

In-situ and remote monitoring of environmental water quality

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Overview

- **Introduction**
 - Water quality monitoring
- **Autonomous monitoring systems**
 - Phosphate sensor
- **Remote monitoring**
- **Integration of data from in-situ and remote sources**
 - Status and challenges



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Introduction

- Water pollution affects human health and reduces the quality of our natural water ecosystems and resources.
- Clean water resources are likely to be of increasing scarcity and importance in the future
- Increasing need for monitoring of environmental water quality



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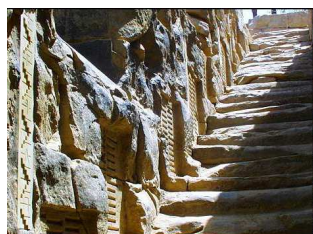
Legislation

- **Major driver for protecting and improving the state of our natural water resources**
- **EU - Water Framework Directive**
 - Aims to achieve "good status" of all European water bodies (lakes, rivers, transitional, coastal & groundwater) by 2015
 - Implemented on a catchment level
 - Related directives on Nitrates, Urban Waste Water Treatment, Drinking Water, Dangerous Substances, Bathing Water etc.
- **US - Clean Water Act**
 - Restoring polluted surface waters with the goal of making US waters fishable and swimmable
 - Total maximum daily loads (TMDLs) for polluted waters
 - Shift from a source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies



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In situ monitoring – a long history



- Nilometer at Aswan, Egypt
- Water level → likelihood of successful crops → tax rates!



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Sampling based monitoring

- **Current approach**
 - Manual collection of samples, followed by laboratory analysis using high-spec instruments
 - High manpower costs → Low measurement frequency, limited number of sites
 - Standards-based, highly accurate... IF appropriate sampling, storage and analysis protocols are followed
- **Portable instruments & reagent kits**
 - Still require human presence to collect sample & operate device



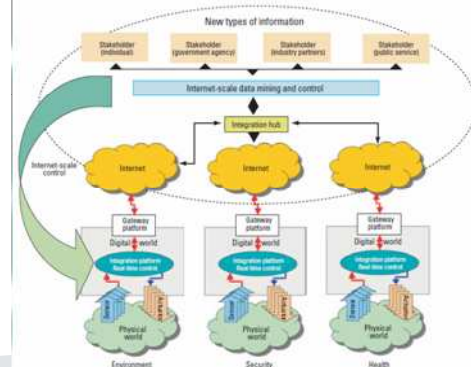
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Autonomous monitoring devices



- Autonomous sensing systems can play key role by allowing high-frequency monitoring of remote locations at lower cost
- Even if in situ sensors do not achieve the same analytical performance as laboratory methods, the increased temporal and geographical resolution is likely to outweigh this
- Complementary to standard techniques

Internet-scale sensing



Challenges



- Based on availability of large numbers of miniaturised, low cost, autonomous sensing devices
- Reliability over long-term deployments
 - Robustness in severe conditions
 - Biofouling
 - Changes in reactivity of surfaces / reagents over long periods → Need for calibration
- Deployment of large-scale wireless sensor networks in unpredictable and lossy environments

Challenges



- Adaptive sampling
 - E.g. higher frequency based on trigger levels
 - Link to other devices measuring related parameters
- Data streams from a large variety of heterogeneous sources, with varying volumes and accuracies
- Need to develop a networked sensing infrastructure that can support the effective capture, filtering, aggregation and analysis of such data

Microfluidic sensors



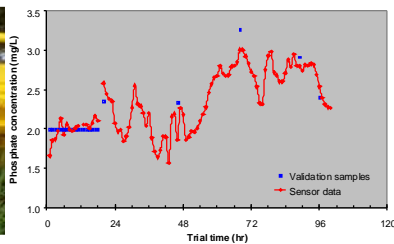
- Microfluidic technology provides a route to the development of miniaturised analytical instruments that could be deployed remotely, and operate autonomously over relatively long periods of time (months–years).
- Autonomous phosphate sensor developed at DCU
- Combination of technologies
 - Colorimetric chemistry (molybdenum yellow)
 - Microfluidic chip for performing mixing and reaction on micro-scale (22µL per analysis)
 - Optical detection based on UV-LED light source and photodiode detector
 - Wireless communications (GSM modem, Zigbee radio, Bluetooth)

Phosphate sensor



- Can operate for 3 months at hourly frequency
- System has been successfully trialled at wastewater treatment plants and in environmental settings

Broadmeadow Water trial



- Estuarine location 10km from Dublin city
- Elevated phosphate levels due to inputs from municipal wastewater plants and agricultural sources

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SmartBay project



- SmartBay is a next-generation water management system (both marine and freshwater) established by the Marine Institute of Ireland.
- Key technological aspects currently under development by CLARITY and IBM's Global Centre of Excellence for Water Management



- Sensors
- Communications
- Data management systems

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Combining in-situ & remote sensing



- Remote observations from satellites and aircraft can provide significant amounts of information on the state of the aquatic environment over large areas
- As in-situ deployments of sensor networks become more widespread and reliable, and satellite data becomes more widely available, information from each of these sources can complement and validate the other
- Increased ability to rapidly detect potentially harmful events, and to assess the impact of environmental pressures on scales ranging from small river catchments to the open ocean.

