4.1 Final Publishable Summary Report

Executive Summary

The NAPES project (Next Generation Analytical Platforms for Environmental Sensing, see http://www.napes.eu) brought together ten partners (three SME Industry, five academic, and two Research Institutes) from Ireland, France, Italy, The Netherlands Spain and the UK to advance the field of environmental sensing by combining parallel 'evolutionary' and 'revolutionary' research activities. Through this strategy, NAPES sought to balance higher risk but potentially disruptive research with lower risk, yet high impact research designed to produce tangible benefits during the term of the project. This proved to be remarkably successful, as the project has generated a broad range of impactful outputs. NAPES has created these advances by bringing together novel technologies incorporating innovative sampling and target pre-concentration, fluid manipulation and precision flow control, microfluidic based sample processing components and highly specific detection methods for determination of bacterial contaminants such as E.coli and chemical pollutants like phosphate and surfactants that can contaminate reservoirs and natural waters.

Specifically, the NAPES project has:

1. ***Created fundamental advances in liquid/sample handling*** **with the potential to make costly fluidic components like pumps, valves and interconnects redundant.** Using nano/micro-structured stimuli-responsive materials fully-embedded micro-scale valves and stimuli-responsive soft polymer structures for fluid control and sample manipulation have been created. Fluidic components dominate the current cost base of many water quality analysers (ca. 70-80%, see main report), so reduction by ca. 90%, could reduce the commercial cost of the entire device by>70%; For a commercial system costing €10K, this becomes ~€2.5K; enabling 4 systems to be obtained instead of 1 for the same budget.
2. ***Developed innovative sampling strategies*** to allow for collection of larger representative samples and to reduce volumes to those compatible with portable detection platforms.
3. ***Created and integrated innovative extraction and detection schemes*** for highly specific detection of chemical and biological targets. Label-free optical detection using water refractive index matched materials and customized lectin panels. The project has performed high sensitivity measurements of waterborne contaminants.
4. ***Integrated novel platforms and demonstration of prototype next generation autonomous deployable systems.*** The Project has combined state-of-the-art chemical, biological and engineering technologies to create and field test prototype systems.
5. **Developed next generation detection platforms.** The NAPES consortium has integrated academic research institutions and private industrial partners in a collaborative effort, reinforcing long-term strategies for productisation and scale-up, in parallel to technical and scientific activities. This encourages research to be focused upon the creation of novel components and platforms with high innovative potential and practical application outside of the lab environment.
6. **Organised two successful workshops on the project research** (Eindhoven, Dublin) and produced journal papers, conference proceedings, videos, animations, graphics, and reports that will be a valuable resource for other researchers, educators, students, national agencies and industry.

Project Context and Main Objectives

Imagine a future in which highly effective autonomous sensors are able to measure and share information about the quality of our environment, and particularly water, in our lakes and rivers, our water supply system, and the outputs of municipal and industrial wastewater treatment systems. These sensors are densely deployed at multiple locations, and the information is available to citizens through the Internet.

It is a matter of great concern that, still today, science and technology cannot deliver an effective platform to make this idyllic vision a reality, and the gap between what is currently available, and what is actually needed remains very significant. This is despite a huge effort to develop innovative molecular sensors over the past 20 years, which has generated thousands of papers in the literature, without delivering a practical solution to the real issues associated with distributed environmental sensing. In recent years, many of these papers describe ingenious use of nanostructured materials, which, under controlled laboratory conditions, exhibit greatly improved characteristics compared to more conventional sensors. However, despite these apparently exciting breakthroughs, there is still not a single example of any of these devices being used in direct contact with water in practical deployments for long-term environmental monitoring. This is due to the impact of direct exposure to real environments upon these exquisitely nanostructured sensor surfaces, which rapidly leads to bio-fouling, leaching of surface components, irreversible binding of interferents, and other processes that change the surface properties, and therefore the response characteristics of these sensors.

Bearing this context in mind, the objectives of the NAPES Project were to:

- Deliver '*revolutionary*' advances in sample handling based on molecular switches and nano-scaled control of polymer structures in microfluidics
- Develop innovative sampling strategies
- Integrate highly innovative analyte extraction and detection schemes
- Integrate components emerging from Objectives (1), (2), (3) into functioning prototypes based on existing platforms
- Demonstrate the utility of combinations of these components in field deployments
- Fully exploit instances of evolutionary Improvements in platform functionality arising from NAPES

Figure 1 and 2 illustrate the initial project strategy for implementation of novel evolutionary improvements to reduce unit costs while concurrently exploring novel sensing and fluid handling technologies.

We believe that this strategy has been strikingly successful, and NAPES has delivered significant outputs of evolutionary and revolutionary nature that will have significant near and long-term impact.

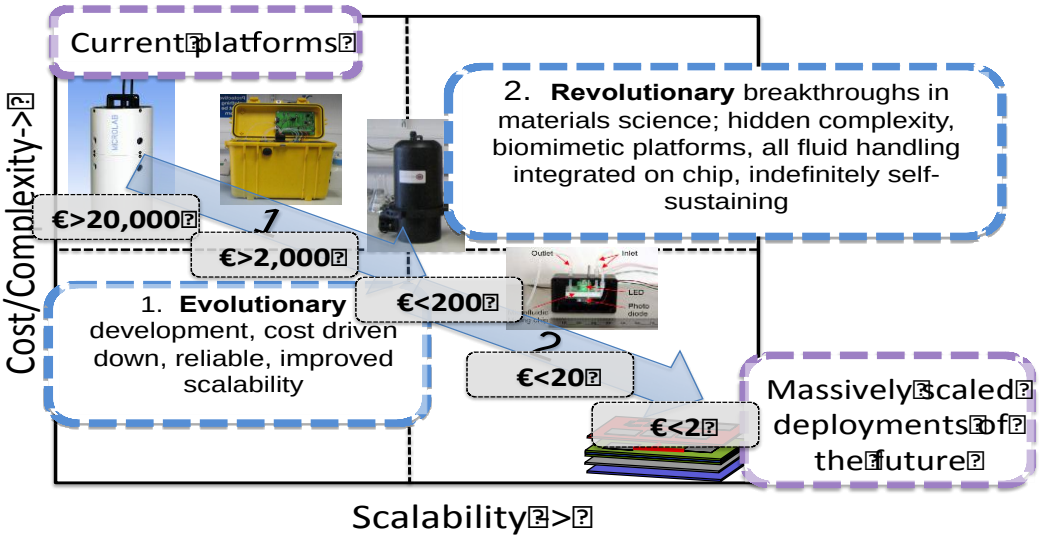


Figure 1: Strategy underpinning this proposal. (1) Use evolutionary improvements in existing platforms to establish credibility, deliver functioning devices and meet real measurement challenges. (2) Truly scalable chemo/bio-sensing can only be realised through revolutionary breakthroughs that emerge from fundamental materials science research. NAPES combined aspects of 'evolution' and 'revolution' and delivered functioning analyser platforms that have been brought through to real in-situ deployments AND fundamental advances in microfluidics with very disruptive potential

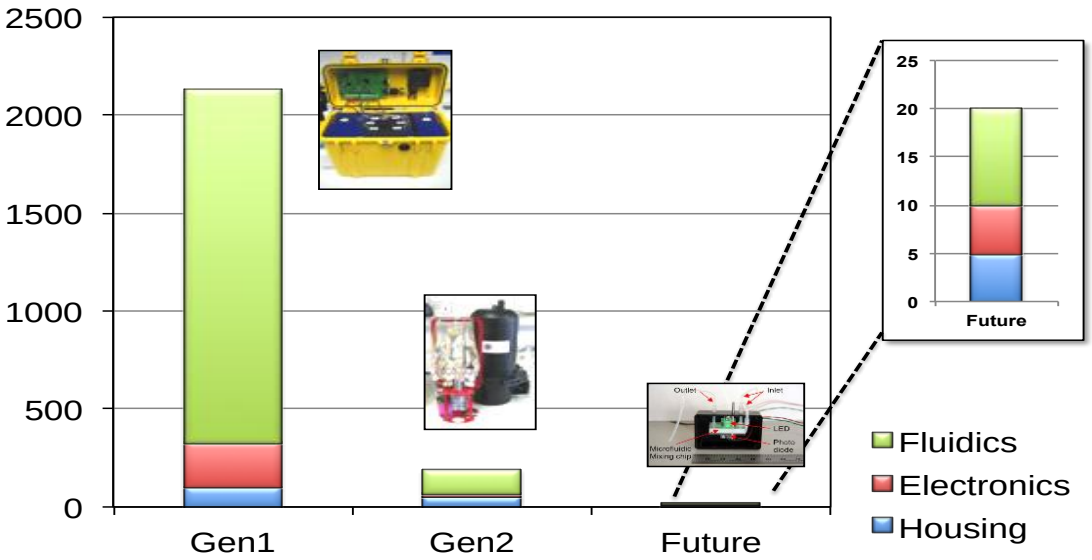


Figure 2: Analysis of the cost base (€) of three generations of environmental analysers developed by DCU. The green section is the fluidics handling contribution (dominates in all cases). Gen1 and Gen2 versions have been extensively field-deployed whereas Gen3 ('future') is a demonstrator concept platform integrating biomimetic polymer pumps

Figure 3 shows how the various project research activities were incorporated into a 'modular' design of the platform technology, that enabled knowledge gained in one area to be effectively transferred into another. For example, existing, fully functioning nutrient analyser prototypes (9) were significantly improved in terms of ruggedness and reliability, and deployed at several locations including waste water treatment plants (DCU, TEL, UMIL). In parallel, developments in the front-end sampling strategies (1-5) could be bolted onto these analysers for tests without affecting the analyser research, as they were mutually independent in terms of progression (TEL, DCU). Likewise, the bio-microbial methods were recognised as very challenging in terms of identification and immobilisation of appropriate bioreceptors (ABL) for selective detection of microbial targets (e.g. ecoli), for preconcentration on bead and tubular filtration platforms (MMBM), combined with triggered release and highly sensitive optical detection (UMIL). However, advances in fluidic control and experience gained in system engineering through the nutrient analyser development (DCU, TEL) were directly transferrable to the bioreceptor research, and enabled a high degree of integration of these complex components (6,7,8) to be achieved. Likewise, advances in microfluidics (UPU/EHU, MG, IK, DCU) and the fundamental chemistry of switchable materials (TU/e, DCU) benefited from the engineering expertise through the creation of prototype platforms that convincingly demonstrated the disruptive potential of these approaches.

