Water Quality Sensors – Global Technology Scan

Executive Summary

Water utilities are in continuous need of **water quality monitoring solutions** to ensure integrity of drinking water quality from source to customer in real-time. Numerous emerging and fully commercialized water quality sensors and analyzers are available to collect water quality and event monitoring data. The challenge is **choosing the most reliable and cost-effective solution** for a specific application while leveraging validation efforts by other users.

Isle Utilities (Isle) is an independent technology and innovation consultancy focusing on cleantech. This project was delivered for a group of 18 globally operating water utilities. The purpose was to **carry out an extensive study of the different types of water quality sensors and analyzers** focusing on physical and chemical parameters and to **compare them in an independent and methodological way**, using Isle's proven horizon scanning methodology.

This project identified and reviewed a wide range of innovative automated sensors and water analyzers; from water footprint monitoring devices, to lab-grade analytical techniques deployed in remote monitoring devices, and to multi-parameter solutions inserted directly into the pipe. The technologies selected in this study demonstrate an innovative differentiation from others on the market.

The **first phase** of the project involved identifying all suitable water quality sensors and analyzers, deciding the parameters of interest and populating a longlist of technologies. High-level information was captured for each solution that indicated, parameters measured, applications, water types, type of installation, case studies and technology readiness level. A total of 60 technologies were identified.

The **second phase** involved capturing detailed information on 26 technologies, based on participants choices. Technology suppliers were contacted to provide additional information. Isle collected information based on a pre-defined questionnaire including criteria defined by the participating utilities such as, detection limit, measuring frequency, maintenance and calibration requirements, installation requirements, and running installations. In addition, technology suppliers were requested to provide a reference contact. When provided Isle attempted to contact and interview the indicated contact.

For more information about the project, final output or for purchasing the report, please contact Ioanna Livaniou (ioanna.livaniou@isleutilities.com).

In the next pages you can find the information coming from Libelium.

Libelium

Technology Name:	**Waspmote Smart Water platforms**
Company Name:	**Libelium**
TRL:	**9**
Country of Origin:	**Spain**
Technology Description	The Libelium IoT Smart Water platform consists of several sensors connected onto a board, the Waspmote Plug & Sense!, with a waterproof IP65 enclosure. The system is solar-powered with an external panel and its battery can recharge using a waterproof USB cable. Sensor probes are easily attached to the Waspmote Plug & Sense! board by screwing them to available sockets at the bottom of the board. This allows the user to add new sensing capabilities or replace existing ones to a board in just a few minutes. Waspmote Plug & Sense! configurations allow connecting up to six sensor probes at the same time and every customer can build the final product based on their needs. There are 3 Smart Water boards available, each integrating different water sensors. 1. Smart Water - Enables monitoring of water quality in rivers, lakes and the sea. 2. Smart Water Xtreme - Consists of sensors for applications such as potable water monitoring, fish farm management, chemical leakage detection, remote measurement of swimming pools and spas, and seawater pollution. Smart Water Xtreme was created as an evolution of Smart Water. The integrated sensors have enhanced accuracy and performance, require less recalibration and are designed for enlarged maintenance periods, making it more affordable to deploy remote Smart Water applications. 3. Smart Water Ions - Specializes in measuring ion concentrations, for drinking water quality control, agriculture water monitoring, swimming pools or wastewater treatment.
Type of installation	- Fixed - In-pipe. The Xtreme Water sensors offer the possibility to be installed directly inside a pipe. As an optional accessory for this sensor, Libelium offers a pipe mounting adapter (available in PVC and stainless steel) which can be connected to pipe segments with a protected measurement point.
Single/Multi	Multi
Parameter measured	Smart Water: - pH - Dissolved oxygen - ORP - Conductivity

	- Temperature Smart Water Xtreme: - Optical dissolved oxygen and temperature (OPTOD) - Titanium optical dissolved oxygen and temperature (OPTOD) - pH, ORP and temperature (pHEHT) - Conductivity, salinity and temperature C4E - Inductive conductivity, salinity and temperature (CTZN) - Turbidity and temperature (NTU) - Suspended solids, turbidity, sludge blanket and temperature (MES5) - COD, BOD, TOC, SAC254 and temp StacSense probe, 2 mm path - COD, BOD, TOC, SAC254 and temp StacSense probe, 50 mm path - Temperature, Humidity and Pressure - Luminosity (luxes accuracy) - Ultrasound - Manta+ 35A - Manta+ 35B - Chlorophyll - BGA - Organic matter sensor CDOM/FDOM - Ammonium - Nitrate - Chloride - Sodium - Calcium - Bromide - Total Dissolved Gas TDG - Rhodamine - Crude oil - Refined oil - Fluorescein - Optical brighteners - Tryptophan Smart Water Ions: - Ammonium (NH_4^+) - Bromide (Br^-) - Calcium (Ca^{2+}) - Chloride (Cl^-) - Cupric (Cu^{2+}) - Fluoride (F^-) - Iodide (I^-) - Lithium (Li^+) - Magnesium (Mg^{2+}) - Nitrate (NO_3^-) - Nitrite (NO_2^-) - Perchlorate (ClO_4^-) - Potassium (K^+) - Silver (Ag^+)

