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HORIZON 2020

**PROJECT DELIVERABLE REPORT**

NAIADES

Greening the economy in line with the sustainable development goals

# D3.3 – CATALOGUE OF WATER MONITORING SOLUTIONS AND DESIGN OF WATER MONITORING SENSOR PLATFORM

A holistic water ecosystem for digitisation of urban water sector

SC5-11-2018

Digital solutions for water: linking the physical and digital world for water solutions

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## Contents

**Abbreviations**

| | |
|---|---|
| BOD | Biochemical Oxygen Demand |
| BTX | Benzene, Toluene, Xylene |
| COD | Chemical Oxygen Demand |
| CPVC | Chlorinated polyvinyl chloride |
| DOC | Dissolved Organic Carbon |
| DPD | N,N-diethylp-phenylenediamine |
| FNU | Formazine Nephelometric Unit |
| NTU | Nephelometric Turbidity Unit |
| NOX-N | Contents of Nitrites or Nitrates |
| ORP | Oxidation-reduction potential |
| PP | Polypropylene |
| PTFE | Polytetrafluoroethylene |
| PVDF | Polyvinylidene fluoride |
| RI | Refractive index |
| SAC | Spectral absorption coefficient |
| TOC | Total Organic Carbon |
| WSDN | Water Supply and Distribution Network |

# 1 Summary

This report is split into two parts:

1) Chapter 4-5: A state of the art study which is made up by a catalogue of available solutions in the market to monitor water quality parameters in the Water Supply and Distribution Network (WSDN). Among all the possible technologies available as well as physicochemical characteristics of water that can be measured, this catalogue has taken into account two main factors to include a technology: first, the measured parameter must be included in the current EU regulation to be controlled by the European water operators. Second, the presented solution must be capable of providing the measured data in real time so that an adjacent communication interface is able to transmit them to an ICT network, such as the one of NAIADES.

2) Chapter 7-10: Prototype units designed according to End User requirements and needs-Alicante and Carouge (Use Case 1) locations- and subjected to be modified for final review. In this part will be presented the technical specification of each element built into both prototypes.

## 2 Introduction

This report is the first step to provide NAIADES end-users and services with an online monitoring station supplying distributed primary data about quality and quantity of water in the infrastructure of operators. This deliverable is then encompassed in the set of results mainly produced in **Task T3.2 – Chemical sensors**. The characteristics of this station must be aligned, therefore, have a straight dependency, with both the needs and requirements of water end-users and of the developers of NAIADES high-level services as well as with all the specifications originated at the characteristics of the NAIADES pilots and their location. This set of needs, requirements, and specifications are an outcome of **WP2 – SDGs and End-user Driven Requirements and Architecture** as summarised in **Objective 6 of the WP ("Map user requirements into system requirements and specifications")**, specified in the activities of **Task 2.4 – End-users and stakeholder requirements** ("Identify the requirements for the system architecture to be defined in T2.6. The requirement engineering process will also identify operational needs imposed by end-users & IT network providers. Also T2.4 will analyse both the capacities and needs of the organisations regarding smart water services and applications. This task will run in an iterative manner (first M18 and second M30). The first version will include the detailed requirements and definition of sub use cases, **guiding the research work to be conducted in WP3-WP5**"), in **Task 2.5 – Reference Scenarios and Pilot Operations Specifications and KPIs**., and **Task 2.6 – Architecture and Detailed Technical Specifications.** This links directly with the definition of the early stage of T3.2, which says that "The task will start with an **evaluation of end-user requirements in terms of different parameter monitoring and the realisation of a sensor catalogue with the different state-of-the-art options**. A careful identification of the most suitable options for the realisation of the pilot will be realised".

Due to restructuring of the project planning, the end-user requirements are not available at the time of delivering this report. Thus, the content of this deliverable exposes a catalogue of the available technological solutions in the market to monitor real-time the parameters of water quality indicated in the current EU regulation. The report is organised by showing a set of available solutions for every one of these parameters. A specific focus is put on technologies that can provide online data so that these can be injected at (near-) real time into the NAIADES system.

## 3 EU regulation overview

Scientific knowledge about the fate and effects of water pollutants has evolved considerably in recent years. More is now known about which compartment of the aquatic environment (water, sediment, or biota, hereinafter referred to as the 'matrix') in which a substance is likely to be found, and therefore its concentration is most likely to be measurable. Some highly hydrophobic substances accumulate in biota and are hardly detectable in water, even using the most advanced analytical techniques. For those substances, environmental quality standards of the biota must be established. However, to take advantage of their monitoring strategy and adapt it to their local circumstances, Member States should have the flexibility to apply an environmental quality standards for another matrix or, where appropriate, other biota taxa.

The Directive 2000/60 / EC of the European Parliament and of the Council of 23 October 2000, establishing a Community framework for action in the field of water policy, lays down a strategy to combat the Water contamination. This strategy involves the identification of priority substances among those that pose a significant risk in the Union for or through the aquatic environment. Decision No 2455/2001 / EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy establishes the first list of substances or groups of substances that are a priority.

The Directive 2008/105 / EC of the European Parliament and of the Council of December 16, 2008, on environmental quality standards in the field of water policy, establishes environmental quality standards of Compliance with Directive 2000/60 / EC, for the 33 priority such substances identified in Decision Nº 2455/2001 / EC and 8 other pollutants that were already regulated in the Union.

Member States shall monitor each substance on the list at selected representative monitoring stations, for at least a twelve-month period. For the first list, the follow-up period will start no later than September 14, 2015 or within six months of the compilation of the list, if it occurs at a later date. For each substance included in subsequent lists, Member States will start monitoring within six months of their inclusion in the list. Each Member State will select at least one monitoring station, plus another if it has more than 1,000,000 inhabitants, plus the number of stations equal to its geographical area in km 2 divided by 60,000 (rounded to the nearest integer), plus the number of stations equal to their population divided by 5,000,000 (rounded to the nearest integer). When selecting representative monitoring stations, frequency and monitoring schedule for each substance, Member States shall take into account the modalities of use of the substance and its possible presence. The frequency of monitoring will not be less than once a year

# 4 Preliminary specifications of NAIADES monitoring station

NAIADES will produce a suite of modular monitoring stations to control relevant parameters related to water quality and quantity online in real or near-real time. These stations will provide solutions to the utilities and, in particular, to NAIADES to collect those data type from WSDN or sewage or will complement the existing solutions in the utility infrastructure. These stations will aim at an effortless integration and networking of the required sensors into the infrastructure of the utility, implementing only those that are demanded by the user requirements.

The stations will consist of an end-user requirement-based electromechanical structure with embedded middleware for collection, pre-processing and transmission of data that will permit to maintain a complete interoperability with the NAIADES framework and with the infrastructure network.

The stations will be designed so that a wide range of available water quality and quantity monitoring sensors can be embedded in a plug-n-play manner, choosing those that are specifically requested to cover the utility needs at every situation. NAIADES monitoring stations will ease the number of steps required to achieve a high degree of interoperability on the way to further standardisation of technologies in the water sector.

The set of needs, end-user requirements, specifications and scenarios of NAIADES are being realised in WP2. Once this set of conditions is produced, WP3 will be able to carry out the specific designs of the stations and start with their manufacturing. Until that point in time, we present here a catalogue of sensing solutions for monitoring online water quality parameters that are required according to EU regulation. We aim at utilising these catalogued solutions to provide the sensing capabilities to our stations.

