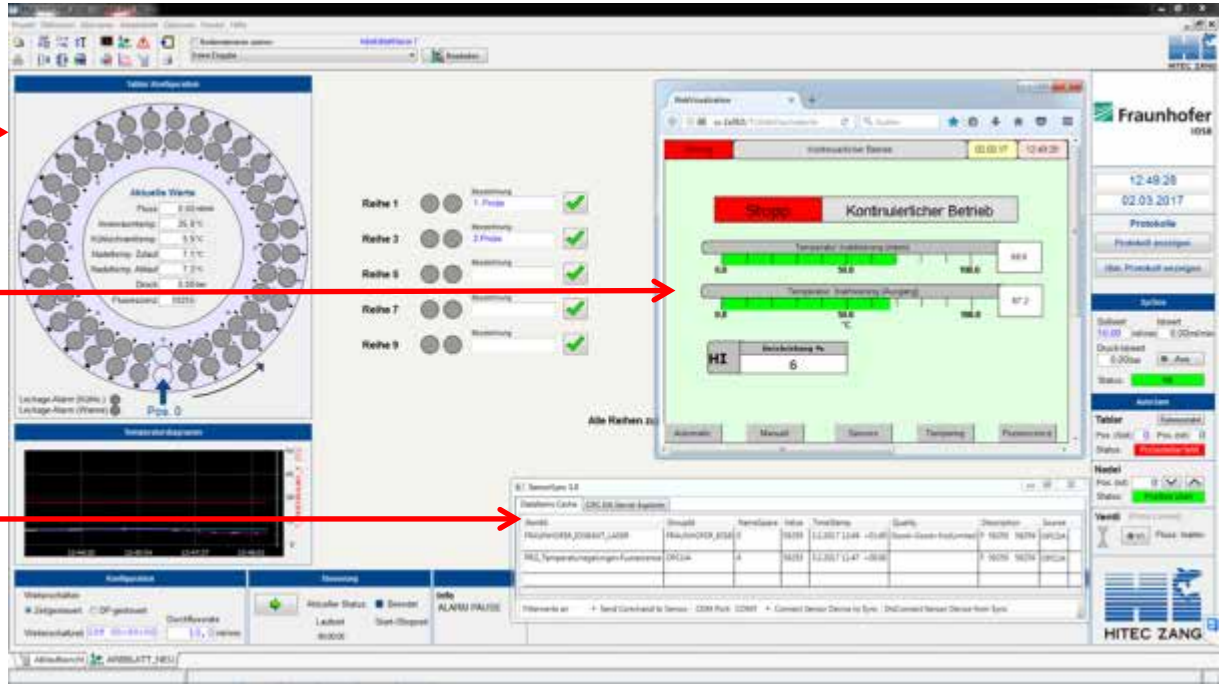
FINAL DEMONSTRATOR

Software modules:

- § Lab-Vision with ResiWater project
- § PLC program for free fall and inactivator
- § Module for fluorescence sensor and data exchange



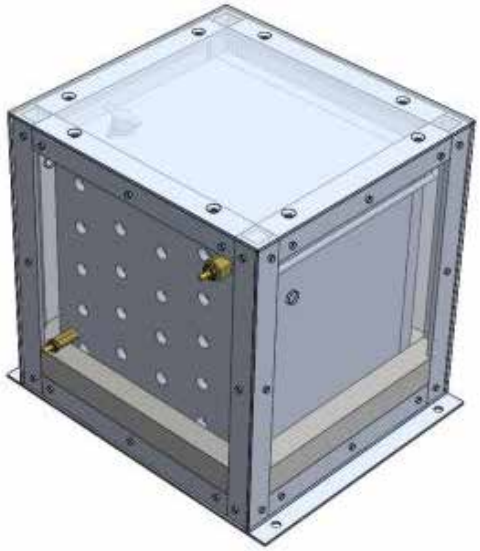
SAFETY ASPECTS

§ **Prevention of reflow of contaminations into the water distribution system:**

Ø No direct connection to the water pipe

Ø Water free fall with sensor based level control integrated in the water intake system of the demonstrator

§ **Prevention of contamination of the environment with micro-organisms by an inactivation unit:**



Ø Inactivation temperature: 90°C, transient time: 100min

Ø Experimental results of microbiological testing: no augmentable bacteria leave the system

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BIOSENSOR SYSTEM

§ **Biosensors:**

Bacterial strains:

- Ø strains react on different substances: extended application
- Ø easily handling
- Ø red fluorescence by genetically engineering
- Ø Real time measurement by newly developed fluorescence sensor

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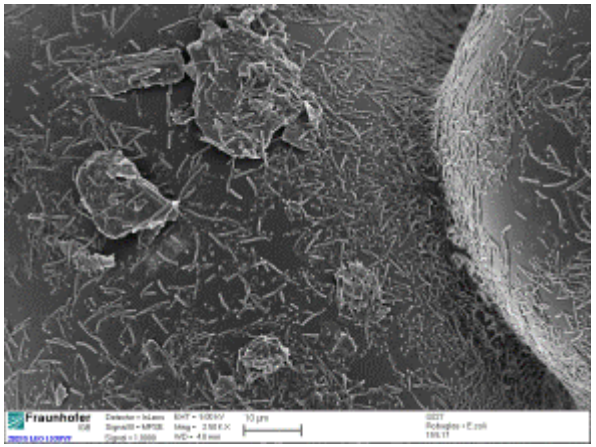
BIOSENSOR SYSTEM

