How Cost-Effective On-Chip Sensors Enable Multi-Stakeholder Smart Water Management

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Internet of Water Flanders

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Spot for video

Introduction

The problem:
- Water scarcity
- Flooding
- Water pollution

The solution: An intelligent water management system
The Internet of Water Flanders is a pilot project in the Flemish Region of Belgium for such an intelligent water management system that proactively tackles growing water risks.

Before an intelligent water management system can be built, we need to monitor the quality of water – digitally, in real-time and on a large scale. Therefore, we need sensors that measure the various aspects of water quality. These sensors not only measure surface waters but also ground water and overflows of sewer systems.
These sensors need to be:
- Cheaper ➔ thousands of sensors are needed for a more extensive and fine-grained network of sensors
- Robust ➔ withstand all weather and water conditions
- Power effective ➔ battery operated
- Maintenance free ➔ maintenance is a large cost
- Send data to a cloud platform ➔ data needs to be accessible
- Small ➔ needs to fit in ground water wells

Figure 1: impression from WQMDs deployed in the field

The imec sensor deployed in the field is called Water Quality Measurement device (WQMD) and consist of 3 parts:
- Sensor Module: contains the sensor chips and its readout electronics to determine the water quality. This part of the WQMD is in the water
- Cable: ensures a reliable communication between the sensor module and measurement station and is used to power the sensor module
- Measurement station: reads the sensor module and sends the data to the cloud. This part of the WQMD is above the water and contains a battery to power the system

Figure 2: overview of the locations where WQMDs are deployed

Results of Field Testing

The first ten WQMDs deployed in the field (Figure 1,2) consist of a conductivity and temperature sensor. Conductivity is a measure of the total concentration of ions in a solution, like salts, acids and bases. Although conductivity is not specific, it is widely used as a basic water quality parameter and often a first indication of pollution and salinization. imec's micro conductivity sensor consists of 4-line electrodes of just a few micrometers: two inner electrodes are placed between two outer electrodes. To determine the conductivity, an alternating current excitation (outer electrodes) and synchronized voltage measurement (inner electrodes) are executed by our inhouse developed readout.

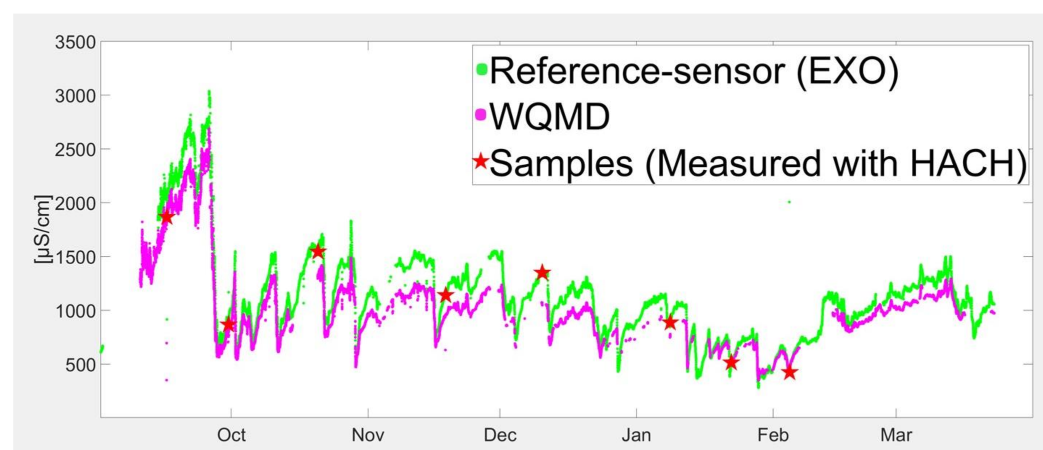

Figure 3: Measurement data (Martjes Vaart, Houthulst, Belgium)

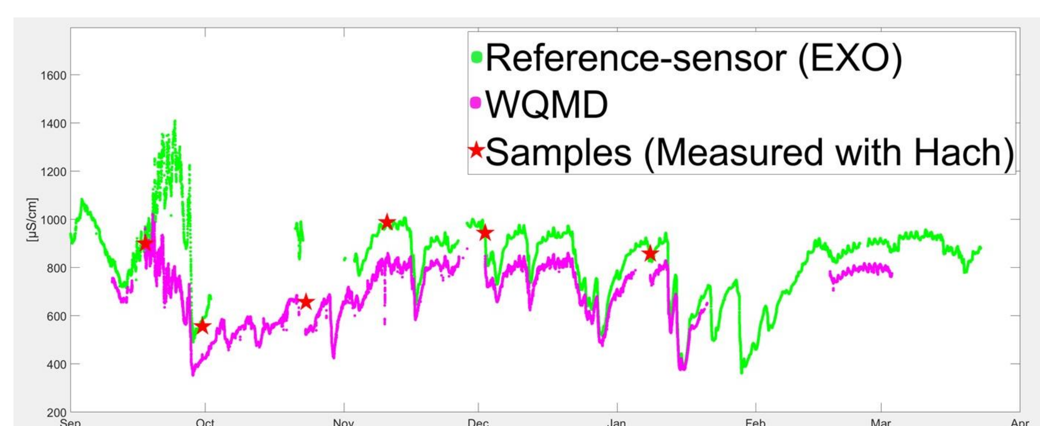

Figure 4: Measurement data (IJzer, Lo-Reninge, Belgium)