# 5 Existing sensing technologies to suit NAIADES needs

The European Drinking Water Directive 98/83/CE establishes a series of parameters that are subject of periodic control by the EU water operators to maintain the quality of water for human consumption via the WSDN. On the other hand, NAIADES aims at promoting innovative water management solutions to improve related services based on the collected and processed real-time data from heterogeneous sources. Our monitoring station for water quality and quantity parameters will be one of these sources. Therefore, NAIADES will have to rely on sensing technologies of those water parameters that are able to inject those data in real time in the overall system.

In the following, we detail the identified market solutions that are capable of providing real-time data of those water quality parameters included in the above-mentioned EU regulation. We will aim at choosing the quality sensing parts of the NAIADES monitoring stations to be designed and integrated among those available solutions.

## 5.1 Chlorine

Chlorine is a powerful oxidising agent used widely in water-supply systems for disinfection. Chlorine responds to a large number of contaminants and reacts with many of the organic compounds and some of the inorganic compounds in water. These chemical reactions consume active chlorine from the water ('chlorine demand'), causing a drop in the measured value proportionate to the concentration of the chemicals that have been oxidised.

### 5.1.1 Global Water's CL500

Continuous online chlorine analyzers instruments for free or total chlorine residual measurement. The online residual chlorine monitors use colorimetric DPD (N,N-diethylp-phenylenediamine) chemistry, proven method for measuring free or total residual chlorine. With no mixing or pump components to wear out, the online chlorine analyzers provide reliable operations with minimal maintenance.

- Colorimetric DPD chemistry
- Low maintenance design
- Range of 0 - 10 ppm

### 5.1.2 Chlori::lyser


Chlori::lyser monitors free or total chlorine - mounted in a flow cell setup. Due to the membrane-covered amperometric measuring principle, flow and pH fluctuations of the water do not influence the measurement result. Additionally, the integrated temperature compensation and the special, third electrode eliminates potential interferences. Readings stable even at high fluctuations of pH, temperature and flow Low cross sensitivity to many surfactants. Ideal for drinking water.

### 5.1.3 Memosens CCS51D

It is an Endress+Hauser closed amperometric 2-electrode measuring cell with a PVDF membrane. The measuring method is an amperometric measurement of dissolved free chlorine by means of the reduction of free chlorine at the cathode. Ensuring reliable disinfection in drinking water. From trace measurement up to free chlorine concentrations of 200 mg/l.

### 5.1.4 OPTISENS CL 1100

The OPTISENS CL 1100 sensor is characterised by standardised design, easy handling and a long life cycle. In combination with the MAC 100 signal converter Designed as a membrane free sensor with gold electrodes, the sensor can be easily adapted to various application requirements and it is extremely service friendly and durable. It provides a combination of a membrane-free sensor with 2 gold electrodes for long-term stability and easy maintenance. It is suitable for measuring free chlorine, chlorine dioxide or ozone.

## 5.2 Fluoride

Ion selective probe that can be used for the online measurement of fluoride. It is used for continuous monitoring and online process control by water utilities that fluoridate their drinking water.

### 5.2.1 9655 Fluoride Ion Selective Electrode (ISE)


Ion-selective indicator electrode for Fluoride measurements. The solid-state sensor design allows for dry storage of the ISE without a shelf life or membrane replacement.

- Sensor type : Solid-state crystal membrane
- Range 0.02-20,000 mg/L F-, 5-50 °C.

## 5.3 Nitrate

The presence of nitrates comes from the dissolution of rocks and minerals, from the decomposition of plant and animal materials and industrial effluents. This must be taken into account, as it becomes a limiting factor for growth in water systems if there is an abundance of phosphorus, promoting undesirable phenomena such as eutrophication.

Nitrate is hardly ever measured these days with cabinet analysers since these also create disadvantages (hydraulic sampling, reagent consumption, maintenance effort etc.) and, in any case, recognized alternative methods exist.

Optical probes have been successful and have found acceptance globally, so today there is generally no longer any real reason to use a cabinet analyser for monitoring of nitrate.

### 5.3.1 CAS51D - Endress+Hauser

Optical photometric sensor for nitrate, CAS51D measures nitrate in drinking water, process water and wastewater applications as well as the utilities sector:

- Organic load or nitrate in inlet and outlet
- Determination of CODeq or TOCeq
- Monitoring, control and optimization of treatment processes
- Nitrate monitoring in the aeration basin and denitrification stage.

## 5.4 Ammonium

Due to human activities (primarily agriculture, industry and insufficient waste water treatment) many natural waters suffer from a surplus of nutrients which severely impairs water quality and ecology. Ammonium can be measured continuously and accurately down to the low concentrations encountered in natural waters.

When drinking water is disinfected with chloramines, formed In-Situ by reaction of chlorine with ammonium, a continuous ammonium measurement is critical for efficient control of the disinfection process

### 5.4.1 Digital ammonium and nitrate sensor CAS40D

CAS40D measures ammonium, nitrate and pH. It is an ion-selective electrode system for the continuous measurement of ammonium and nitrate. Ion-selective electrode for compensating cross-interference and a temperature sensor.

- Determination of ammonium and nitrate concentration
- Control and regulation of ammonium decomposition

### 5.4.2 Ammo::lyser from Scan:

A multi-parameter probe for the online measurement of ammonium.

- measuring principle: ISE (ionselective electrodes) - with optional potassium compensation
- multiparameter probe
- long term stable, factory precalibrated
- automatic cleaning with compressed air
- non-porous / non-leaking reference electrode for consistent performance
- automatical temperature compensation, pH compensation possible

## 5.5 Turbidity

Turbidity is a measure of cloudiness of the water and is caused by suspended particles (matter or microorganisms). Pathogens are more likely to be present in highly turbid waters.

Turbidity sensors measure suspended solids in water, typically by measuring the amount of light transmitted through the water. Turbidity may be useful in understanding observed changes in other parameters.

An increase in the concentration of suspended contaminants in the water will cause an increase in water turbidity. The above increase, or the crossing of a maximum threshold value, is a reliable indicator that the water quality has changed and an alert should be raised.

The measuring unit for the turbidity is Nephelometric Turbidity Unit (NTU) or Formazine Nephelometric Unit (FNU).

### 5.5.1 SuSix

The SuSix sensors' 6 optical windows (six-channel optics with pulsed, infrared light with modified absorption) and measuring system delivers measurements from turbidity in clean drinking water to suspended solids in heavy sludge, all from only one sensor model. The SuSix has special directionally polished optics that controls and steers the infrared beams in selected patterns for measurement of turbidity and suspended solids.

The ranges covered in turbidity are 0,001 to 9999 FNU / NTU / FTU and suspended solids in the range from 0,001g/l to 400 g/l.

- Easy calibration
- Strong correlation with laboratory results
- High stability
- Universal sensor

### 5.5.2 OPTISENS TUR 2000

Krohne optical turbidity sensor for water and wastewater applications. The turbidity sensor is available as insertion version for flow cell installation in water treatment plants and as immersion version for installation in open basins and channels. According to ISO 7027, turbidity values below 40 NTU / FNU have to be measured with the 90° scattered light method. The light source and receiver are positioned in a 90° angle to each other. The metre now compares the light from the reference receiver and scattered light receiver and calculates the turbidity value. The cleaning of the sensing element is performed by the injection of pressurised clean air, provided by the user. This submersible turbidity sensor provides a 4...20 mA current loop or a RS485 output.