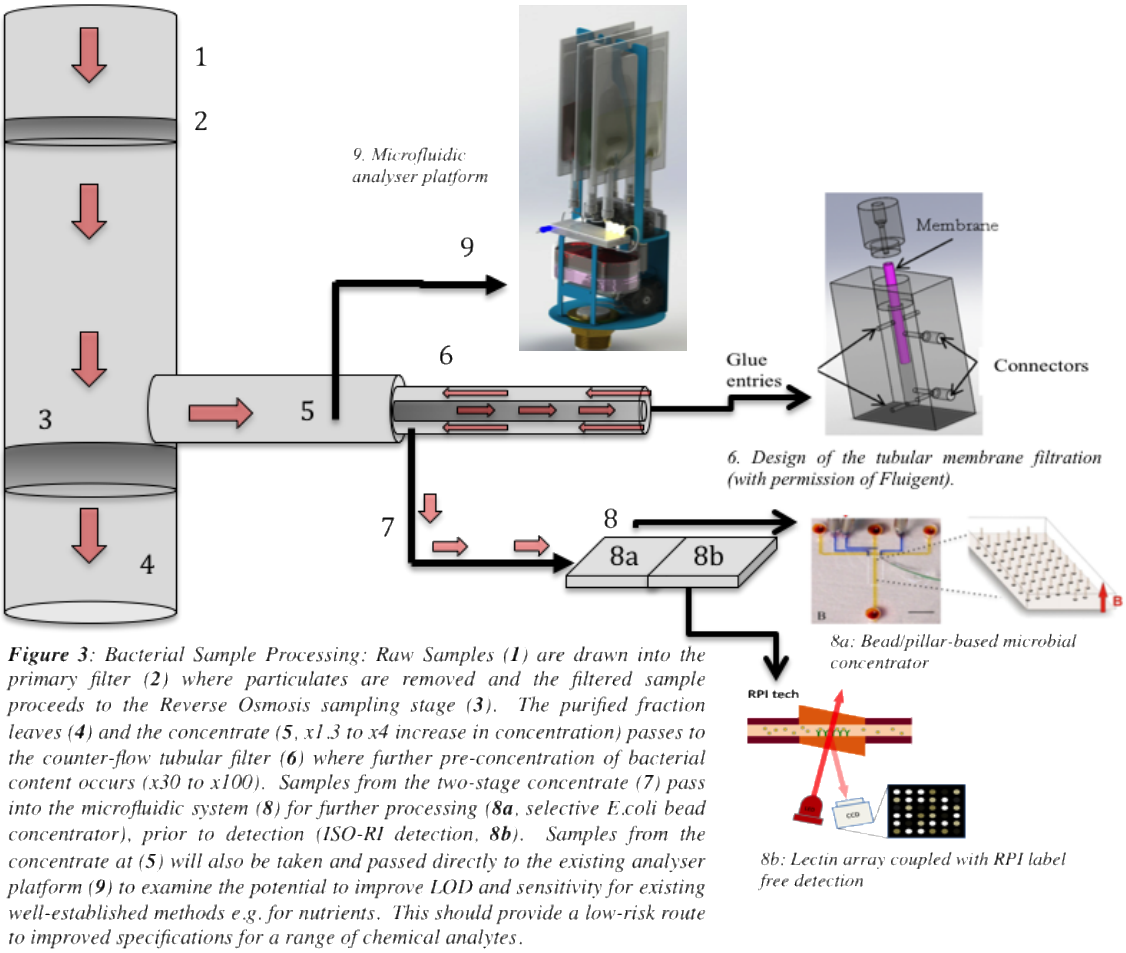


***Figure 3**: Bacterial Sample Processing: Raw Samples (**1**) are drawn into the primary filter (**2**) where particulates are removed and the filtered sample proceeds to the Reverse Osmosis sampling stage (**3**). The purified fraction leaves (**4**) and the concentrate (**5**, x1.3 to x4 increase in concentration) passes to the counter-flow tubular filter (**6**) where further pre-concentration of bacterial content occurs (x30 to x100). Samples from the two-stage concentrate (7) pass into the microfluidic system (**8**) for further processing (**8a**, selective E.coli bead concentrator), prior to detection (ISO-RI detection, **8b**). Samples from the concentrate at (**5**) will also be taken and passed directly to the existing analyser platform (**9**) to examine the potential to improve LOD and sensitivity for existing well-established methods e.g. for nutrients. This should provide a low-risk route to improved specifications for a range of chemical analytes.*

Conclusion

The NAPES platform and the development of its components have demonstrated pathways to significantly reduce the cost of deployable environmental monitoring platforms through integration of novel materials technologies. The corresponding reduction in cost and increased accessibility of technology should allow for greater implementation of such technologies and result in a more widespread environmental monitoring network across Europe. The creation of such networks within member states and across the EU as a whole will provide an infrastructure that will allow for increased awareness of chemical and biological contamination events with a corresponding decrease in EU citizen illness. The creation of rapid warning systems will contribute to the goal of providing technologies to enable environmental legislation and directives to be much more effectively policed and enforced; then making this information available to the citizen and to specialists; it can provide the basis for new services to industry and society[1]. NAPES partners have been very successful in winning additional research funding from multiple sources, some of which involve several NAPES partners continuing to work together, both demonstrating the competitiveness of the partners, and the importance of research pioneered through NAPES.

[1] https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/SI31of2014290114.pdf

NAPES Science & Technology

The consortium partners and team members (effective April 2017) are listed in Appendix A. The NAPES project was organized into nine workpackages, seven of which were science and technology focused (WPs2-8), with WP1 covering project management (led by DCU), and WP9 Dissemination and Exploitation (Co-led by TEL and DCU), see Appendix B.

WP2 focused on fundamental materials research and was led by TU/e, who have a long-documented track record in the field of novel materials. Input from DCU, UMIL and ABL also meant that considerable additional contributions were also made, relating to stimuli responsive compounds, novel optical detection platforms, and selective biological detection respectively. A strong collaborative approach between all 4 partners, spanning chemistry and biology, resulted in 7 high-impact publications and directly contributed to integrated prototype platforms presented in WP7.

TUE and DCU worked on on the synthesis, characterisation and optimisation of novel molecular photo switches based on spiropyrans and liquid crystals. Incorporation of these molecules into gel networks enabled stimulated control of the bulk material characteristics, resulting in actuation and guest uptake/release. Optimisation of the molecular design allowed the stimuli-response to be maximised within hydrogel matrices. These hydrogel materials were then used as light-controlled actuators in microfluidic channels (for examples, see Lab Chip, 2017,17, 2013-2021, J. Mater. Chem. A, 2016, 4, 8676-8681) and even to harness cell adhesion and migration (Adv. Mater. 2017, 29, 1606407). These discoveries represented significant progress in materials' research but also formed the basis for prototype devices integrated in WP7.

From a biological perspective, the work carried out by ABL in identifying and screening lectin-based bio-receptor libraries for selective recognition of targets, such as E-Coli., as documented in Chem. Sci., 2017, 8, 1329-1336, signified an extremely important output from the work package. Subsequent immobilization of these bio-receptor molecules on reverse phantom interface (RPI) particles and surfaces, in conjunction within UMIL partners allowed for the production of biological target detection platforms which are outlined in further detail in WP5 and WP7. The ability to selectively detect faecal coli forms of this nature represents a significant achievement for novel material development, moreover, its subsequent incorporation into a low-cost optical platform, with relatively fast throughput times is an extremely noteworthy output from this work.

WP3 focused on sample preparation for the applications outlined in WPs 4, 5, 7, in particular through sampling, filtration and concentration. From a chemical perspective, this was achieved by the development of a reverse osmosis (RO) filters, led by TEL. For biological systems, the development of a tubular filtration (TF) system was carried out by MMBM.

To remove bulk contaminants from water samples and achieve pre-concentration of components (metal ions, nutrients, charged surfactants etc.) TEL developed a system based on the principal of reverse osmosis. Through the use of a thin-film Alumina membrane filter it was possible to prevent components,

such as dissolved salts, from crossing the barrier. The accumulated impurities could then be collected by the membranes and flushed from the system, for further analysis. This allows for concentration of nutrients within a sample, in addition to reduction of sample volume, thereby enabling the use of microlfluidic analytical devices for large representative sample. The fully automated RO system showed concentration factors of two to four-fold for environmentally relevant nutrients, such a phosphates, nitrates and nitrites. Further integration and prototyping allowed for the introduction of fluidics and automation, thereby resulting in a low-cost, deployable prototype for the pre-concentration of nutrients in water samples.

In a similar fashion, MMBM also focused on filtration and concentration methodologies to enable microfluidic scale detection of biological contaminants. Based on the principle of cross-flow filtration, using a 0.2 μM tubular alumina filter, MMBM achieved a fully-functioning device which offered concentration factors of x20-60 for E. coli bacteria. With a run-time of 10 mins and a final output volume of 250 μL, this provided a compatible platform for integration with microfluidic-based biological monitoring platforms presented in WPs 4 and 5.