<table>
<tr><td></td><td>- Sodium (Na^+)</td></tr>
<tr><td>Application purpose</td><td>Source water, treatment, distribution network, leakage control, pollution control and other</td></tr>
<tr><td>Water type</td><td>Water, Wastewater, Water reuse</td></tr>
<tr><td>Measuring principle</td><td>Different measuring principle based on sensor.
Physical, electrochemical, optical, colorimetric, and more.</td></tr>
<tr><td>Weblink</td><td>http://www.libelium.com/libelium-pushes-the-water-quality-market-ahead-with-its-new-smart-water-xtreme-monitoring-platform/</td></tr>
<tr><td colspan="2">Technology Capabilities</td></tr>
<tr><td>Detection limit; measurement range; Resolution; Accuracy</td><td>Each Smart Water Board is equipped with different sensors. Libelium has an extensive documentation with all the information regarding the detection limits, accuracy and resolution of the different sensors. More can be found here with a few examples listed below.
From the Xtreme Line, the Optical Dissolved Oxygen Temperature (OPTOD) sensor probe:
<table>
<tr><th>Parameter</th><th>Range</th><th>Resolution</th><th>Accuracy</th></tr>
<tr><td>Dissolved Oxygen [mg/l]</td><td>0 - 20.0</td><td>0.01</td><td>±0.1</td></tr>
<tr><td>Temperature [°C]</td><td>0 - 50</td><td>0.01</td><td>±0.</td></tr>
</table>
Technology for DO: Optical luminescence
Frequency of recommended measure for DO: > 5 secs
Technology for Temperature: Negative Temperature Coefficient (NTC)
Frequency of recommended measure for Temperature: < 5 secs</td></tr>
<tr><td>Measurement/Sampling frequency and size</td><td>Recommended sampling frequency is once every hour.
Sampling frequency depends on the type of application, parameters to be measured and quality of the sampling water. The system has the flexibility and technical ability due to a software configuration to perform readings once per second.
Sampling size: Libelium sensors do not take samples and are deployed directly in the water.</td></tr>
</table>

Possible interferences to detection limit	The effect depends on the type of sensor. Libelium is implementing methods to isolate the targeted parameter from external interferences. The sensors are equipped with internal methods for mitigating the interference of other parameters. This can be done through the Programming Cloud Service. The software uses proprietary algorithms for correcting the values of recorded measurements, such temperature corrections for example. Optical sensors are not affected by any parameters. More information on interferences is included for each individual sensor in the technical guides provided by Libelium. For example, the optical dissolved oxygen and temperature OPTOD sensor probe has sensitivity to organic solvents, such as acetone, toluene, chloroform or methylene chloride or chlorine gas. Most of the sensors offered by Libelium come already calibrated to be immediately installed.
Unique selling point	- Libelium offers flexible and easily configurable solutions. With multiple sensors in their portfolio, the user can choose and tailor the final product based on specific needs. - Applied sensors are accurate (especially in the Smart Water Xtreme line), reliable and durable. - Programming Cloud Service allows binaries to be created for the nodes automatically using a user-friendly web interface just by filling out a web form. - Autonomous: Battery operated with a wide variety of power recharging solutions such as the use of an external solar panel or an accessory to extend the battery life. - Non-captive software/cloud system. - Possibility to integrate additional sensors, especially industrial sensors via RS-485, Modbus and CAN Bus.
OpEx	Libelium has provided the price catalog for the 50+ sensors available in their portfolio. It can be downloaded here. Libelium offers calibration kits with liquids, which can be used multiple times. One solution is between €20/US$22/AUS$34 and €60/US$67/AUS$102. Next to that, there is a connectivity fee which must be paid to the local mobile network supplier for wirelessly transferring the data as Libelium does not offer a communication channel. These are additional fees that need to be paid by the user (e.g. 4G services) and use of a cloud computing service (e.g. Microsoft Azure).
CapEx	Libelium has provided the price catalog for the 50+ sensors available in their portfolio. It can be downloaded here. As an example, a node for Smart Water Xtreme costs €686-€1,006/US$750-US$1,095/AU$1,140-AU$1,665, depending on the wireless options.