### 5.5.3 CUE21

CUE21 is an Endress+Hauser online turbidity metre for water quality monitoring in water works and distribution networks, a compact device for bypass-installations. Turbidity measurement using standardised 90° scattered light method acc. to ISO 7027/EN27027(Infrared Light). It has an Automatic ultrasonic cleaning function reduces maintenance effort. Digital high-speed connections through RS-485 with Modbus. Range from 0 - 1000 NTU.

## 5.6 pH

The pH value is a measure of the activity of hydrogen ions in water; therefore, it is a measure of the degree of acidity or alkalinity of the water. Most chemical and biochemical processes are pH dependent.

The measuring principle of a pH sensor is based on a pH sensitive glass (membrane glass). When the pH sensitive glass gets into contact with a liquid, a thin layer of hydrated gel develops on the surface, enabling an ion exchange between the glass surface and the liquid. The so-called Nernst potential builds up on the glass surface. If both sides of the glass are in contact with liquids, a voltage may be detected between the two surface potentials. The voltage correlates to the difference in H+ ion concentration and thus to the difference of pH values in both liquids.

A change of more than 0.5 pH units indicates a problem. Changes in pH-level readings of the sensor above or below determined threshold values can be used as an input signal for alert determination.

### 5.6.1 pHix Compact Transmitter

The pHix Compact is a pH and Redox transmitter, (all-in-one electrode) designed for easy installation and maintenance with electrode, transmitter, and mounting in one unit. Automatic buffer sequence started via switchable handle or through tilt switch.

### 5.6.2 SMARTPAT 1590 pH sensor

Potentiometric pH sensor for potable, process or treated water applications. The sensor is equipped with a large ceramic diaphragm, glass sensor and Pt1000 for temperature compensation and is available with CPVC body material. 2-wire loop powered sensor with integrated transmitter technology Smartpat analytical sensor sends these as bidirectional digital signals with 4...20 mA / HART 7 protocol to the control and asset management systems, handhelds, PC and other peripherals.

### 5.6.3 pH::lyser


pH::lyser is a multi-parameter probe that measures the pH value and temperature directly in the water. The pH::lyser uses the temperature to correct the result of the pH measurement online. The non-porous, solid-state reference electrode ensures excellent pH readings and a long lifetime of the electrode.

### 5.7 Conductivity

Dissolved mineral substances in the water are directly related to the total ionic concentration and electrical charge of the dissolved matter, and can be measured as conductivity. A high volume of contaminants is needed to change the sensor readings significantly.

The conductivity parameter is an indicator for several contaminant classes such as inorganic compounds, metals and radionuclides. Many organic materials do not exhibit a net electrical charge and hence are not detectable through changes in bulk conductivity.

Electrical conductivity changes above or below determined threshold values may be used to raise an alert signal.

#### 5.7.1 SMARTPAT conductive conductivity sensor

Smartpat is a digital conductive conductivity sensor for the water and wastewater industry, with 2-wire loop powered sensor with integrated transmitter technology and integrated temperature sensor. Measuring range 100 µS/cm...20 mS/cm (c=1) at 25°C.

Conductive probes feature two electrodes that are positioned opposite from each other. An alternating voltage is applied to the electrodes which generates a current in the medium. To measure low conductivities in pure water.

#### 5.7.2 Condu::lyser


Conductivity measurement with conductive 4-electrode sensors

4-electrode sensors have two electrodes that are currentless and therefore not affected by the polarisation effect (due to a high ion concentration. They measure the potential difference in the medium. A connected transmitter uses the measured potential difference and current to calculate the conductivity value. 4-electrode sensors are used where a wide measuring range is required.

The condu::lyser does not require a minimum flow to produce accurate readings and uses the temperature to correct the conductivity measurement online. The 4-electrode measurement of the electrical conductivity produces results that are practically independent of possible fouling.

### 5.7.3 OPTISENS IND 1000

Toroidal sensors are used in media with high conductivity. Toroidal probes contain a transmission and a reception coil and measure conductivity in several steps.

OPTISENS IND 1000 is a fully enclosed inductive conductivity sensor for use in heavily contaminated, aggressive media such as municipal wastewater. It features an extremely rugged design using corrosion-resistant and dirt-repellent materials like PP or PVDF. The measuring cell with two inner ring-shaped measuring coils is completely enclosed and is thus not in contact with the media.

## 5.8 Oxidation-reduction potential

The oxidation-reduction potential (ORP) is the tendency of the water to oxidise or reduce another chemical substance. ORP sensors measure the ORP of the water. Used in tandem with a pH sensor, the ORP measurement provides an insight into the level of oxidation/reduction reactions occurring in the water.

Some chemical contaminants can affect and change the redox-potential readings produced by the sensor.

Significant changes in the readings above or below determined threshold values may be used to raise an alert signal.

### 5.8.1 Orbisint CPS12D

Endress+Hauser sensor ORP / Redox. The measuring principle is a gel compact electrode with teflon diaphragm and double gel reference, and measuring part as gold-pin or plating ring. Is a robust electrode with long poison diffusion path, requires low maintenance due to large, dirt-repellent PTFE ring diaphragm.

### 5.8.2 OPTISENS ORP 8590 T

The OPTISENS ORP 8590 sensor is a potentiometric ORP sensor for water and wastewater applications manufactured using a very pure platinum electrode, which can be used in almost all standard water and wastewater applications due to its robust sensor design.

### 5.8.3 1.1.3 Online Process ORP Sensor RD1R6

This sensor uses three electrodes instead of the two normally used in conventional ORP sensors. Process and reference electrodes measure the ORP differentially with respect to a third ground electrode. The end result is unsurpassed measurement accuracy, reduced reference junction potential, and elimination of sensor ground loops. These sensors provide greater reliability, resulting in less downtime and maintenance.

- Cable connection: Analog.
- Electrode type: Specialty – Gold.
- Measuring range: -1500 - +1500 mV
- Operating temperature range: -5 - 110 °C.
- Pressure range: 0 - 6.9 bar (100 psi)

## 5.9 Particle counter

These sensors count the number and size distribution of suspended particles in water. As particles in a water stream pass through a measurement cell they break a laser beam inside the particle counter. A detector opposite the laser beam measures this break, the number of breaks is equal to the number of particles and the size of signal (created as the particle passes through the beam) is proportional to the size of the particle.

An increase in the readings of particle-count values in comparison to a specific water pattern background may raise an alert.

The particle size ranges may be related to biological organisms. Particle-count measurements may be related to turbidity measurements.

### 5.9.1 Chemtrac PC3400 online particle counter


Provides particle size and quantity information and detects particulate down to low ppt levels. User friendly calibration routine makes calibrations fast, simple, and lowers maintenance cost because units don't need to go back to factory for routine calibration. Detection 2-900 microns, Sizing 2-100 microns. MODBUS RTU communication.

### 5.9.2 Pi particle Counter


The Particle Counter range from Pi allows multiple sensors on a single analyser. The CounterSense is a sophisticated online particle counter with the capability to size and count particles from 2-127 microns and to count from 2-750 microns. The FilterSense has the capability to size and count particles from 2-127 microns, and the ParticleSense is a standalone counter with the capability of counting and sizing particles from 2-125 microns.

### 5.9.3 Hach ARTI Particle Counter


This particle counter is an accurate particle counter with up to 1 μm sensitivity. The ARTI's external mounted sensor is easily cleaned and separated from the instruments electronics providing lifetime peace of mind. Measurement data is available on the instrument's LCD display or remotely via an RS485/4-20mA output. The ARTI can be used as a stand-alone instrument or in combination with turbidimeters for the ultimate filtration optimization.