Figure 3, 4 show the conductivity measurements of 2 WQMDs deployed in rivers in Belgium for 6-7 months **without maintenance**. The result is represented by a pink line. At both locations, a commercial reference (EXO) sensor was present (green line). This sensor was regularly cleaned and calibrated. Moreover, on regular basis samples were taken and measured with a commercial calibrated sensor (Hach), represented by red stars. All measurements shown are corrected for temperature (20°C). As can be seen at both locations the trend the WQMD is the same as for the reference sensor. Also, for the sensor at location IJzer, Lo-Reninge (Figure 4), this WQMD continued to function even after deposition of large amounts of dirt (Figure 5).

Figure 5: Pictures of the WQMD deployed in the IJzer, Lo-Reninge, Belgium

The Figures 6,7 show the calculated difference (percentage) from the WQMD and the commercial reference sensor as blue dots. In the same graphs the green stars represent the difference between the samples and the reference sensor. The pink stars represent the difference between the samples and the WQMD.

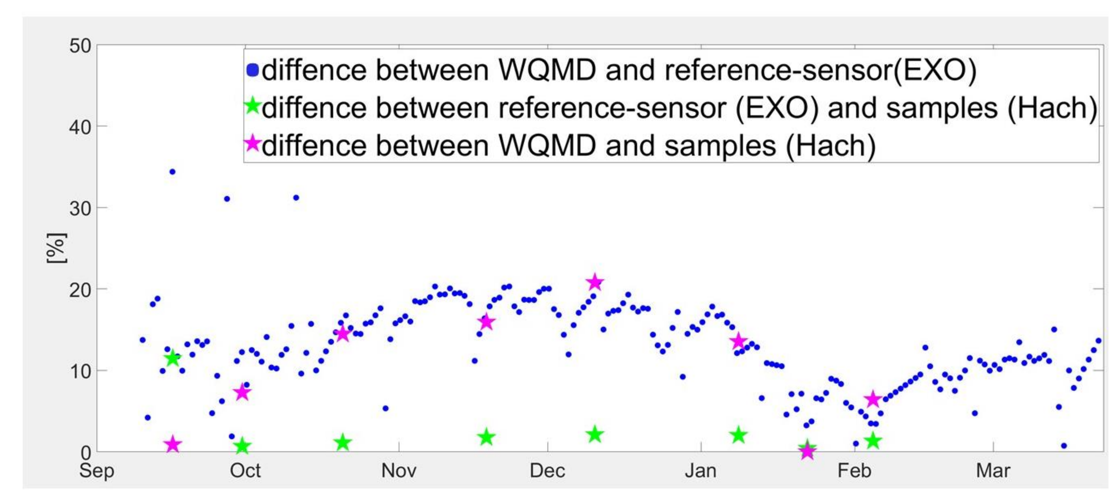

Figure 6: Comparison of sensors deployed in a river (Martjes Vaart, Houthulst, Belgium)

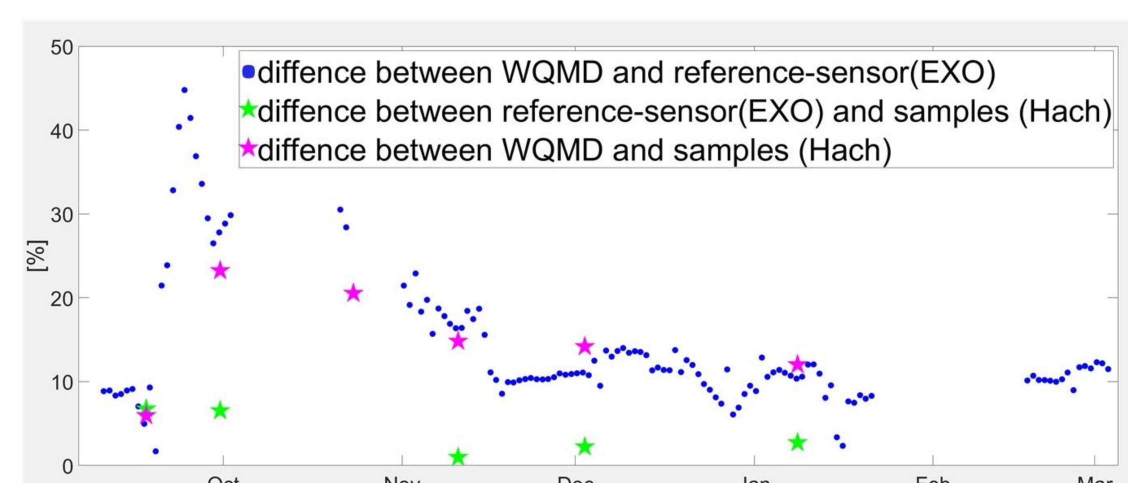

Figure 7: Comparison of a sensor deployed in a river (IJzer, Lo-Reninge, Belgium)