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Remote sensing



- "the science of observation from a distance"
- Detection of
 - Acoustic waves
 - Force fields
 - **Electromagnetic energy**
- Techniques
 - Visible imaging (photography / videography)
 - Infrared (imaging / spectrometers)
 - Microwave radiometers
 - Microwave radar (RAR / SAR / SLAR)
 - Lidar (Laser radar)
 - Scatterometers

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Remote sensing



- Platforms
 - Surface (ground / vehicles / masts)
 - Airborne (unmanned drones to heavy aircraft)
 - Space (orbiting satellites, deep space probes)
- Applications
 - Meteorology, Climatology, Geology, Soil studies, Agriculture, Land use, Built environment, Ecology, Conservation, Resource management
 - **Water in the environment**

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Examples



- Wetlands monitoring
 - Surface water area
 - Plant communities
- Water quality parameters
 - Turbidity
 - Suspended sediment
 - Chlorophyll / Phytoplankton
 - Water temperature
 - Salinity
- Flood monitoring & management

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Precipitation monitoring

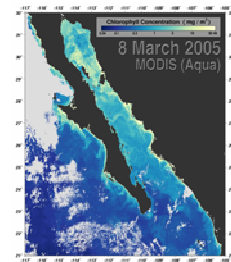


- Radar
 - Frequent, real time estimate of rainfall intensity
 - Met Eireann rainfall radar captured during phosphate sensor deployment



- In situ alternative - rain gauges
 - Sparsely distributed
 - Can give inaccurate estimates due to local variations
 - Important for calibration

Chlorophyll / Phytoplankton



- Phytoplankton bloom in Baltic Sea (MERIS/Envisat, 13 July 2005)
- Chlorophyll concentrations in the Gulf of California (MODIS/Aqua, 8 March 2005)

Surface temperature



- Ireland and surrounding ocean. Temperature range is about 277K (dark blue) to 292K (dark brown) (ATSR/ERS satellite)

Pollution detection



- Point sources
 - Airborne data used to identify and map discharge patterns from sewage outfalls and industrial complexes
- Pollution events
 - 2 October 1994, Oporto, Portugal, crude oil spill from tanker
 - The ESA ERS-1 satellite acquired this SAR image two days later



Treatment of remote sensing data



- Pre-processing
 - Geometric corrections (mapping)
- Processing
 - Selection of data subsets
 - **Calibration**
 - Enhancement of features of interest
 - Noise reduction etc.
- Analysis
 - Feature recognition
- Interpretation & decision-making

Calibration of remote data



- Pre-launch calibration of instruments
- Commonly performed w.r.t. in situ data
 - IS data must be statistically representative
 - Not always available, may be costly to obtain
 - Not always appropriate due to basic differences between the RS and IS datasets
 - Accurate positioning of both datasets is critical
 - Lack of standardization of IS data
- Training sets
 - Data (sub)sets with well-established features
 - New/unclassified data compared to these using a variety of algorithms

Limitations of remote monitoring



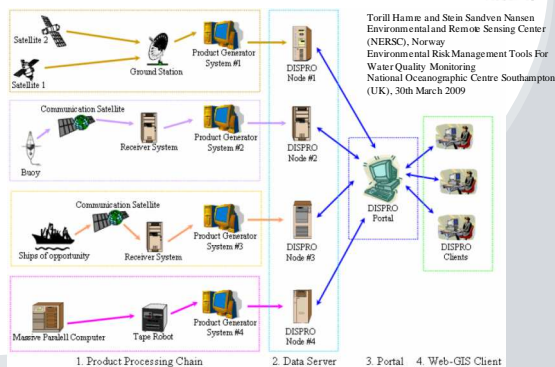
- Data available for limited range of parameters
 - In situ data essential for in depth analysis / chemical speciation
- Availability can be limited by natural factors
 - Cloud cover / flying conditions
- Frequency limited / fixed
- Resolution
 - Varies with source, measurement technique and parameter
 - Limits ability to monitor freshwater bodies

Data management / distribution issues



- Many national monitoring services are well developed, but they are customised to their country's territorial waters, and often based on proprietary or nonstandard solutions preventing smooth data exchange
- Need systems to provide access to data, including observations, derived parameters and model predictions of future conditions, and systems to retrieve, compare and analyze different types of data
- Range of users with different requirements
- Projects such as InterRisk and ECOOP moving towards pan-European systems

InterRisk Service Content



Conclusions



- Combination of in-situ and remote data has huge potential for improving environmental monitoring
- Need to improve data availability
- Interoperability of data systems to allow efficient access by users with varying requirements
- Need for mathematical models with the ability to utilise data from various sources to deliver reliable forecasts at scales from river catchments to the open ocean

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