	Sensors cost €825-€4,000+/US$900-US$4,350+/AU$1,365- AU$6,620+.
Business Model	Both direct sales to final customers and direct sales to distributors (approx. 40 companies worldwide).
Maintenance requirements	It is crucial to maintain any sensor which is submerged. Naturally, it will be covered by a layer of biological dirt (biofouling caused by algae) and must be cleaned and recalibrated. The frequency of these operations depends on the type of water and the accuracy required. As a general criterion, each sensor must be maintained every 1 - 2 months. Optical sensors maintain calibration longer and require less cleaning whilst chemical sensors must be maintained more frequently.
Training requirements for operation and maintenance by operators	Libelium's devices require proper software integration. The user must create its own software or use Libelium's Programming Cloud Service, which automatically creates a database for acquired nodes by filling out an online form. Completing the form does not require software skills. Maintenance is straightforward - cleaning can be done by anyone and recalibration requires basic software skills. Libelium also offers kits on their IoT Marketplace which are delivered with the final software for the nodes and also the cloud service.
Calibration requirements and frequency	A periodic recalibration of the sensors is highly advisable in order to maintain an accurate measurement across time in order to correct changes owed to a drift output, polarization or wear. The frequency of the recalibration process will be determined by both the accuracy required in the given application and the environment in which the sensors will be operating. The more accurate measurements required, the more often it will be necessary to recalibrate the sensor. The recalibration process, which basically consists of the repetition of the calibration indicated for each sensor, will be different depending on the place where the conversion into useful units is performed. Calibration usually includes going on site and making use of the proprietary calibration liquids. Sensors must be submerged for some minutes in the controlled liquid; then the user must save the new calibration values on the node, via software.
Power requirements Battery operation	Every Plug & Sense! comes with a rechargeable Li-ion 6600 mA·h battery. The lifetime depends on many factors, mainly the frequency on which the user wants to get data.

	Recommended data transmittance frequency is 24 times per day. With this, the sensors can have node longevity around one year on pure batteries. Libelium offers accessories to recharge the battery: solar panel, 220 VAC / 5 VDC adapter. With these accessories, node lifetime is virtually infinite.
Connection requirements	Libelium provides all necessary instruments for installing the device.
Data and communication options	Libelium does not offer its own communication program, however, the sensors are compatible with many different options from which the end user can choose the one that suits them the best. Libelium is integrated with 60+ cloud partners, including market leaders like Amazon Web Services (AWS), Microsoft Azure or ThingWorx. Users can send their data to those final cloud services. Libelium has an alternative cloud called Services Cloud manager which eases the forward of data from node to the final cloud. The Bridge, a service on the cloud created by Libelium, sends information from any IoT device to the main worldwide cloud platforms simultaneously and without having to implement each specific cloud protocol or authentication process. Libelium is not integrated with any SCADA system. Communication options: XBee 802.15.4, XBee ZigBee, XBee 868LP, XBee 900HP, Wi-Fi, 4G, NB-IoT, Cat-M, Sigfox and LoRaWAN. Each radio may have sub-versions (e.g. 4G is available in 3 options - Europe/Brazil, US/Canada and Australia).
Local data storage capacity	Every Plug & Sense! comes with a 16 GB SD card. It is easy to create a program which transfers the content of the SD card via the USB port.
Ability to accommodate multiple probes in one controller	Yes, each Plug & Sense! can accommodate up to 6 different sensor probes.
Installation requirements and environmental constraints	Sensors must be installed in a way that there is no interference between them and near objects, making sure that the sensing parts are not in touch with the objects nearby. Secondly it must be ensured that the sensors are completely and constantly submerged in the liquid, otherwise the sensors may give an incorrect output. This problem may appear in locations where the volume of water is variable due to changes in flow. The best method to avoid all these problems is to select a location where a minimum level of steady water is constantly available. If the future sensor deployment location does not meet these requirements and it is not possible to find a more suitable place, it will be necessary to build a

	protection system. This system will ensure that the sensor is completely immersed and that there is no airflow disturbing the measurement. The node must be installed close to the sensors. Ambient temperature (min.): -30 °C. Ambient temperature (max.): 70 °C. No discharge line needed.
Footprint	The dimensions of the Plug & Sense! Node are: 124mm/4.9” (H) x 122mm/4.8” (L) x 85mm/3.3” (W) Sensor probes are: approx. 140mm/5.5” (H) x 25mm/0.98” (L) x 25mm/0.98” (W). They come with a long cable, usually 10m, to ease remote installation.
Geographical presence	Libelium has a global presence. Available distributors in more than 30 countries. But Libelium does not have exclusivity with any of them.
Case Studies	Libelium have various recorded case studies where their system is applied. A partner company of Libelium was commissioned to design a solution to monitor a natural gas leak near Alaska due to the area being a critical habitat for endangered beluga whales. For this specific purpose a buoy was designed and equipped with Libelium’s Plug & Sense! platform to monitor methane, oxygen and CO_2 levels above the surface of the water while, simultaneously monitoring dissolved methane, dissolved CO_2, pH and conductivity directly beneath the surface of the water. The platform collected and transmitted environmental data to a gateway on-board a near-by-ship. More case studies can be found here or a selection is available as attachments.
Attachments	1. Libelium products price catalogue 2. Smart Water Ions sensor board - Technical Guide 3. Smart Water sensor board - Technical Guide 4. Smart Water Xtreme - Technical Guide 5. Waspmote Plug and Sense - Overview 6. Case study - Gas leak, Alaska 7. Case study - Early flood detection, Argentina 8. Case study - Irrigation water, Spain 9. Case study - Drone design in the Volga River, Russia