WP4 centered, primarily, on the design and development of microfluidic manifolds to further the application of discoveries of WPs 2, 5 and 6. From WP2, novel materials, responsive to light, electrolyte concentration and temperature were incorporated into microfluidic chips to exhibit flow control and active mixing. For example, a micromixer based on a light-responsive switchable surface was incorporated into the channel of a microfluidic device. The responsive polymer could then expand and contract from the walls of the functionalised channel, to disrupt flow regimes. This represented a significant milestone in achieving a dynamic microfluidic device which can be probed from outside the device.

UPV/EHU developed novel procedures for the fabrication of 2D and 3D microfluidic chips from cyclic olefin polymer (COP). This represented a fast and cheap fabrication method for microfluidic devices. One such application of this technology was used to demonstrate thermo-responsive hydrogel valves from WP2, which formed the basis of a recent high-impact publication (Sensors and Actuators B: Chemical, 247, 2017, 749-755). In direct collaboration with IK, a microfluidic heating platform was developed which could accurately heat the valve, showing the instantaneous response of the material and demonstrating another application of using the chemistry of functionalised microfluidic channels to control the nature of flow.

Collaboration between MMBM, ABL, & UPV/EHU resulted in the generation of a functionalized magnetic beads platform for the specific pre-concentration of bacteria and subsequent release and detection. Integration of GSL-I lectin, as identified by ABL, into magnetic beads allowed for highly-specific E. clocae isolation of 85% ±3%. After a growth phase, bacteria can then be released for further analysis, without the need for washing. Development of a COP origami microfluidic device, as developed by UPV/EHU, has enabled the realisation of this platform by simplifying the introduction and organisation of the functionalised magnetic beads in the bead-based concentrator device. Subsequent design and development yielded a fully integrated table-top bead-based concentrator.

WP5, lead by UMIL, focused mainly on the design of label-free detectors based on iso-reflective materials (RPI). After the design and production of an initial prototype, it was demonstrated that selective binding of biologically relevant molecules, such as bacteria and other pollutants (surfactants) could be detected by monitoring binding within a flow-cell containing functionalised phantom membranes. For detection of E.coli, strain-specific lectins, as screened by ABL, were functionalised on to the fluidic chips. Optimisation of the microfluidic chip, surface-immobilisation strategies and visualisation methods allowed for the creation of functioning, low-cost protype for the optical detection of specific bacteria strains in water samples. Its operation was subsequently demonstrated in conjunction with other platforms in WP7.

In conjunction with UPV/EHU this technology was also successfully applied for the detection of chemical surfactants. In this instance, using fluorinated elastomer beads within a COP microfluidic it was possible to adsorb surfactants and to detect them through an optical response within the RPI detector. The device was then used to differentiate between different classes of surfactant in real water samples.

The main objective of WP6 was to enable the integration of the different microfluidic modules generated in WPs 2-5. An emphasis was placed on the compatibility of integrated modules to allow for further integration with the prototype platforms presented in WP7. A modular approach allowed for standardised interconnectivity between the units.

The photo-actuated valves, outlined in WP2 were successfully integrated with an optical detection platform for the detection of iron. The platform, designed and fabricated in WP7, used a microfluidic chip with photo-actuated hydrogel valves, to control flow and mixing within a colorimetric assay, using a PEDD platform. This was the first documented instance of using the flow-control of soft hydrogel actuators to control flowrate and mixing within an analytical microfluidic device.

From a biological perspective, several of the standalone pre-concentration and detection modules were adapted to allow for compatibility of operation. An example of one such successful integration was a collaborative effort between MMBM and UMIL to integrate the BBC and RPI modules. The final design of the automated BBC device, outlined in Interim Report 4, allows for direct input of the concentrated sample of bacteria to into the RPI detector. Similarly, DCU, UMIL and MMBM achieved integration of the TF and RPI systems. The design of a programmable pumping mechanism allowed for the output of the TF to be inputted to the RPI detector at a flow rate conducive to the RPI flow-cell. Both of these endeavours twinned a pre-concentration technique for bacteria with a novel detection method. This demonstrated the ability to increase relative concentrations and decrease sample volumes, thereby enabling more facile detection using the optical RPI platform.

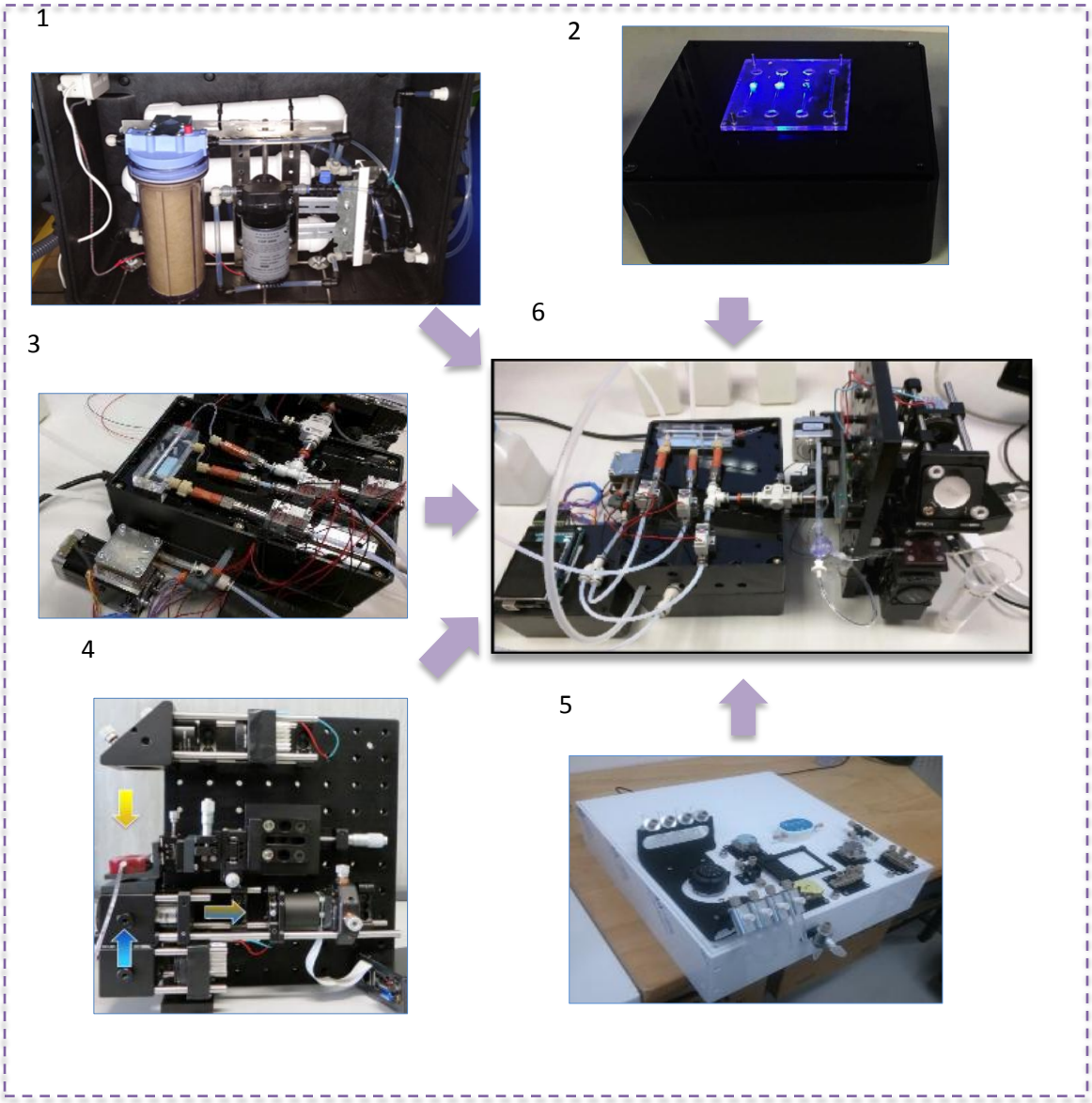


Figure 4 Integration testing of prototype devices. (1) Reverse Osmosis (RO) analyser. (3) Automated Tubular Filtration (TF). (4) RPI detection module with microfluidic cell. The path of yellow and blue light is shown by arrows. (5) Bead-Based Concentrator 6.

Integration of various devices for chemical and biological concentration and detection in this work package enabled significant inroads to be made towards prototype development. The holistic approach towards component design allowed for easy pairing of sample manipulation and optical detection systems.

WP7 focused on the development of several technologies and prototypes used across WPs 3-6. A CD platform with integrated photo-switchable valves, a Proportional Integral Derivative (PDI) for on-chip actuation of spiropyran micro-valves, a photo-switchable mixer chip was tested and the characterisation of the optical response of the chips hosting the phantom membrane was completed. The development and integration of an automated TF system with the RPI detector was also completed.

Figure 4 shows each element integrated during WP7. The manual TF was automated and integrated with the RPI platform. A modular approach was adopted during the design and development of the TF system, allowing each part to be easily replaced or upgraded if required. A syringe pump was integrated with the RPI allowing the output of the TF to be passed to the RPI.

An integrated platform that allows the flowrate within a microfluidic chip to be reproducibly controlled by one of four LEDs was developed. Software that allows the user characterised the performance of the system and determine the experimental values required to optimise the control software for each new valve design was developed and tested. The software enabling the user configure automated test protocols and store the results within an Excel spreadsheet.

A fully integrated platform was also developed to allow the flowrate to be reproducibly controlled in a microfluidic chip (Figure).