Conclusions

The results show that low cost maintenance free WQMD's can give a good first impression of (changes in) the water quality. An offset is, however, observed between our WQMD's and the references: EXO sensor and measured samples. This offset can be improved by employing algorithms to improve the sensor calibration, and by potentially combining information of larger numbers of sensors in a fine-grained water quality network.

These WQMD's offer the potential to develop a large network of sensors that will be employed in a multi-stakeholder collaboration of environmental agencies, waste water treatment companies and drinking water companies to evaluate the availability of water sources of sufficient quality at moments of water stress.

Next Steps

Add more functionalities:
Miniaturized potentiometric sensors for pH and nitrate are under development that will be integrated with the conductivity sensor on the same WQMD. These sensors employ a reference electrode and liquid-free ion sensitive micro electrodes for pH and nitrate, which are functionalized with ion sensitive materials to achieve high selectivity to the ion of interest.
The pH electrode has a wide pH sensitive range, which is suitable for monitoring pH in surface water. The pH electrode measured with inhouse developed electronics, shows a lifetime in excess off 7 months in a sample of surface water during continuous validation in the laboratory (Figure 8).

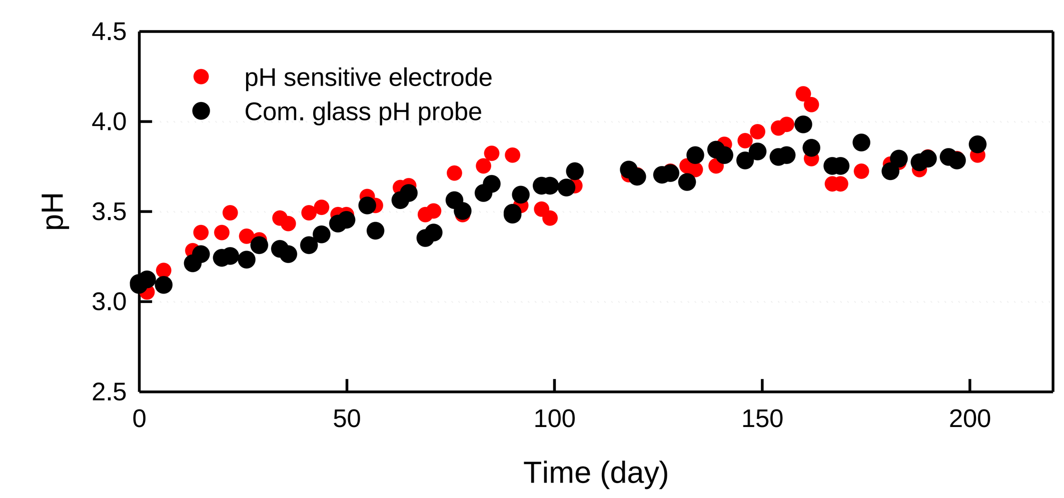

Figure 8 Long term accuracy of an imec pH sensor measured in surface water for 7 months is benchmarked with a commercial glass pH probe.

The developed nitrate indicating electrode shows a low detection limit of ppm level and good sensitivity comparable with commercial nitrate probes.
The miniaturized stable reference electrode, which is used for both pH and nitrate sensor on the WQMD has a long microfluidic channel to minimize its drift rate during continuous monitoring [Ref.1]. This reference electrode has been validated in lab conditions showing a drift rate as low as 0.006 pH points per day. Integration of the pH sensor in the WQMD and development of algorithms for sensor drift correction are in progress.

Extend field tests:
- Next 10 WQMDs with conductivity and temperature will be deployed May 2021 (with updated readout and housing)
- Extra 10 WQMDs with conductivity, **pH** and temperature will be deployed **June 2021**
- Extra 10 WQMDs with conductivity, pH, **Nitrate** and temperature will deployed in **August 2021**

More info : www.internetofwater.be

Bibliography

1. Zevenbergen, M.A.G. et al. 2016 *Solid State pH and Chloride Sensor with Microfluidic Reference Electrode. Int. J. Climatol.* Report of the IEEE International Electron Devices Meeting (IEDM) 18, 26.1.1 – 26.1.4 etc.
2. Brom-Verheijden, G.J.A.M., Goedbloed, M.H., Zevenbergen, M.A.G., *4-electrode conductivity sensor with enhanced measurement range*, Eurosensors 2018, 9-12 September, Graz (Austria)