## 5.10 Ultraviolet-visible spectroscopy

Spectrophotometry is a well-established analytical method, which has been used for decades in chemistry, physics, biochemistry, and chemical engineering for quantitative analyses. A light source and sensor are used to measure the intensity of light passing through a water sample in a known path length cell. Most commonly, ultraviolet and visible (UV-VIS) light sources are used. The principle is that substances in the water sample absorb or transmit light over a given wavelength range.

According to Beer's Law the measured absorbance of substances in the water sample is directly proportional to their concentration.

Ultraviolet-visible spectroscopy optical spectrometer probes allow the monitoring of many different parameters such as nitrates, total organic carbon, colour, turbidity, temperature, etc. in one single measuring device. Another major advantage of using real-time spectrophotometers for water and wastewater applications is the simplicity of the method. The measurement process does not require sample preparation, nor does it require reagents or changing the sample composition in any way. For this reason, operation is very straight forward and maintaining the instrument is both easy and low cost. Spectrophotometric sensors offer new opportunities for process control applications.

The ultraviolet (UV) 254 nanometre wavelength (UV254) absorption sensor can measure organic compounds that absorb photons at 254 nm. It is indicative of organic compounds with an aromatic chemical structure and conjugation. However, monitoring of the UV spectrum provides much more information from organic compounds. Monitoring of the UV spectrum, as recommended by EPA, even makes it possible to detect deviations from 'typical' water quality by detecting unusual peaks of absorbance in the UV spectrum.

### 5.10.1 Spectro::lyser


Spectro::lyser UV-VIS monitors depending on the application an individual selection of: TSS (est), turbidity (est) NO3-N, , BOD, TOC, UV254, NO2-N, BTX, fingerprints and spectral alarms, temperature and pressure. two different fractions of the organics can be distinguished (TOC, DOC) and simultaneously the levels of turbidity, nitrate and colour can be determined in a single measurement.

The measuring principle is UV-Vis spectrometry over the total range (190-750 nm or 190-390 nm). The multiparameter probe has adjustable open path length. It features automatic cleaning with compressed air or brush. Mounting and measurement is carried out directly in the media (InSitu) or in a flow cell (monitoring station).

### 5.10.2 Nitratax

Nitratax includes digital, optical probes for the high precision determination of nitrate concentration directly in the medium. Featuring a high degree of accuracy due to direct UV measurement, without cross sensitivities, Nitratax Nitrate Sensors are ideally suited to statutory limit value monitoring. The low maintenance, reagent-free optical probes offer a broad application spectrum, thanks to turbidity compensation and self-cleaning even for sludge applications. It can be connected to all SC controllers, providing versatile output options including 4-20 mA Output, Modbus RS485. 0.1 - 25 mg/L NO2+3-N, 0 - 100 mg/L NO3. Nitratax sc Sensors can be connected to all SC controllers, providing versatile output options including 4-20 mA Output, Modbus RS485, Profibus, or Hart.

#### 5.10.3 CAS51D

CAS51D measures nitrate or SAC in drinking water, process water and wastewater applications as well as the utilities sector: organic load or nitrate in inlet and outlet, determination of CODeq or TOCeq. UV Optical photometric sensor for nitrate and SAC (spectral absorption coefficient, it is used to determine the sum of the dissolved organic water content substances)

To quantify the concentration of organic substances in drinking water and natural waters usually sum parameters such as TOC, DOC or SAC are used. These sum parameters can be used because the total organics is composed of a multitude of substances. (See sensors above).

### 5.11 Total organic carbon

Total organic carbon (TOC) reflects the amount of organic carbon-containing compounds. TOC sensors are successful in detecting many hazardous organic chemicals and biological contaminants such as petroleum products, pesticides, chemical warfare agents, pathogens, bacterial toxins, plant toxins and persistent chlorinated organic compounds. TOC may be correlated to chemical and biological oxygen demand.

A rise in the TOC values in the water above a threshold value can be used as an input signal for alert determination.

#### 5.11.1 Carbo::lyser III

Carbo::lyser III is a Scan that monitors turbidity & TOC & DOC, with measuring principle: UV-Vis spectrometry over the total range (190-720 nm) long term stable and maintenance free in operation range (190-720 nm). s::can spectrometer probes record the complete absorbance spectrum between 190 and 720 nm (UV-Vis) or 190 - 390 nm (UV) resolving it into 256 wavelengths - the result is the "Fingerprint" (absorbance spectrum). Using the information contained in the fingerprint it is possible to monitor multiple parameters simultaneously and at the same time compensate these parameters for possible cross-sensitivities. The correlation with laboratory results reaches a quality that was unknown from the previously used simple optical instruments.

### 5.11.2 B3500s TOC Analyser

Semi-annual reagent replacement and seamless integration with a sample homogenisation unit, make the B3500s a good solution for regulatory TOC monitoring in municipal wastewater. Designed to communicate with the sample homogeniser, the system provides an off-the-shelf solution to meet TOC effluent monitoring regulations

## 5.12 Dissolved oxygen

A concentration of oxygen dissolved in water can serve as an indicator of chemical and biochemical activity in water.

### 5.12.1 Oxix Dissolved Oxygen Transmitter

The Oxix (from MJK) optical sensor does not deplete oxygen. The sensor contains a light source with a specific wavelength that shines on the back of a membrane containing a special compound immobilised in a gel matrix (optical fluorescence measurement). When the light hits the gel, a fluorescence process is initiated and the sensor detects the fluorescence which is proportional to the amount of dissolved oxygen. The resulting signal is sent to the converter for processing and calculation of a proportional, analogue 4-20 mA output signal. The Oxix sensor has no membrane to change, contains no chemicals to foul, and requires little or no calibration.

### 5.12.2 Oxi::lyser


Is an optical multi-parameter probe that measures the concentration of dissolved oxygen and the temperature directly in the water. The oxi::lyser does not need a minimum flow to produce accurate readings and integrates the temperature measurement for On-Line correction. The sensing element, which uses the principle of fluorescence for the oxygen measurement, is neither affected nor damaged by direct exposure to sunlight. To be sure that fouling is kept to a minimum, the oxi::lyser can be cleaned automatically with compressed air. pH ranges from 2 to 10.

### 5.12.3 OPTISENS ADO 2000


OPTISENS ADO 2000 is a dissolved oxygen sensor with integrated temperature compensation. The amperometric sensor is used in wastewater treatment plants to monitor and control the oxygen concentration during biological treatment of wastewater. Its stainless steel housing makes the sensor also ideally suited for use in harsh environments as well as for oxygen monitoring in ground water basins.

## 5.13 Temperature

The measurement of water temperature is especially relevant since a number of biological and chemical activities are heavily influenced by this generic parameter. Dissolved oxygen and specific conductance change with temperature. For that reason, temperature sensors are commonly found as part of sensors of temperature-dependent parameters (see prior sections).

## 5.14 Microbiological parameters

The availability of the microbiological online or in-line sensors is limited.

There are several bacteriological sensors for E. coli, coliforms, and total bacterial count. As the required detection time can be longer than for other parameters, the suitability of its measure can be indicated more for the control of the processes.