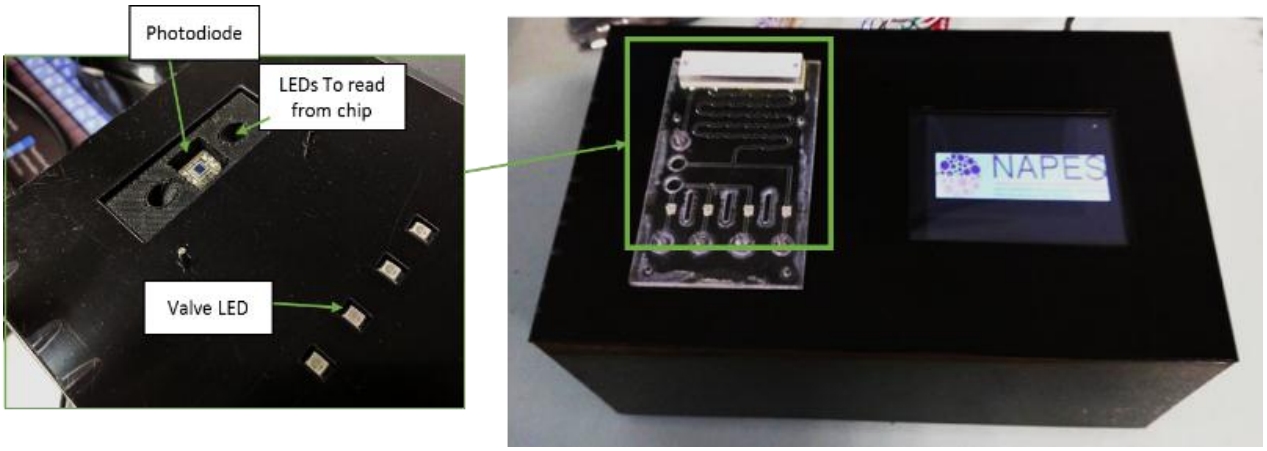


Figure 5 Photo-actuated Valve Platform with integrated flow sensor and PID control. The system runs the Raspbian Linux OS. A touchscreen allows the user to set the flowrate through the chip.

Figure 5 shows the finished system with the LEDs used to control the flowrate shown alongside the photodiode used to detect the colour change within the chip. The prototype device integrated the flow sensor and the required hardware to both control the flowrate and allows the user to interact with the system with the use of a touchscreen. Firmware was developed to integrate the flowrate sensor and allows the user characterise the response of the system. The touchscreen and wireless access allows the prototype to be managed independently of a laptop or viva a remote connection if required. The prototype integrates a photodiode and LED to take analytic readings from a microfluidic chip used in T7.4 .

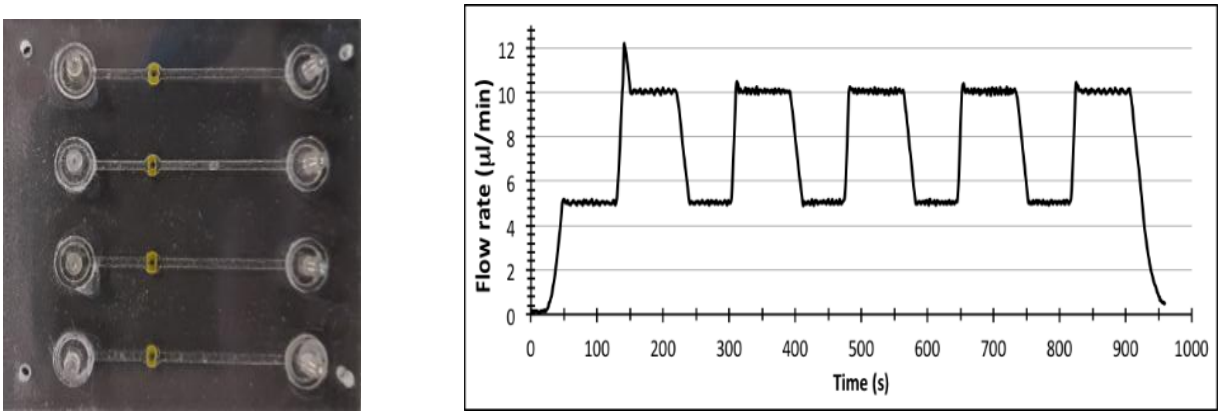


Figure 6 Variable flow rate control with cycles between 5µL/min and 10µL/min flow rates.

Figure 6 (left) shows four parallel fluidics channels each incorporating a photoswitchable valve (small yellow 'doughnut' structure located between a fluid inputs and outputs). The valves a located above an LED that is used to trigger valve opening and closing (not visible). Figure 6 (right) shows the output from the system when the flowrate in one selected channel was switched between 5 µL/min and 10 µL/min The results show the system enables the flowrate within the channel to be controlled very precisely and accurately (for more details see Lab Chip. 17 (2017) 2013–2021. doi:10.1039/C7LC00368D).

WP7 has seen the development of three prototypes and the integration of the RO, TF BBC and RPI systems, detailed in WP3-5. Prototypes were also deployed for field testing. This work-package has benefited from ongoing input and technical collaboration from all project partners.

Societal Impact

Access to clean water for drinking, cooking, washing and recreation is a basic human right which is safeguarded through EU legislation, and policed by national Environmental Protection Agencies. Policing is only as effective as the ability to measure key water quality parameters, in multiple locations as often as possible, at an affordable cost. NAPES had two parallel objectives related to;

1. Generate significant advances in fundamental challenges related to water quality monitoring that will have strategic impact in future years (>5 years, e.g. microfluidics, biodectection, optical sensing)
2. Produce practical advances in analytical platform capabilities that will have significant impact in the near term (<5 years, e.g. in-situ monitoring of nutrient concentrations)

Such advances are critically important for European and Global society, as maintenance of water quality is a constant and continuing challenge and improved monitoring capabilities will play a central role in supporting strategic decision-making and strategies for classifying water status. A striking example of the need for increased monitoring is given by the latest report by the Irish EPA[2], which reported that;

- Elevated nutrient concentrations (phosphorus and nitrogen) continue to be the most widespread water quality problem in Ireland.
- 1,015 monitored river water bodies (43%) were classified at less than good ecological status.
- 97 fish kills were reported in the 2013–2015 period, which represents an unwelcome change when compared to 72 fish kills between 2007 and 2009 and 70 fish kills between 2010 and 2012.
- Twenty-three of 1,654 stations showed evidence of strongly increasing phosphorus concentrations. In most cases these are close to wastewater treatment plant discharges. However, as with nitrogen, there appear to be upward trends in phosphorus concentrations in some rivers since 2013, although nationally concentrations remain lower than in 2007–2009.

In the following sections, we summarise the achievements of each partner in the NAPES project, and explain how these achievements will lead to improved tools for improving water quality monitoring which in turn will impact positively on the health and quality of life of citizens, besides creating significant economic opportunities for companies seeking to exploit these advances.

Dublin City University (Beneficiary 1)

Photo-actuated Valves

Over the last 30 years microfluidics research for the analytical science sector has centred on the development of ever faster, smaller and more versatile microfluidic chips. This has rapidly led to the emergence of 'Lab on a chip' technologies. The flow of liquid analyte in LOAC devices is controlled by valves which open and close, to physically control the release and movement of fluid. Until now, these

[2] http://www.epa.ie/pubs/reports/water/waterqua/Water%20Quality%20in%20Ireland%202010-2015.pdf

valves have been too cumbersome to be fully incorporated into a microfluidic chip. As a result, the current microfluidic chip model requires connection to externally-located valves. While advances have been made, through the use of pneumatic valves based on soft-polymers, there still exists a paucity of low-cost and precise actuators. Through the NAPES project, the Adaptive Sensors Group at DCU, led by Prof. Dermot Diamond, has made significant progress in the field of soft polymer valves which can be directly incorporated into analytical microfluidic devices. Through the use of light pulses, from low-power LEDs it was initially possible to achieve simple open/closed control of fluid flow within a microfluidic device which was subsequently improved by pulsing the light source to achieve long term regulation of flow rates. The microfluidic market is currently seeing growth of approximately 25% across diagnostic, pharmaceutical, environmental, drug delivery and micro-reaction sectors. With this growth comes a significant need to miniaturise size, reduce cost and maintain accuracy. The outputs of the ASG group at DCU surrounding photoactuated microfluidic valves has garnered attention from across a broad range of applications. The ability to fabricate low-cost valve manifolds with extremely high accuracy holds potential in the realm of wearable point-of-care devices, where sampling and analysis of body fluids, such as blood or sweat can be performed by a minimally invasive patch. The control exhibited by these microfluidic valves also lends itself to the ability of controlling flow within a simplified circulatory system which currently forms the basis of organ-on-a-chip technologies, used for simulated organ and pharmaceutical testing in 3D tissue models. Controlling the perfusion of liquids to and from testing platforms using highly-controllable biomimetic polymers has the potential to complement major inroads being made in the area.

Through the NAPES project, the photoactuated valves have been developed from a proof of concept to a functioning pre-competitive prototype platform. In addition to representing a significant contribution to the upcoming HOLIFAB H2020 proposal, several collaborations are also currently being explored to provide a direct pathway to application. Considering that fluidic components comprise up to 80% of the components costs for environmental analysers, these advances have the potential to significantly drive down the cost and complexity of these devices, which will allow reliable measurements to be made more frequently and in more locations, thereby producing a more complete picture of water quality status for citizens, regulatory agencies and industry/agriculture.

