# Innovative approaches in monitoring rapidly changing environments in different socio-economic contexts around the globe

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## Abstract

Water resources are very important for livelihoods, as well as natural ecosystem settings. There is urgent need for developing methods that are capable of monitoring fast-changing water systems (for indicators such as pollution) affected by climate change and the increase of anthropogenic pressures. Updated and real-time detailed data is necessary to support water and soil management strategies. This study evaluates the implementations of novel techniques in different socio-economic settings. Sensors and cameras were installed in mobile platforms (including boats and underwater drones), and deployed to assess spatial data variability. Environmental scans were performed at multiple locations with different water systems in The Netherlands, Indonesia and Denmark. Results from the multiple methods provided new insights into spatial variation of water quality, contrasting with traditional point sampling. Feedback from water authorities and other stakeholders indicate that collected data can be used to support management actions, and that such increasingly accessible technologies contribute to creating awareness of water-related issues.

***Keywords:*** *Water quality, 3D Data visualisation, Mobile sensors, Underwater drones, Unmanned ROV*

## Introduction

With climate change and increasing anthropogenic pressure, alarmingly accelerated changes to water bodies and catchments are being observed all around the globe. There is an urgent need for monitoring methods that are capable of accompanying these trends, which can

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provide updated and detailed data that supports water and soil management actions. The usability and effectiveness of different methods is investigated with regard to different socio-economic contexts in Europe, Asia and (South) Africa. This article describes the method and results in a recent pilot in Surabaya, Indonesia. Special attention is given to methods that raise awareness, capacity building, or serve educational purposes for training of stakeholders, water managers or populations.

## Objectives

The objective of this work is to describe novel and versatile *in-situ* data collection possibilities in catchment-scale surface water bodies that enhance data spatial resolution with reduced costs. This work focuses on the case of Indonesia and Mali, and relates findings to results from previous field implementations in Europe (de Lima et al, 2015a; de Lima et al. 2015b, de Lima et al., 2017; Boogaard et al., 2017). There, different *in-situ* methods were used to monitor and perform quick scans to the current status of surface water bodies.

## Methodology

Sensors and cameras were combined with boats and unmanned underwater vehicles (ROVs) in order to enable the continuous collection of data along surface water bodies and to get insight into underwater life from underwater footage. Vertical profiling from boats/bridges, use of test strips combined with apps and strategic placement of static sensors in outlets were also applied. These methods enabled spatial visualisation/mapping of water quality concentrations, and assess stratification/variation with depth.

The different measuring locations were selected to cover most sections within the investigated water systems and basins (e.g. spring/source, big reservoirs/dams, upstream/downstream of industry and urban areas, some tributaries and at the mouth/estuary). Measurements took place in the Brantas Basin near Surabaya, Java Islands, in February 2017 (Dutch Water Sector, 2017) and Mali (Dutch Water Sector, 2018). Measured parameters include turbidity, electrical conductivity, dissolved oxygen or nutrients (ammonium/nitrate).