### 5.14.1 Proteus Water Quality Sensor

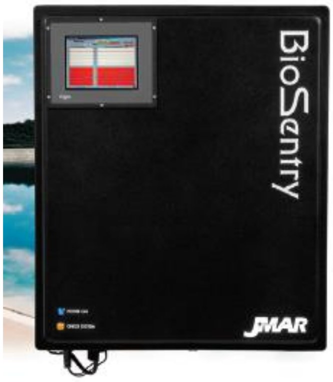

The Proteus instrument is a multisensor solution that will allow biological agent detection and classification. The proposed technologies are all based on the detection and measurement of fluorescence of the living agents. Fluorescence-based detection uses natural fluorophores contained in biological agents, like amino acids (e.g. tryptophan), nicotine amides (NADH), and flavins (e.g. riboflavin (RBF) and flavoproteins), as characteristic tracers of their biological nature. The technology used in the Proteus will allow a continuous on-line, real-time monitoring for microorganism in water.

The sensor is able to detect parasitic oocysts, vegetative bacteria and algae within minutes of entering water supply. The data output is shown in counts/minute for each category, and can be converted to organisms/ml allowing comparison with standard microbial assays such as colony forming units/ml or spores/ml.

### 5.14.2 Colifast ALARM


Colifast Alarm sensing device will measure the enzymatic activity of living agents. It will allow classifying and quantifying total coliforms, thermotolerant coliforms or E. coli able to analyse the collected samples when an alarm is triggered. The detection of down to 1 viable target bacterium is based on bacterial growth, group specific enzyme activity and measured concentrations of a fluorescent product (ppbMU). An increase in the number of target bacteria means an increase in the amount of β-D-glucuronidase (E.coli enzyme).The enzyme hydrolyse the growth medium substrate that releases MU (the fluorescent product) which yields a higher fluorescence signal on the sensor. The Colifast growth media contains inhibitors to prevent growth of non-coliforms. 100 ml water samples are automatically collected at programmed intervals and analysed for total coliforms, thermotolerant coliforms or E.coli. In addition, the sensor measures the turbidity level of the water.

### 5.14.3 BioSentry




It is a laser-based technology to provide continuous, on line, real-time monitoring for microorganisms in water systems. BioSentry provides both detection and classification of waterborne microorganisms, without the need for consumables or reagents. It utilizes laser-produced, multi-angle light scattering (MALS) technology to generate unique microorganism biooptical signatures for classification using JMAR's pathogen detection library. BioSentry can immediately detect the presence of microorganisms, then classifies them within minutes, helping to ensure the continuing safety and quality of the water supply.

Surveillance Volume Up to 3 liters per hour.
Data Communication: Encrypted Internet connection
• Ethernet - standard RJ45
• Modems for dial-up access
SCADA 4-20 mA

### 5.14.4 Enviro-T2

In-line fluorometer to continuously monitor levels of algae or cyanobacteria.

Enviro-T2™ is an accurate, single-channel fluorometer that easily installs in-line and integrates with data collection systems. When configured with a Blue Excitation LED, Enviro-T2 detects fluorescence from all algal groups; when configured with a Red Excitation LED, it has maximized sensitivity for better detection of Cyanobacteria. Simply connect the analog output cable to a SCADA system, data logger or any control cabinet that accepts a 4-20 mA output.

MDL for Chlorophyll 0.03 µg/L
Dynamic Range for Chlorophyll 0-100 µg/L
Input Voltage 8 – 30 VDC
Signal Output 4 – 20 mA
Light Source Light Emitting Diode
Detector Photodiode

### 5.14.5 BioSentry

BioSentry is designed to monitor water with normal background particle counts of less than 1,000 particles per mL. It detects parasitic oocysts, vegetative bacteria and algae within minutes of entering water supply. Fully automated and remotely accessible, the BioSentry system offers low

maintenance and low cost of ownership.

## 5.15 Refractive index (RI)

The refractive index (RI) is based on the property that describes how light propagates through water. A known matrix of dissolved compounds has a specific RI; when different compounds are dissolved in this matrix, the RI can change.

### 5.15.1 EventLab 2.0

EventLab 2.0 builds upon Optiqua's established optical lab-on-a-chip technology to detect the whole range of chemical contaminations with a single refractive index sensor. Optiqua's optical chip is a highly sensitive sensor for refractive index (RI) changes. RI is a useful generic indicator of water quality as any substance, when dissolved in water, will change the refractive index of the water matrix in proportion to its own RI as well as its concentration. The generic Optiqua sensor chip operates at a sensitivity level equivalent to parts per million (ppm) levels for any chemical contaminant.

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## 5.16 Flow rate

### 5.16.1 Krohne Waterflux 3070


Electromagnetic water meter for district metering of potable water and custody transfer (CT) measurement

Integrated temperature and pressure measurement for leak monitoring.

3070 is a battery powered electromagnetic water meter for use in water abstraction wells, district metering areas (DMA) and custody transfer measurement of potable water (MI-001, OIML R49). With optional pressure and temperature sensors, the meter can also be used for leak detection, quality control and pressure management systems.

### 5.16.2 iMAG 4700 Electromagnetic Flow Meters


Flanged electromagnetic flow meters for full-pipe municipal or industrial water and wastewater applications.

- No moving parts for low maintenance & long life
- Minimal straight pipe required
- Water resistant enclosure (IP68 rated)
- Pulse output for loggers, PLC's, or telemetry

## 5.17 Water level

### 5.17.1 KROHNE OPTISOUND 3010

Ultrasonic level transmitters are used for continuous measurement of liquids and bulk goods in nearly all sectors of industry. The OPTISOUND 3010 is a 2- or 4-wire ultrasonic level transmitter for basic applications up to 5 m / 16.4 ft. It is designed for continuous measurement of liquids such as rainwater and wastewater as well as bulk solids in nearly all sectors of industry. The level transmitter is particularly suitable for use in small tanks or in open channels for flow measurement.

• Ultrasonic level transmitter for simple water applications
• Continuous, non-contact measurement up to max. 5 m level
• Analogue outputs 4…20 mA

### 5.17.2 VEGAPULS C 21 – Vega


MEGAPULS C 21 is a sensor for non-contact level measurement in simple applications where a high degree of protection is required. It is particularly suitable for use in water treatment, pumping stations and rain overflow basins, for flow measurement in open channels and level monitoring.

Axial cable outlet, measuring range up to 15 m, accuracy ±2 mm, 4 ... 20 mA, HART, SDI-12 or Modbus output,

### 5.17.3 Global Water Shuttle Ultrasonic Level Transmitter

The Shuttle Ultrasonic Level Transmitter measures the distance to a liquid and is used primarily to measure the level in tanks, pump wells, sludge tanks, storm flow weirs, channels, etc. The transmitter is not in physical contact with the liquid measured.

Shuttle sends a strong, narrow ultrasonic pulse to achieve stable and reliable measurements even from turbulent and polluted surfaces.

The transmitter is simple and logical to operate. The instrument is intelligent; it recognises and eliminates signal impacts from its surroundings, e.g. piping and flanges inside a well.

Shuttle needs no operation after initial set-up. The instrument has an automatic start function. The sensors cover measurement ranges from 0-10 cm up to 0-25 m.