Integration of Platforms

A common challenge for research scientists is to efficiently translate discoveries to end-user application. To truly yield platforms with the potential for environmental monitoring it is necessary to more closely integrate prototype design/integration and fundamental science. This was identified at the conception of the NAPES project and is best highlighted by the nature by which integration activities were woven throughout the work packages and deliverables. From WP2, the integration of actuation platforms and control software was integral in developing the applicability of the discovery from crude valve control to highly efficient microfluidic control, offering flow control accuracy in the nanolitre/min range. Through PID closed-loop control algorithms, these dramatic improvements in performance of fully integrated, photo controlled valves have been practically demonstrated. In work packages 3, 4 and 5, integration carried out between DCU, MMBM, UMIL and TELLABs generated working prototypes which were developed and tested over the course of the NAPES project. For example, a reverse osmosis (RO)

prototype developed by TELLABs was integrated into DCU Analyser platforms for field testing during deployments. Similarly, advances in the technologies underpinning tubular-filtration (TF) and bead-based concentration (BBC) enabled the development of two novel prototypes which were successfully used to monitor real samples. Between DCU and UMIL advances in the reverse phantom interface (RPI) detector allowed the technology and processing techniques to be integrated into a portable user-friendly prototype which was used in tandem with other techniques for the quantification of bacterial samples in deployment samples. Figure 7 shows a fully integrated nutrient analyser platform incorporating fluidics, microfluidic chip, reagent/calibration solutions, sampling port, waste storage, electronics module, battery, and wireless communications housed within a ruggedized case; during lab trials (left) and in-situ deployment at a waste water treatment plant (right).

Figure 7 Fully-functioning autonomous nutrient analyser developed by DCU (left) and in deployment (right) at a waste water treatment plant in Milan (organized by UMIL and DCU)

Eindhoven University of Technology (Beneficiary 2)

During this project, the main role of Eindhoven University of Technology was the development and implementation of novel molecules for light responsive materials inside microfluidic devices. Hereby, an increase in speed of the molecule by a factor of 20 was achieved compared to previously used materials, allowing the materials to be used in a wide variety of applications, where the forward and backward reaction of the molecules must be in the same timescale. This translated to new microfluidic valves that were capable of not only opening within seconds/minutes, but closing in the same timescale, in contrast to previous similar work, where the opening of the valve was in seconds, but the closing took up to 1 to 2 hours. Using these rapidly responding molecules, micromixers that respond to light within the same timeframe where also realised, allowing on and off switching of these materials on demand. These materials are of upmost importance to generate the new generation of analytical platforms, whereby expensive components e.g. pumps and mixers can be replaced by a simple light responsive hydrogel, that allows downscaling of the device, lowering energy demand and reducing the cost tremendously. This has the potential to open a new market of users for these analytical platforms, where cheap and

high frequency measurements of the environment are important. To further extend the socio-economic and wider societal impact, it is also shown that these materials can be grown on cotton material, providing a green and renewable substrate for these materials and allowing collection and release of water from this material using light, expanding the field of applications for these materials. These materials all work in a water environment by swelling and absorbing part of the environment, which is not always desired. To allow light responsive materials to be used in a water environment without absorbing any species, liquid crystalline polymers are used. Hereby, the effect of topology and roughness is investigated for cell growth, which shows the possibility to use these materials for anti-fouling applications, as well as selective culture of cells on demand.

Institut Curie (Beneficiary 3)

The technology developed and validated by MMBM during this project has a high potential impact to make sample preparation and analyte pre-concentration much easier. Indeed, this technology allows handling of samples of different kinds (river water as developed in the NAPES project, but also milk or blood), and it could have relevant applications in several fields beyond water monitoring and environmental safety, such as food quality control and biomedical analyses.
As a striking example of how our technology could have a strong societal impact, we could consider food quality control. Foodborne illnesses alone are responsible for 600 million infections and 400,000 deaths each year worldwide (9.4 Million infections and 1,351 deaths in the US). Considering the slow progress in new antibiotics discovery, the main hopes of control lie in the development of prevention and of fast, convenient and low-cost technologies for early pathogen identification in clinics, environmental control and the food and beverages economy. This is critically true in the food industry and the water industry, for which, due to the long time required by existing detection methods, pathogenic bacteria can be widespread before alert, resulting in disease outbreaks with high risks for consumers and important economic costs. In the developing world, production and consumption mostly remain local, so testing should be able to accommodate non-centralized and low technology environments. The cost and technology of current analysis techniques often make them unsuitable or unaffordable where analysis would be needed. Microfluidic-based technologies can offer platforms for faster and more automated detection systems, while reducing testing costs. Compact microfluidic devices could be used allowing sensitive, fast and low-cost pathogen detection directly from a complex raw liquid sample, down to a few cfu in a few hours. It relies on our innovative microfluidic technology: a microfluidic fluidized bed in which superparamagnetic beads bearing specific ligands of the pathogens of interest recirculate continuously while the raw sample is passed through. To our knowledge this is the first time the concept of a magnetic fluidized bed has been transferred to the microfluidic scale. This approach ensures a high density of beads and specific surface to improve target capture, combined with low working pressures and high resistance to clogging.

University of Milan (Beneficiary 5)

Contamination of water is a constant concern all over the world. The availability of uncontaminated water for drinking and for the agricultural processes is a fundamental need of any human being. Moreover, pollution of water basins has a strong impact on the overall environmental equilibrium. Every

day, as a result of both domestic and industrial activities, substances threatening the survival of flora and fauna enter into the aquatic ecosystems. Some of the most widespread contaminations include faecal pollutants, harmful organic and inorganic substances, oils and emulsifiers, such as the compounds that are present in detergents and soaps. The current standard analytical methods require fully furnished laboratories and highly trained personnel. Consequently, the required sample collection and transportation necessarily prevents the possibility of a rapid intervention in case of contamination. In order to overcome these limits, different kinds of autonomous and deployable analytical platforms have been proposed. However, their overall cost per analysis is typically high and consequently the sampling frequency and the number of sampled sites are largely affected by budget restrictions. In contrast, it would be extremely important to develop autonomous analytical systems capable of on-site, continuous and extensive monitoring of different kinds of contaminants.

The technologies developed by the team of the University of Milano in the frame of the NAPES project provide novel paradigms for autonomous detection of microbiological and molecular contaminants in environmental water. One of the realized prototypes is an optical instrument integrating a microfluidic cell that enables the enumeration and screening of different bacteria strains in a water sample. The instrument is as small as shoe box and the analysis is performed by a cost effective processing unit based on Raspberry PI. Another set of prototypes are plastic microfluidic devices embedding innovative sensors based on perfluorinated polymers with refractive index similar to that of water. These sensors are produced in the shape of micro-porous membrane or micro-column of packed micro-spheres and enable the continuous monitoring of molecular contaminants without sample treatment.

All these prototypes realized in the NAPES project and exploiting the technology developed by the team of the University of Milano have been tested and validated with real river water collected from different locations, thereby advancing the practical application of these technologies towards water quality monitoring.

Aquila Bioscience Ltd (Beneficiary 8)

The main role of Aquila Bioscience in the NAPES project was to develop a library of biological receptors that have high binding affinity and high specificity for bacteria commonly found in contaminated water i.e. coliforms such as *E.coli* and *E.cloacae.* In particular, ABL identified lectin WGA to have high specificity for the pathogenic *E.coli* O157:H7 and was able to differentiate it from non-pathogenic *E.coli* strains. Also, lectin GSL-I-B4 was identified to have high specificity for *E.cloacae* ,another coliform commonly associated with contamination. The incorporation of a biological detectior in the NAPES platform, capable of detecting pathogenic bacteria, will have a major socio-economic impact in the areas which the platform is deployed. The platform will be able to identify contamination in lake water before it reaches uncontrollable levels, reducing the economic burden on the council that will have to treat the water. Furthermore, the potential for the water to cause infection and illness to individuals using the lake or animals who may drink from the water, will also be reduced having a direct socio-economic impact. The use of lectins to specifically bind and isolate particular pathogens can also be applied to novel decontamination strategies. Aquila Bioscience are investigating the use of Lectins for decontamination of sensitive equipment and body parts (i.e. skin, mouth, eyes). Lectins can be used for

detection, decontamination and isolation of targeted bacteria, expanding the potential societal implications that lectins can address.

IKERLAN (Beneficiary 9)

The technology and developments produced in this project around microfluidics and system integration has contributed to revolutionary advances in liquid/sample handling, combined with new approaches to performing sensitive in-situ analytical measurements, will make easier to deploy environmental sensing policies by using low cost instruments, what will allow a wider network of control sites.

One of the results of this project, which includes the different modules for an effective chemical analysis, is well suited for waste water treatment plants, having therefore a clear societal impact in assisting the effectiveness of policing European water quality regulations and improve water status for the benefit of the citizen and industry.

University of the Basque Country/EHU (Beneficiary 10)

The generation of new fabrication pathways for microfluidics devices (*e.g.* origami technique, membrane and beads microfluidic devices), the implementation of functional materials within nano/micro-sensors (*e.g.* nitrate/nitrite sensor) and the integration of novel actuators in the microchannels of the device (*e.g.* CD photeresponive valves and thermoresponsive valves) have been the heart of UPV/EHU contribution to the project. Moreover, UPV/EHU has also participated actively on the integration of the different modules.

Origami technique is providing the research community and to industry with a new way of fabricating microfluidic devices without the need of any laboratory equipment more than a low cost cutter plotter (<200€) at a very low cost. Moreover this technique allows for sensor integration and for the generation of complex 3D microfluidic structures in a relatively simple manner.

The integration of smart materials for flow control into microfluidic systems (rather than off-chip pumps and valves) has the potential to drive down the costs associated with manufacturing at large scale, rendering many of the current technologies and operational practices obsolete. The fabrication, for instance, of thermoresponsive actuators in a modular way (chip unit) and photoresponsive actuators in microfluidic platforms increase the options to generate novel microfluidic structures and provides a new set of tools for the fabrication of microfluidic devices.

During NAPES we have focussed on addressing microfluidic challenges such as to reduce cost of microfluidic production, simplify fabrication protocols, and integrate new functionalities in order to generate autonomous analytical platforms for environmental monitoring. Water is an essential resource for living systems, industrial processes, agricultural production and domestic use the outputs generated by UPV/EHU in the project will contribute to the generation of novel analytical platforms for water monitoring. They have the potential to provide citizens with access to rich environmental data, through which much more informed decisions can be made about water-related issues.