Biosensor immobilisation on carrier material:

Ø Material:

Porous glass particles (Robu Glass)



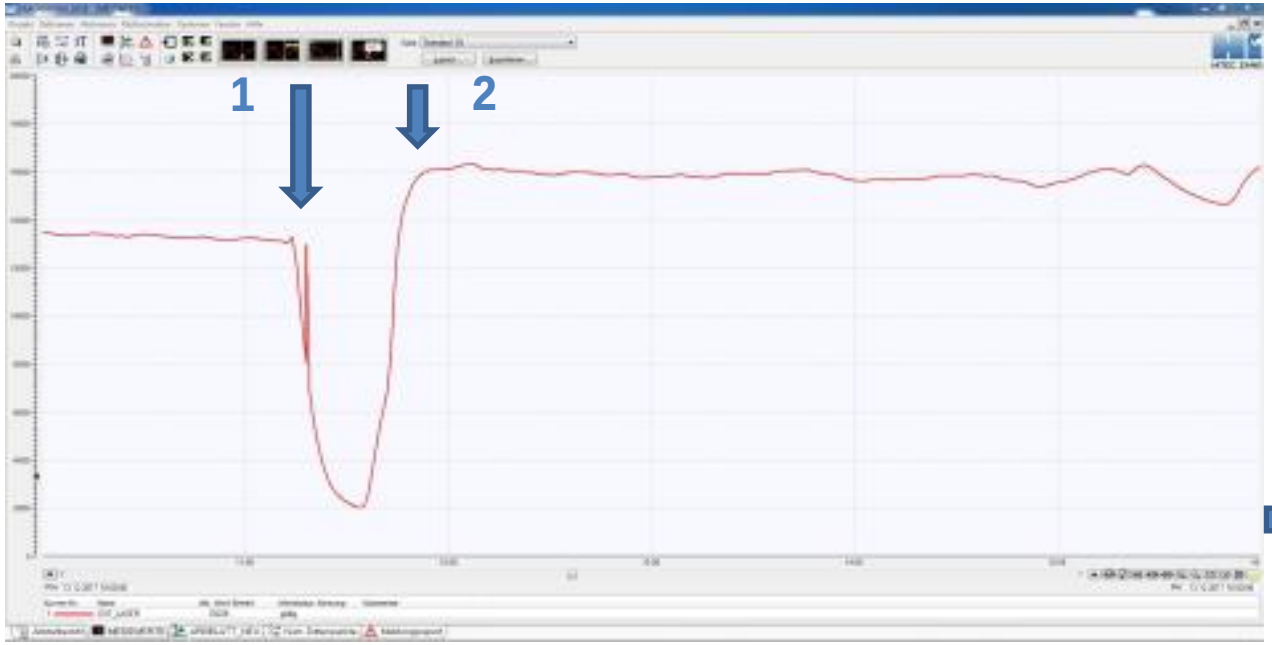
Ø **Advantages:**

- High amount of biosensor cells available for a significant reaction
- Biosensor stabilized
- Preservation for more than 6 month under cooled conditions
- Long term operation possible

EXPERIMENTAL RESULTS

§ **Experimental testing of influence of toxic substances on biosensors in the automated system:**

Example: Influence of pH effect on biosensor (*E. coli* RFP)



Addition of acetic acid pH 4 **(1)**
Regeneration of fluorescence by addition of water (pH 7) **(2)**

Reaction time: < 1 min

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Results with selected substances and toxins:

tested by Fraunhofer IGB and TZW

Agens		Biosensor	
		E. coli RFP	*Caulobacter vibrioides* RFP
Buffered solution	pH 4 pH 5 - 7	84 % < 3 - 8 %	80 %
Ethanol	30 % 50 %	4,5 % 40 %	Not tested
Substance #1*	42 mg/L	< 2 %	40 %
Substance #2*	430 mg/L	54 %	< 2 %
Substance #3*	1 g/L	26 %	< 2 %

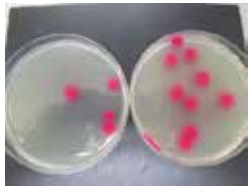
*) Name hidden (confidential)

decrease of fluorescence in percentage (%)

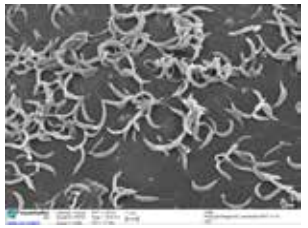
EXPERIMENTAL RESULTS

Characterization of the biosensors:

- ü Biosensor types: 2
  Escherichia coli RFP
  Caulobacter vibrioides RFP



- ü Method of application: immobilisation on carrier material



- ü Time for response: < 1 min → real time measurement
- ü Long term stability tested: 3 weeks
- ü Storage of biosensors under cooling conditions (8°C): > 6 months
- ü Availability in the demonstrator:
  about 6 measurement cells (more are possible) → operation of system
  theoretically possible for about 6 months
- ü Before leaving the demonstrator: cells are effectively inactivated by heating (90 °C)

CONCLUSIONS

- The biosensor prototype *AquaBioTox-II* for broadband detection of chemical contaminants has been developed to a fully automated and long term stable system
- A stable operation for more than 30 days was achieved
- The targeted maintenance effort of 4 weeks was fulfilled

Recommendations for future work:

- For robuster continuous operation the hydraulic part of the sensor system has to be optimised (pipes, pumps)
- The size of the sensor system could be minimised