Single cable design with lengths up to 100 meters

• 4 port cables feature user-replaceable sensors; universal ports can accept any 4 sensors; optional depth sensor available (with depth and no depth)
• Long-life rechargeable lithium-ion battery to power handheld and sensors
• Color display and backlit keypad; menu-driven operation
• Digital smart sensors are automatically recognized by the instrument and store calibration data
• Rugged, waterproof case (IP-67 rated) with rubber over-mold and metal, military-spec (MS) cable connectors as well as rugged titanium sensors

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## 5.18 Radioactivity

The measurement of radioactivity in water supply and distribution networks is of interests in specific regions. All waters present a level of radioactivity that is, in any case, comparable in order to the background radiation that is measured in the environment due to cosmic rays or terrestrial sources. Depending on the radiochemical composition of the earth in contact with natural water sources or to potential presence of accidental radioisotope remains, the radioactivity of water may vary. The EU regulation obliges to control the levels of dose as well as concentration of tritium and radon. The following equipment is able to provide information about the water radioactive, providing the data in real time to the central system.

### 5.18.1 AT1117M Radiation Monitor

This configuration of the Atomtex radiation monitor is a gamma radiation detection unit in sealed container. This is an immersion-type measurement instrument designed to measure gamma radiation ambient dose equivalent and ambient dose equivalent rate in fluid media, wells, underground storage and other inaccessible areas. It also simultaneously monitors gamma radiation ambient dose equivalent rate and ambient dose equivalent at system operator location.

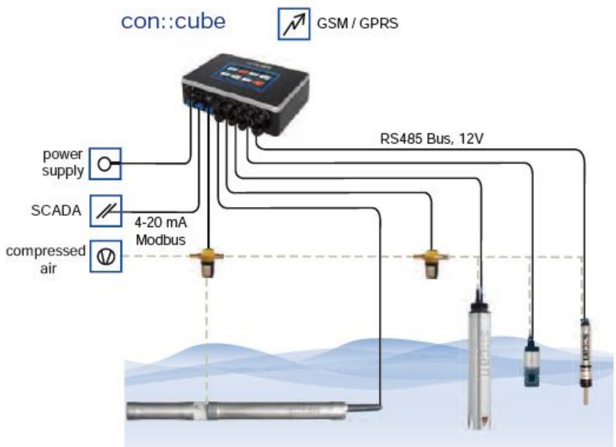
### 5.18.2 GAMON Diver

**GAMON Diver** is a CAEN compact underwater radionuclide identification system specifically designed for submerged radiometric measurement and radiological alerts. It can be used as a quick response measurement device, or it can be installed as a permanent monitoring device for sensitive underwater locations. GAMON Diver has a submersible hermetic case and its weight allow an easy gamma spectroscopic measurement in real time.

## 5.19 Control interfaces

### 5.19.1 Con::cube

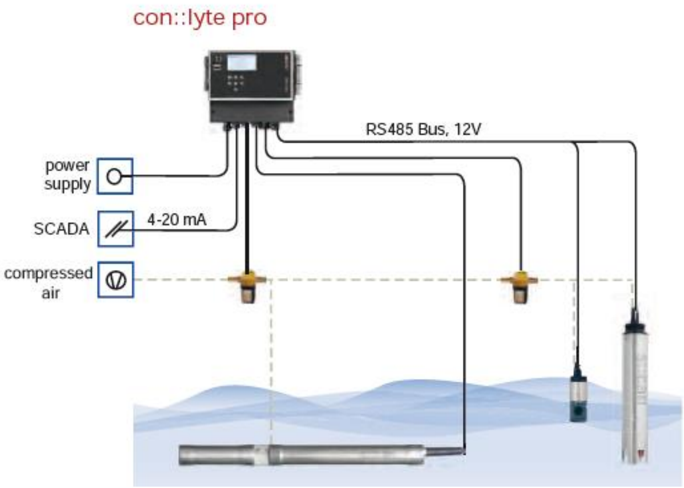
Industrial Pc with touch screen of 7" in colour to motorize locally the water quality parameters. It provides global connectivity network thanks to technology Quad-band WCDMA network connection and dual-band EV-DO and an integrated WIFI interface for termite control of data transferring as well as ethernet interface (100Mb/s) to be integrated in greater systems.




It is also incorporated a process interface to SCADA with 4-20 mA, SDI-12, Modbus RTU/TCP y Profibus DP outputs. Con::cube arranges a "plug & measure" operation of 5 s ::can sensors as standard; unlimited number of sensors(optional). Support for two cleaning valves external

### 5.19.2 Con::lyte

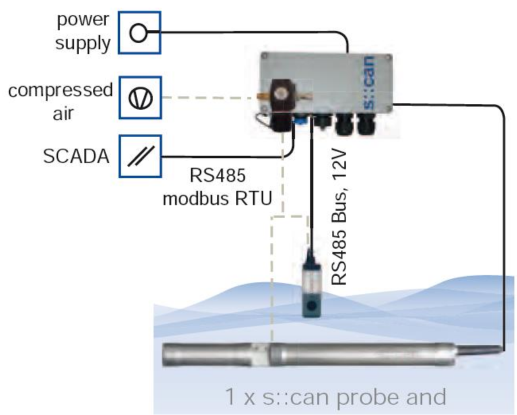
Operation of up to 3 sensors/probes (plug & measure), shows up to 2 (echo) or 6 (pro) parameters.




It enables a user adaptable interface SCADA interface via 4-20mA analog outputs, optional: modbus RTU or profibus DP and providing digital inputs and outputs (PULSES or PMW), analog inputs and wash valve control, logbook / registration. As optional: data-logger and PID controllers (max. 3) can build in.

### 5.19.3 Con::nect

It includes an interface functionality RS485 to SCADA (Modbus RTU integrated). Operation of a spectrophotometric probe and sensors / ISE probes. It enables a USB interface to PC / notebook




## 6 End-user requirements

The monitoring station aimed at providing water quality and quantity related parameters to the NAIADES platform will yield a design that is compatible with the identified gaps, needs and further requirements of the project end-users as well as from developers of NAIADES tools that may require these parameters as input. These factors are subject of current discussion in the course of WP2 tasks and will be collected by T3.2 in order to proceed with the design of the monitoring stations.

Thus, this design will need the following items as input:

- Water parameters to be measured by sensors
  - From end-user needs
  - From NAIADES services needs
- Main characteristics of the monitoring locations
  - Type of water conduction
  - Approx. dimensions
  - Characteristics of the monitored water (approx. flow, drinking water/waste water/sea water..)
  - Existing infrastructure at the end-user side
  - Planned infrastructure to be implemented by end-user

These parameters will be specific for every monitoring location of every pilot in Alicante, Carouge or Braila. However, NAIADES will intend to homogenise the characteristics of the station design so that it is adaptive to the location as far as possible.

# 7 Water Monitoring Station (Alicante location).

AMAEM, as the NAIADES end user, is very focused on analysing and predicting short-term water consumption fluctuations and monitoring. Accurate information enables them to regulate their systems accordingly. Real-time acquisition of a wide range of data parameters would mean trends or patterns governing water consumption can be better identified and water more efficiently thus managed.

Picture 1: A water well register in Alicante

High salinity levels in the treatment of wastewater reduce efficiency. Furthermore, salinity hinders water reuse as conventional water recycling through tertiary treatment is not able to reduce conductivity. As the water does not meet the requisite agricultural and urban standards, use is restricted. To overcome this, reverse osmosis is applied following tertiary treatment which significantly increases costs and energy demand. On the other hand, the quantity of water that is recyclable is also lessened - so the aim of the pilot is to identify and control saline intrusion points so corrective measures may be applied.

The first case, the water demand forecast, does not require installation of any new device and will make use of existing infrastructure and data.