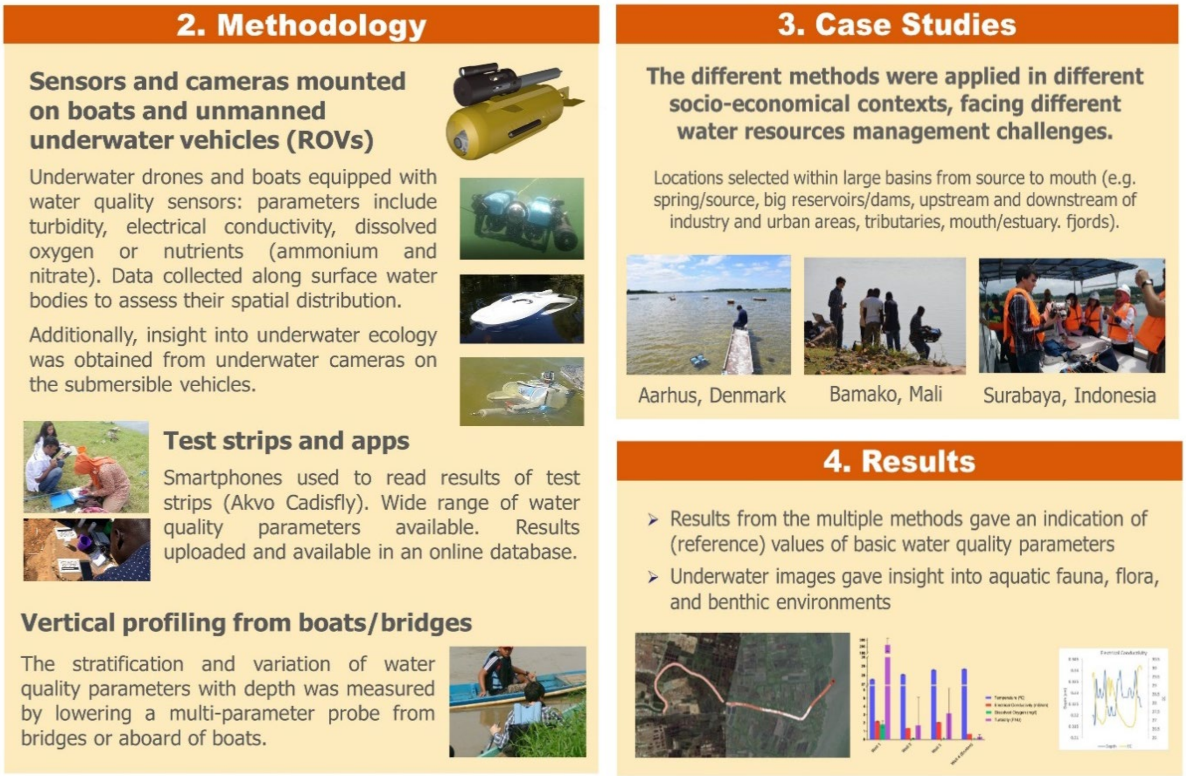


*Figure 1. Methodology, case studies and results (Source: Authors own)*

## Findings

Results from the multiple methods gave an indication of (reference) values of basic water quality parameters. Areas with higher concentrations of parameters could be identified, and potential pollution sources tracked. When in low turbidity conditions (rare in polluted rivers of Indonesia), underwater images allowed to get insight into aquatic fauna, flora, and benthic environments. The collected data allowed researchers to further understand the behavior of the water systems, and to utilise as a base for intervention recommendations. Additionally, the work conducted showed how local water managers and stakeholders can use new technologies in favor of data quality and quantity.

The data generated by the underwater drone contrasted with the lack of updates in the region (only a few points along the river were available). The local actors in Indonesia and Mali see high value in the water quality maps and results produced, which emphasised spatial variation (even in very small distances – for example, as shown in **Figure 2**).

***Image 1. Local stakeholders received training on how to operate and interact with new technologies in the Niger river near Bamako, Mali. The aim of the monitoring is to enable river basin commission, Agence du Bassin Fleuve Niger, to provide reliable and continuous data to policy-makers (Source: Dutch Water Sector, 2018)***

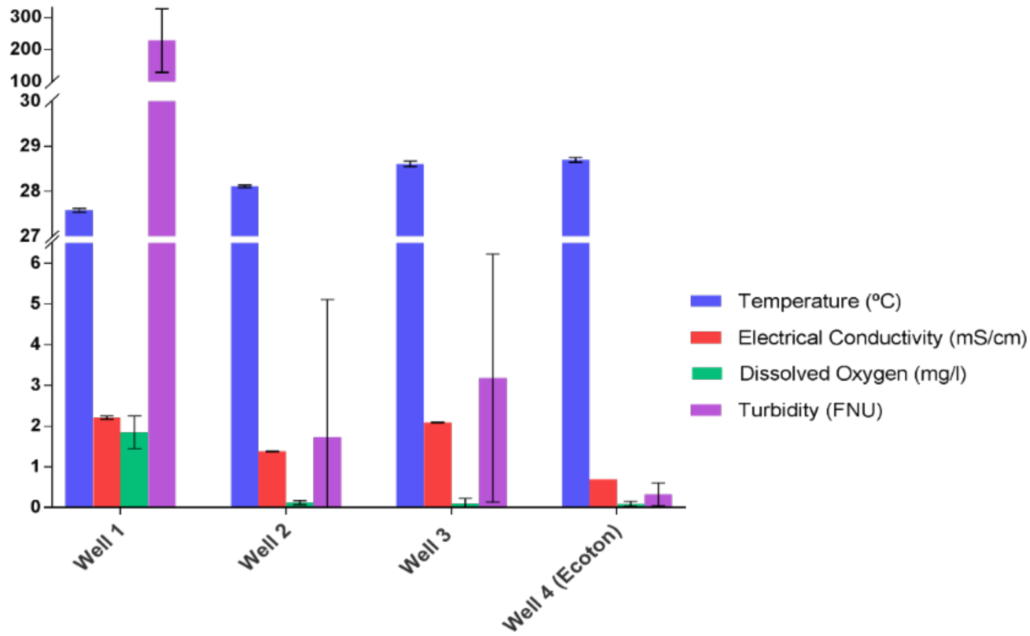


*Figure 2. Scanning of water quality in multiple wells within a village dealing with industry waste contamination (Source: Authors own)*

Industry/domestic outlets could be located, based on the fact that the water has different characteristics (e.g. different temperature and nutrient and dissolved oxygen content). Autonomous collection of data, real-time access to datasets and quick response triggered by events, were highlighted as top needs for monitoring improvement. In small catchments, this technology can have high impact by supporting better informed resources management decisions.

## Conclusion

Fast changing water quality due to climate change needs to be tracked as fast as it changes, and records made of what is influencing the changes. This can be done efficiently by using smart technology such as 3D data visualisation, mobile sensors, underwater drones, and unmanned ROVs. The significance of this work is to introduce novel and versatile *in-situ* data collection possibilities catchment-scale surface water bodies that enhance data spatial resolution with reduced costs. Innovative/dynamic monitoring methods (e.g. underwater drones, sensors on boats) contribute to better understanding of the quality of the living environment (water, ecology, sediment) and factors that affect it. Although further research is still needed to fully characterise these processes and to optimise the measuring tool, the method provides valuable information about the behaviour of water systems and spatial/temporal variability, and shows potential as an efficient monitoring system. In the Netherlands and Denmark, where water bodies are already monitored regularly, this type of monitoring is requested to investigate in detail certain specific issues (e.g. presence of mussels at the bottom of lakes, blue-green algae monitoring) that require comprehensive data to complement existing information. In developing countries such as Indonesia or Mali, due to the inexistence/scarcity of reliable and updated data, the main use of the unmanned vehicles is to survey large areas in order to characterise the water system, and identify pollution sources. The cooperation of local managing organisations, and their willingness to work together is important to ensure participatory actions and social awareness regarding the process of adaptation and strengthening of regulations, or for the implementations of water management actions.

## Acknowledgements

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