Finally at UPV/EHU, the education of new generations (young children and general public) on water quality monitoring in order to increase a global conscience on water quality protection has been very important. We have carried out several outreach activities to promote this important challenge (*e.g.* Science Week, visits to schools, university courses).

Dissemination activities and exploitation of results

As part of the NAPES project strategy, dissemination of emerging technologies and scientific advancements has been identified as a key activity during the project's term. This is due to the importance of interaction with the wider research community for adoption of NAPES outputs and to generate interest amongst the Industrial sector to encourage commercialization of the platforms developed during the project and potential activities beyond the period of the project.

The Dissemination and Exploitation plan was established at the commencement of the project in December 2013 to provide protocols ensuring that all relevant knowledge coming out of the project was carefully managed from the very beginning. All project partners were involved in dissemination and exploitation in order to foster awareness and transfer results from the consortium. Dissemination of results is a contractual obligation of participation in research initiatives supported under the European Union's Seventh Framework Programme for research (FP7). The specific aims of this provision are to promote knowledge sharing, greater public awareness, transparency, and education.

Project partners engaged in regular focus group meetings (http://www.napes.eu/2016/11/umil-and-abl-visit-dcu/) and in other dissemination activities with many displaying the generic project poster at various national and international scientific as well as industrial conferences and exhibitions attended.

Dissemination activities for the NAPES Project included some of the largest scientific conferences, such as MicroTAs held in Dublin in October 2016 (http://www.microtas2016.org) where project partners DCU, Milan, & MMBM presented (Oral and Poster Presentations) on the technologies developed in the NAPES project (http://www.napes.eu/2016/07/microtas-2016/). NAPES was also represented at the IEEE Sensors Conference in 2016; Rapid Methods Conference 2016; NanoBiotech 2016; IC-Anmbes 2016; Eurosensors 2016; E-MRS Spring Meeting 2016; The Optical Society Meeting (USA) 2015. NAPES has also been represented at various water conferences including meetings organized in the UK and Ireland by SWIG (Sensors for Water Interest Group) and also the European Waste Water Conference in 2015 & 2016.

Another example of NAPES event attendance was the presentation of the project at the Science Open Day Workshop at DCU demonstrating the technologies to second level students. This workshop was attended by over 60-second level students and their teachers.

NAPES Workshops

The NAPES partners also organised two very successful workshops during the project lifetime. Workshop 1 (D9.3) was divided into two separate sessions:

Figure 8: NAPES Workshop 1 Session panel; (l-r) Mark Bowkett (TEL), Janire Saez-Castano (UPV/EHU), Shane Deegan (ABL), Roberta Lanfranco (UMIL) and Jeroen Ter Schiphorst (TU/e)

In October 2015 (M23) NAPES took part in the Italian Nanoforum. This involved a panel of 5 NAPES partners discussing the various research areas of NAPES in addition to a stand in the main hall to showcase NAPES technologies (Figure 8). Mark Bowkett (TEL) was chosen to chair the session due to his role as Exploitation Leader (WP9) within the project. The panel consisted of 5 project partners with the following talks presented:

Presentation Title	Presented by	Description
An Introduction to the FP7 Project NAPES Detailing Commercial Opportunities for Project Outputs	Mark Bowkett TE Laboratories TEL	An introductory talk on the NAPES project as a whole and discussion the commercial values and exploitation potential of the research arising from the project.
Molecular Design of Light-Responsive Hydrogels for In-Situ Generation of Fast and Reversible Valves for Microfluidic Applications	Jeroen ter Schiphorst, Eindhoven University of Technology (TU/e)	Discussion on the synthesis and characterization of photoresponsive valves based upon spiropyran and their subsequent optimisation and initial applications within microfluidic channels for development of low cost, reusable and reliable flow control within analytical platforms.
Direct Optical Detection of Molecular Pollutants In water by Invisible, Micro-Porous, Polymeric Materials	*Roberta Lanfranco, University of Milan (UMIL)*	Presentation of technologies for surfactant and hydrocarbon detection based upon spontaneous adsorption to the surface of amorphous fluorinated plastics that are iso–refractive to water and integration of these materials in to microfluidic devices as micro-

		porous membranes and microparticles for continuous monitoring of environment.
Smart Thermal Actuation to Control Fluid Flows in Origami Fabricated Microfluidic Devices	*Janire Saez-Castano, University of the Basque Country (UPV/EHU)*	Overview of the development of very low cost 3D fluidic chips based upon stacked, knife cute 2D layers of COC polymer sheets and integration of thermoresponsive ionogel materials for the formation of additional low cost valving materials. The ability to produce customised chips for very low costs greatly increases the feasility of the production of analytical platforms at the fraction of the cost of current technology.
Integration of Bio-Recognition Molecules into a Label Free Optical Detection Platform and a Cell Sorting Pre-Concentration Module for High Troughput Detection of Bacteria in Contaminated Lake Water.	*Shane Deegan, Aquila Bioscience Ltd (ABL)*	Discussion on the development of Lectin and antibody based approaches for the highly specific determination of pathogenic bacteria present in environmental waters used for human consumption. Integration of these biomolecules with platforms developed by UMIL and UPV/EHU will result in the ability to continuously monitor such water bodies with high selectivity against false detections from safer bacteria strains

NAPES Demonstrator Stand

In parallel to the themed session, a point of presence stand was also presented at the event. The stand consisted of booth containing a table for demonstrator modules and a Poster board illustrating the entire proposed NAPES platform and the individual partner contributions to the subsystems being developed for integration. The stand is shown with completed set-up in figure 9 below.

Figure 9: Left: NAPES Point of Presence stand at the Italian Nanoforum. Right: Selection of NAPES Sub-platforms on display

At the stand, four demonstrator platforms were on display for showcasing to the event attendees (see figure 10 for two examples). The four demonstrators present were:

Demonstrator	Developer
Microfluidic flow control using light responsive polymer valves	*Simon Coleman, Aymen Ben Azouz, Dermot Diamond (DCU)* *Jeroen ter Schiphorst, Albert Schenning (TU/e)*
Microfluidic bacterial pre-concentration platform based upon functionalised magnetic microbeads	*Amel Bendali, Clémence Vergne, Stéphanie Descroix (MMBM)*
Portable platform for reagentless optical determination of bacterial contamination	*Silvia Biffi, Giovanni Tagliabue, Marco Buscaglia (UMIL)* *Shane Deegan, Marta Utratna, Nahidul Islam (ABL)* *Janire Saez Castano, Fernando Benito-Lopez (UPV/EHU)*
Rapid fabrication of microfluidic chips using "origami" method of embedding membrane and bead based sensing substrates	*Janire Saez Castano, Fernando Benito-Lopez (UPV/EHU)* *Roberta Lanfranco, Marco Buscaglia (UMIL)*

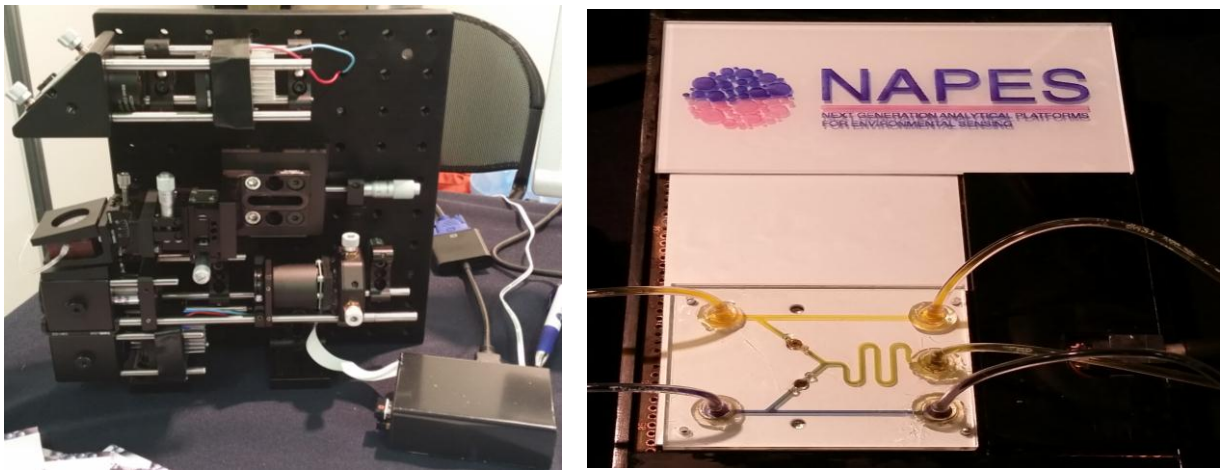


Figure 10: Examples of demonstrator platforms. Left: RPI fluidic chip optical platform (Demo 3: UMIL, UPV/EHU, ABL). Right: Photoresponsive polymer valves for microfluidic flow control and mixing (Demo 1: DCU, TU/e).

NAPES Workshop 1 – "From Molecule to Device"

The 1st NAPES Workshop was held in The Holiday Inn Eindhoven, The Netherlands on 17th & 18th November 2015. The theme of the workshop was "From Molecule to Device" reflecting the philosophy of the host partner's institution, Eindhoven University of Technology (TU/e) and included speakers from various chemical, biological, engineering and environmental backgrounds discussing technologies that are producing cutting edge technologies for improvements in water quality analysis, commercialization of such technologies and their potential impacts on global society.

A high impact, diverse range of speakers were chosen for the workshop to cover the various research areas being investigated by NAPES as well as related fields where the project and its outputs could generate interest.

NAPES Workshop 2 "Sensing our Environment: From Innovative Materials to Autonomous Sensors and Earth Observation

NAPES held its second workshop and its final event in Croke Park, Dublin, Ireland on the 27 and 28th of March 2017, attended by all project partners, industrial and scientific leaders in the areas of material, analytical environmental science. The event also attracted important stakeholders involved in environmental monitoring. The two-day workshop provided in-depth context on the challenges and importance of improving methods and available technology in environmental monitoring.