In the second case, the wastewater network, parameters to be monitored are:

- Conductivity
- Wastewater levels in the network

The water monitoring station will consist of middleware able to integrate conductivity and water level sensors into a communication protocol output, which in turn can be easily plugged into the Alicante pilot network. The three main elements making up the water monitoring station are:

1) Water monitoring sensors: sensing equipment to measure and collect conductivity, water level data.
2) Data-logger: Middleware with a flexible and adaptive interface architecture ability.
3) Electromechanical structure –power, wiring and enclosure-

When visiting Alicante, AMAEM showed IBATECH some potential locations for the water monitoring station:

Picture 2: potential location of a water monitoring station

As a result, the water monitoring station should preferably be wall-mounted on the well interior as should the sensors.

### 7.1 Water monitoring sensors

The water monitoring station shall include two types of sensors:

1) Conductivity sensor
2) Water level sensor

Conductivity sensor.

Conductivity is defined as the degree to which any material conducts electricity. Specific conductivity is defined by 1/Resistance = Current/ Voltage. Basically if the voltage is fixed at a certain value, we can measure the conductivity by the variation of current values. This is normally expressed in µS/cm. It is also important to evaluate electrode geometry. The relationship between the electrode distance (L) and electrode surface (A) must be correctly configured for the desired measuring range where the cell constant (c) = L/A.

Conductivity results are expressed in siemens per centimeter (S/cm). Water conductivity is closely correlated to temperature so results are interpolated on conductivity values at either 20ºc or 25ºc. This is why the conductivity sensor requires an additional temperature sensor.

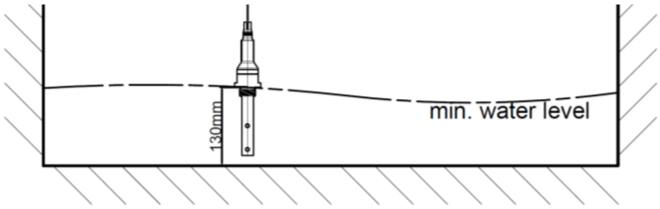
The normal values of conductivity in urban waste waters range from 500 to 1,500 µS/cm. Values with high conductivity, i.e. > 3,000 µS/cm, affect the biological purification process.

> Note: High conductivity values mean typically high salinities which prevent the development of a stable bacterial community. Then there is a mismatch in the bacterial colony; the filamentous bacteria are more resistant which causes the floccule structure of the active sludge to weaken, decreasing its density and therefore its sedimentation rate

In urban water waste, high conductivity values are not unusual and are usually due to infiltrations of marine waters in coastal areas or in industrial water waste. See below some references:

- https://doi.org/10.1016/j.scitotenv.2017.02.137
- https://pubs.usgs.gov/sir/2004/5067/sir2004-5067.pdf
- https://water.usgs.gov/ogw/gwrp/saltwater/salt.html

The conductivity sensor should be in contact with the water level and at least the probe head immersed in the water reservoir. The conductivity probe head should be immersed with a min. water level of 130mm to be properly covered. Schematic conductivity sensor deployment as shown *below*:



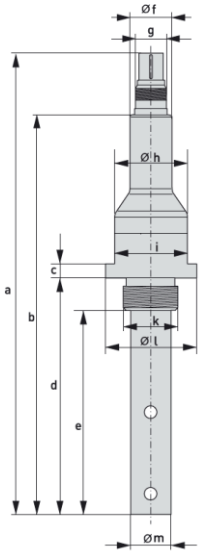

We propose a conductive measuring range of 200µS/cm (minimum) to 20mS/cm (c=1), to cover properly the typical waste water conductivity range (500 to 1,500µS/cm) in urban areas and that of sea water detection (>3 mS/cm). Sea water reaches 50mS/cm, therefore it will be able to measure up to 40% of it.

The conductivity probe shall have an analytical sensor with a built-in integrated transmitter, preferably. A complete circuit will be in place a t the sensor head and will measure water conductivity. The output of the conductivity sensor shall provide standard open communication to the data logger via a fieldbus. The sensor should preferably have a two-way 4...20mA /HART output, or similar. Such protocols are easily integrated to the data logger.

The sensor shall be water-resistant to IP67or higher, with stainless-steel electrodes and an integrated temperature system (i.e. Pt 100 or similar) for conductivity data correction. The power supply must be Direct, in the range of 12 or 24Vdc, to keep energy consumption at the lowest possible.

The probe will be connected to the electromechanical enclosure though a 7/8m cable and no mounting of fixing points is needed.

Preliminary layout (mm):




| Approximate dimensions (mm) | |
|---|---|
| a | 228.2 |
| b | 198 |
| c | 7 |
| d | 116 |
| e | 100 |
| f | ø20.5 |
| g | TBD |
| h | ø24 |
| i | TBD |
| k | TBD |
| l | Ø45 |
| m | Ø20 |

Water level sensor:

There is an extensive range of water-level sensor technology currently available. We consider the Radar level sensors to be the best option for the Alicante water well operation owing to their protection properties and that they are maintenance light.

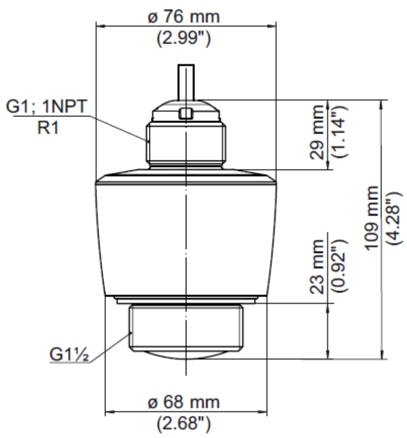
Radar lever sensors work with high-frequency radar pulses (around ~GHz) emitted by an antenna which are reflected off the water's surface which produces a change in the value of the sensor's relative dielectric constant. The reflected radar pulse time-of-flight is directly proportional to the distance travelled. If the geometry of the tank is known, the level can be calculated from this variable. The frequency difference between the signal sent and the signal received is proportional to the distance and varies according to the water level. The water level determined in this way is converted into a signal of corresponding output and delivered as a measurement value.

Some of the main advantages of this technology are the following:

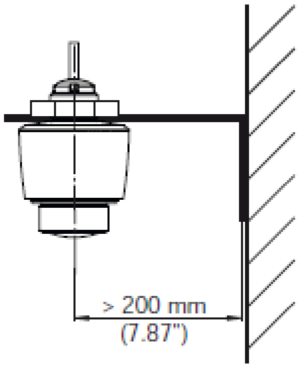
- Maintenance-free operation using radar technology 80 GHz contactless
- Accurate measurement results regardless of conditions product, process and environment
- . Operational round the clock as they do not wear and are maintenance free

As with the conductivity sensor, the output protocol should be 4….20mA and easily-pluggable to the data-logger communication protocols.

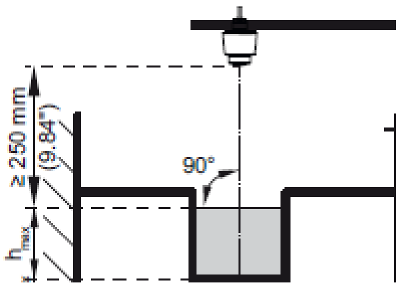
Preliminary layout (mm):




For rigid mounting, a mounting bracket with a G1½ opening thread is recommended, as follows:




The mounting location of the radar sensor should be a place where no other equipment or fixtures cross radio signal pathway. We strongly recommend the inner wall of the water wells. The sensor should be fixed as perpendicular as possible to the water level to achieve optimum measurement results. The max. measuring range will be around 15 m depth. The sensor shall be easily configurable to Bluetooth via PC, tablet or smartphone.




| | |
|---|---|
| **1** | **Reference plane** |
| **2** | **Measured variable, max. measuring rang** |

A 7/8m cable will connect the probe to the electromechanical enclosure.