There were presentations from Academia; Industry; Funding Agencies and demonstrations of the technologies developed in the project (see Figure 11). External stakeholders, academic, and industries were invited to attend and view how the technologies were developed, and how they can work together. Developers were then available to discuss the technical components of the sensors developed as well as engaging in discussions with outside industrial and academic communities about further collaborations and applications for the technologies developed. These activities are detailed in the NAPES video[3] and in deliverable report D9.2.

Figure 11: Selection of photos from the Second NAPES Workshop, Croke Park Stadium, Dublin. Top left: Prof. Jed Harrison (University of Alberta) speaking on microfluidics; Bottom Left: Marco Buscaglia (University of Milan) showing the integrated biocontamination detector to Workshop attendees; Right: View down part of the main exhibition room showing teams explaining their research to attendees.

[3] https://vimeo.com/adaptivesensorsgroup

Publications

The NAPES consortium ensured that research findings of importance were disseminated to the broader scientific community through scientific (peer reviewed) publications and conferences. Scientific NAPES results have been and will continue to be published in high impact general and specialised journals.
The full list of publications can be seen in the dissemination section of the NAPES website (http://www.napes.eu/research/publications/).

NAPES achieved an effective visual brand identity by the consistent use of particular visual elements to create distinction, such as specific fonts, colours, and graphic elements. NAPES brand is implemented in its promotional material such as the website, PowerPoint templates, posters, etc. Further promotional material was developed to support the dissemination of the project. These included: project pens and key rings for use at general dissemination events, a new project poster, a 3-minute information project video, project animation and a project pull up banner.

Footage for the project video was captured during dissemination activities such as focus group meeting, uTas conference, the NAPES two-day workshop and during field testing activities. This footage was edited to produce the final project video, which will be an excellent vehicle for disseminating project results not only during the project lifecycle but also in the legacy phase. An initial shorter video was screened at the two-day workshop dinner with the final video available to view on vimeo https://vimeo.com/adaptivesensorsgroup and on the project website and twitter account.

The project partners considered that the project outreach and engagement activities could be further strengthened by a social media platform and a project twitter account was subsequently established for this purpose. This can be viewed here: https://twitter.com/napes_fp7?lang=en.

Project Animation

As part of the NAPES education and outreach activity, an animated movie was commissioned to provide a clear explanation of the project vision, together with a series of vignettes explaining the concepts and science driving aspects of the project microfluidics and materials research. This animation storyboard was developed with the assistance of Mats Bjorklund, Magipics, Melbourne, an experienced scientific animator. Two stills from the animation are shown in figure 12. The full animation can be downloaded at https://vimeo.com/232542255. This has proven to be a very successful initiative, as extracts from the material produced have been used in conference presentations, scientific publications and general undergraduate lectures. It will continue to have significant scientific value well into the future.

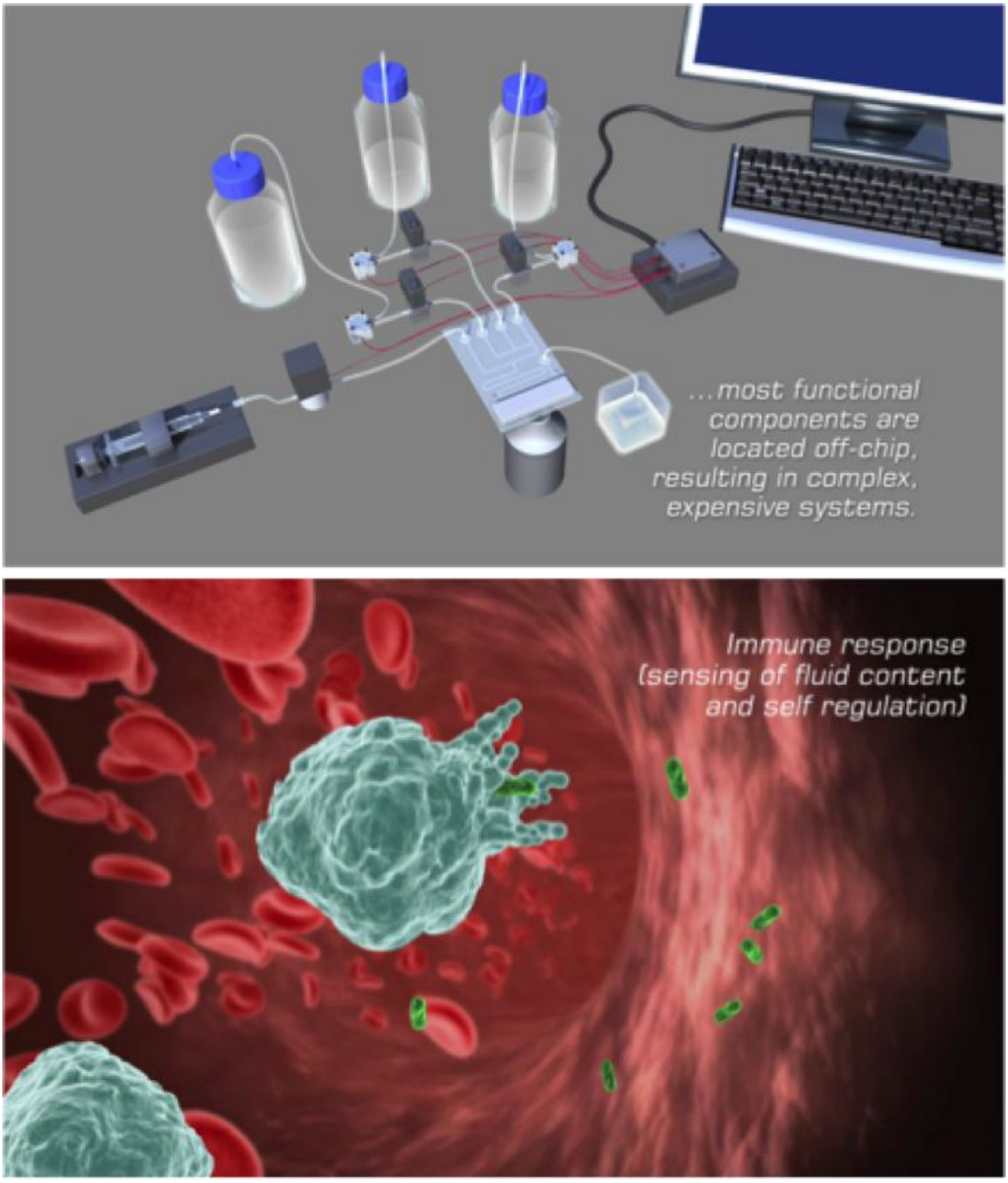


Figure 12: Stills taken from the NAPES animation comparing the crudity of microfluidics (top) with the elegance and complexity of the human blood circulation system (below).

Exploitation

The project aim initially was to develop an integrated system, however, each individual system can be stand-alone functioning units based on the modular design of the integrated system. Therefore to maximise exploitation and to ensure that market needs are met, each individual system can be exploited by itself or in combination with the other systems that make up the NAPES platform.

Key Exploitable Outputs (KERs)

The key exploitable outputs identified at the exploitation workshops are outlined below indicating the method of exploitation and the partners that will be involved to bring about the most effective exploitation.

KERs Table (version 3):

Key Exploitable Outputs	Method of Exploitation	Partners expected to exploit	TRL
WP 2			
Photo responsive valves	For use in microfluidic chips Approved funding: Innovation Partnership Programme (IPP), Enterprise Ireland (with TEL Proposals under assessment: Holifab (H2020 Pilot -04-2017 call) which aims to reduce manufacturing costs and improve manufacturing processes	DCU TU/e	8
Receptor arrays (separate to valves)	As part of RPI and BBC systems Future proposals: H2020 Marie Curie ITN proposal which will be submitted in January 2018	UMIL MMBM	4
Microporous receptors (Beads)	Publish in peer review papers Future proposals: H2020 Marie Curie ITN proposal which will be submitted in January 2018	MMBM UMIL ABL	4
Alginates	*N/a; not exploitable on their own. Part of microbiological analysis system*		
WP 3			
Bio-Detector System (Tubular Filtration)	Patentable Can form part of the RPI system	Fluigent (Fluigent was a subcontractor in the project and own the IP)	5-6
Reverse Osmosis (RO) Sampler /Concentrator	Commercially exploitable as a stand-alone unit or as part of a modular platform. May have to wait for sensor technology to catch up; particularly useful in relation to emerging contaminants that are at very low levels (micro -levels) but that have a cumulative negative effect on aquatic life and human health	TEL	For nutrient and metal concentration: TRL 8 For emerging contaminants: TRL 4

Key Exploitable Outputs	Method of Exploitation	Partners expected to exploit	TRL
WP 4			
Microfluidic systems: (incorporating the NAPES integrated / individual systems including Portable microfluidic device to detect Nitrate-Nitrite)	Possible follow on projects: Granted proposals: IPP (Enterprise Ireland grant) and Marie Curie ITN 'MaMi'(UPV-EHU) Euro CPS for incorporation of comms module (TEL) Proposal under assessment: Holifab (H2020 Pilot -04-2017 call) which aims to reduce manufacturing costs and improve manufacturing processes for microfluidic devices. Future Proposals: Marie Curie ITN proposal – to be submitted Jan 2018	All partners	Each system is a at a different TRL: ranges from TRL 4-8
Bead Based Concentrator (BBC)	Publish in peer reviewed journals. Future proposal: H2020 Marie Curie ITN proposal which will be submitted in January 2018	MMBM UMIL All partners involved in future proposal	4
Lectin magnetised receptor beads	Option for licensing (based on validation /QC for specific use, detection of specific bacteria)	ABL (depends on staff requirements)	7
WP5			
Reflective Phantom Interface Optical Detection platform	Platform can be combined with BBC or TF or RO concentrator; more collaboration required for it to become commercially viable. Future proposals: Marie Curie ITN proposal – to be submitted Jan 2018 and National funding in Italy	MMBM ABL UMIL All partners involved in the future proposal	4
Surfactants/Materials	Incorporated in photoresponsive valves Possible part of a suite of technologies to academics; this route for exploitation is just at the concept stage Further development to investigate if these material could be used prevent biofouling and in Point of Care Diagnostics.	DCU TU/e	4-5
WP8			
Integrated NAPES Platform	Commercial exploitation as individual systems or as combined systems (either for combined microbiological and chemical testing or for chemical analysis alone) as indicated in the BMCs. If not commercially viable peer reviewed articles will be submitted for publication. Granted proposals: IPP (Enterprise Ireland grant) and Marie Curie ITN	All	Integrated NAPES system: TRL 4 NAPES chemical analyser: 6

Key Exploitable Outputs	Method of Exploitation	Partners expected to exploit	TRL
	'MaMi'(UPV-EHU) Euro CPS for incorporation of comms module (TEL) Proposals under assessment:H2020 'Holifab' Future Proposals: Marie Curie ITN proposal – to be submitted Jan 2018		

Only some of the KERs have Business Model Canvases prepared for them. The BMCs were completed based on the needs of the individual partners who developed the KERs and who has IP rights. These KERs are also considered to be the main potential key exploitables that can be exploited as standalone systems rather than as parts of a detection system. However there is a plan in place for each of the KERs, for further exploitation, through collaborative research projects, peer reviewed articles or possible commercialisation pathways. This is detailed in Deliverable 9.8.

Concluding Remarks and Acknowledgements

The NAPES project has been very successful in terms of the scientific and technological outputs as summarized above. The research and innovation momentum created will continue into the future, and will have significant positive impact through the emergence of analysers with significantly improved performance compared to the current state of the art, and at a much lower cost than existing systems. This is urgently required to enable society to be much better informed about the status of the environment, through data sets automatically updated by autonomous sensors deployed in much greater numbers, tracking a wider variety of target species. The progress we have made towards our ambitious objectives has been the result of the combined efforts of the partners, which, although at times demanding, was always exciting and enjoyable. This in turn happened because of the close collaborative ethos that permeated the consortium from the start to the end, and the use of informal 'Focus Group' meetings in addition to the formal scheduled meetings, which were designed to provide focused effort from the partners in response to difficult challenges that arose from time to time. This was coupled with highly effective project management and administration, and the invaluable assistance of our project international advisors (Appendix C), whom we thank sincerely for their contributions to the project's success. We also thank our project officer, Hans Hartmann Pedersen and our project Technical Advisor, Dr. Sergey Gordeyev, for their guidance and advice throughout the project.

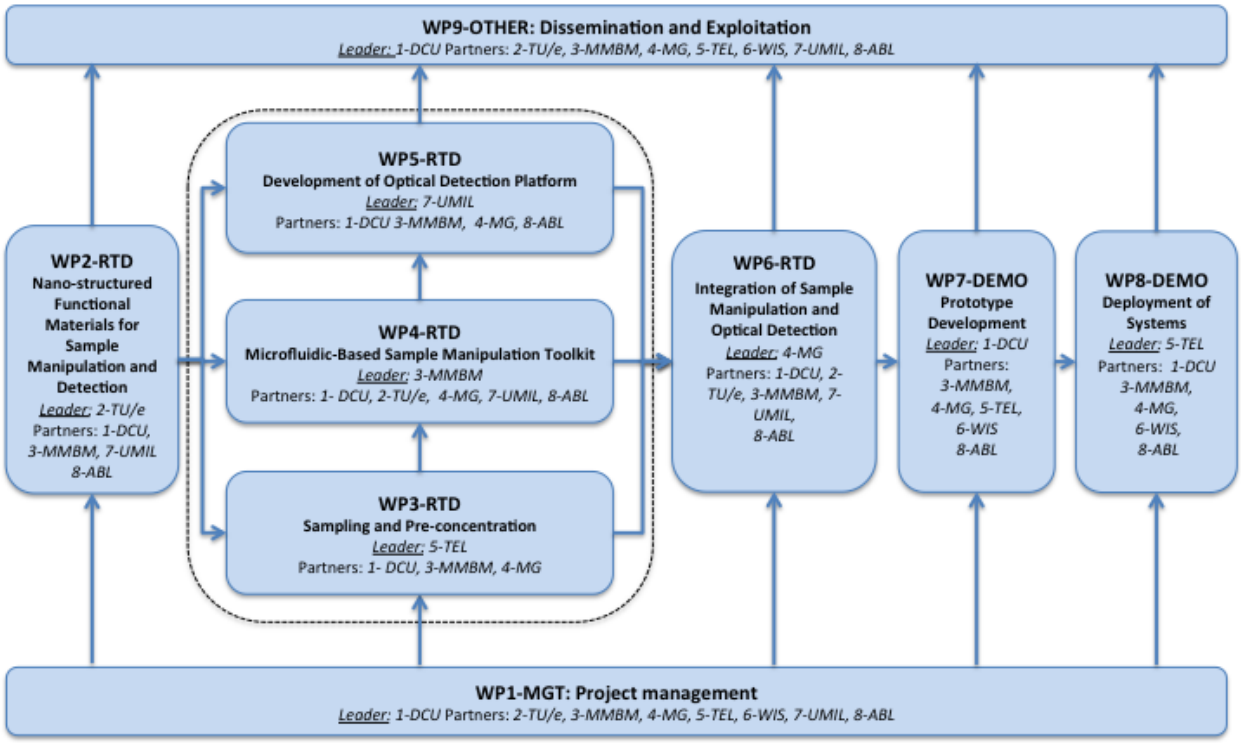
APPENDIX A

Consortium Partners and Team Members

Participant No.	Participant Legal Name	Key Personnel	Country	Organisation Type
1 (Coordinator)	National Centre for Sensor Research, DCU, Ireland (**DCU**)	Dermot Diamond Colm Delaney Peter McCluskey Margaret McCaul Angela Lally	IE	AC
2	Eindhoven University of Technology, The Netherlands (***TU/e)***	Albert Schenning Jeroen ter Schiphorst	NED	AC
3	Macromolecules and Microsystems in Biology and Medicine, Institut Curie, Paris, France (***MMBM)*** ***Third Party CNRS***	Jean Louis Viovy Stephanie Descroix Amel Bendali	FR	AC
4	CIC MicroGune Microtechnologies Cooperative Centre, Arrasate-Mondragón, Spain (***MG)*** ***PARTNER LEFT EFFECTIVE 15TH APRIL 2015***		ES	RES
5	TE Laboratories, Ireland (***TEL***)	Mark Bowkett Breda Moore Ionut Ichim Sandra Lacey	IE	SME
6	Williams Industrial Services, Northern Ireland (***WIS***) ***PARTNER LEFT EFFECTIVE 1st DECEMBER 2016***	John Toner	UK	SME
7	University of Milan, Medical Biotechnologies and Translational Medicine, Complex Fluids and Molecular Biophysics Lab, Milan, Italy (***UMIL***)	Marco Buscaglia Roberta Lanfranco Silvia Biffi	IT	AC
8	Aquila Bioscience Ltd, Galway, Ireland (***ABL***)	Lokesh Joshi Shane Deegan Nahidul Islam Marta Utratna	IE	SME
9	IK4-IKERLAN, Goiru Kalea 20500 Arrasate-Mondragón (Gipuzkoa), Spain (**IK**)	Maria Tijero Maria Aguirregabiria Kepa Mayora	ES	RI
10	University of the Basque Country**,** Paseo de la Universidad, 7, 01006, Vitoria-Gasteiz, Spain **(UPV-EHU)**	Fernando Benito Lopez Lourdes Basabe Desmonts Janire Saez Castano Luis Angel	ES	AC

APPENDIX B:

Work Package Organisation and Partners Involved



APPENDIX C

International Advisory Board Members

- **Prof. Antonio Ricco**, Stanford University, USA: Prof Ricco is one of most highly respected experts in microfluidic based instrumentation world-wide, and he is highly networked within the global micro/autonomous analytical instrumentation community, both industry and academic. He is a regular visitor to Dublin City University as an adjunct faculty staff member, and his involvement with NASA brings the added value of contacts within the remote satellite (earth monitoring) community. Ultimately, we seek to link our distributed ground-based sensing of water quality with the global spatial coverage of satellite-based sensing, and Prof. Ricco is uniquely placed to provide this experience and expertise.
- **Prof. Wilson McGarel**, Queens University Belfast (QUB), Ireland: Director of the QUESTOR Centre, a global environmental research network based at QUB. QUESTOR is the only centre outside the US to be included in the NSF's Industry/University Cooperative Research Centre Programme. QUESTOR has been in operation for 20 years and during that time has built up a strong international network of industry engagement with companies like BP, Shell Global Solutions, Chevron North Sea Ltd., ExxonMobil R&E, and Modern Water. Project partners TEL, WIS and DCU (NCSR) are members of QUESTOR.
- **Dr. Elizabeth Pollizer**, Portia Ltd., UK: Set-up the not-for-profit organisation, Portia Ltd. in 1997 – mission is to advance gender equality in science through research evidence, dialogue, and consensus between the scientists, gender experts, and policy makers. Expert advisor on gender issues to the EC and for the Horizon 2020 programme.
- **Dr. Anton Gerritsen**, DeWaterspin, The Netherlands: A private consultant with a background in environmental toxicology and water management. His mission is to get promising new technology in water monitoring implemented as effectively as possible. For this project he has focused on communication to the end-user - how to get the end- user interested.