## 7.1 Data logger (Middle-ware)

A sensor network, defined as a collection of devices, might be heterogeneous. In recent applications, a sensor network consists of different sensors of different natures that can perform different tasks. For example, some nodes are equipped with special kinds of sensors, whereas others may have more processing power for complex calculations or act as gateways to infrastructure-based networks. Furthermore, the specific requirements for the network depend heavily on the application. If these requirements change or another application is executed, the network must adapt itself. To develop an adaptation for every application is complex. In order to simplify application development, a flexible and adaptive solution is clearly needed.

So far, the Alicante scenario is the only one clearly identified. In order to provide a flexible sensor interfacing architecture, we propose the use of a 3G/GPRS data-logger with multiple analog (4-20mA and 0-10V) and digital inputs (pulse inputs) which include three-way data transfer to the NAIADES data collection layer:

- Direct Modbus protocol support: any SCADA could easily perform Modbus read requests to the monitoring station;

- FTP push: the station could send csv files to a remote FTP server periodically and;

- MQTT: the monitoring station will be able to send JSON-formatted messages periodically to an MQTT broker.

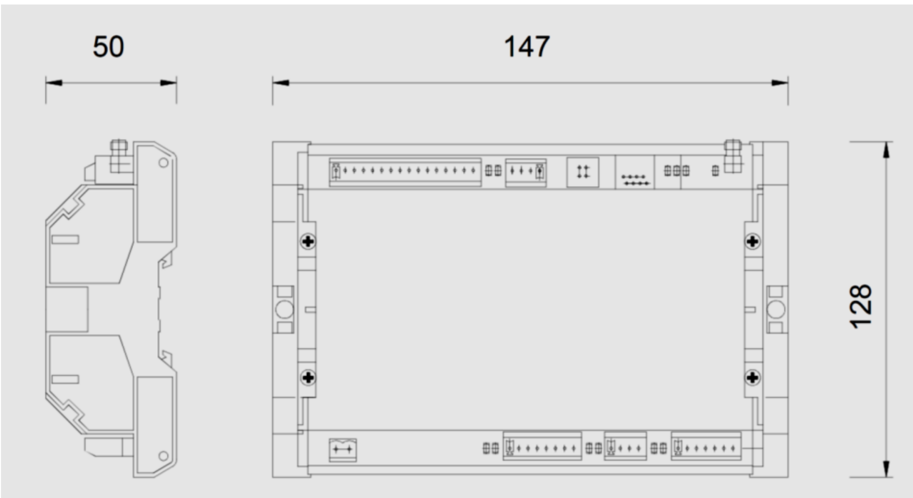
In any of the cases, if there is a momentaneous or temporary lack of power supply, the device should be able to firstly, send an alarm message to the server through MQTT and operate in a low power mode, making use of an embedded backup battery so that it can collect and log data even in such an event. When the supply is restored, data would be sent to the server as usual.

As a general requirement, any sensor installed in such a monitoring station will be subjected to widely-used industry standards to avoid any compatibility problems with communication network and the NAIADES data collection layer.

The datalogger will be built as follows (overview):

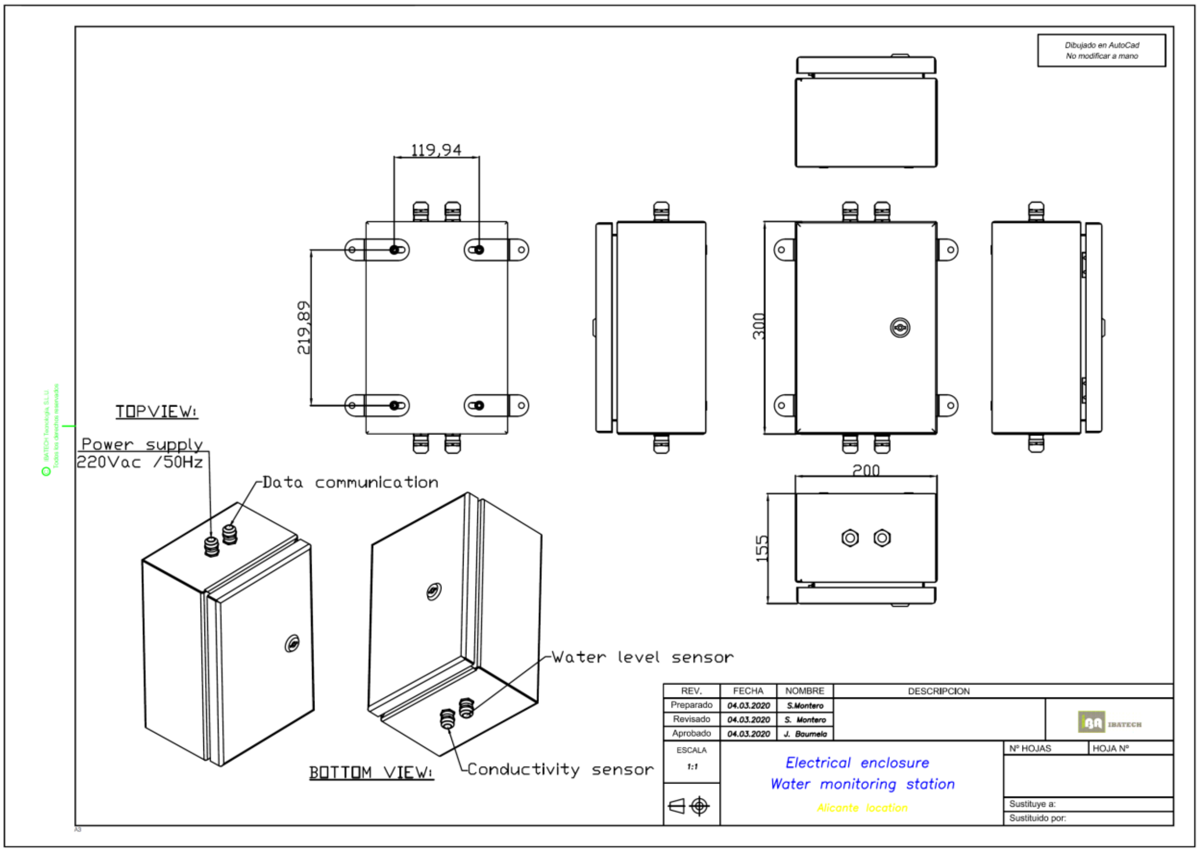
- Datalogger with records timestamp (RTC, real time clock) synchronized through NTP protocol
- RS232, RS485, USB, Ethernet, 3G(UMTS/HSPA+) communication
- M-Bus master (can read up to 20 devices)
- Up to 6 analog inputs (current, voltage, resistance ortemp. probe)
- Up to 4 digital inputs (contact, impulse counter, alarm)
- Controller with up to 2 relay outputs (230Vac, 3A)
- Automatic weekly scheduler for relay outputs
- Dimmer with up to 2 analog outputs (4..20mA; 0-10V)
- 8GB microSD card included
- FTP client able to send periodic data in csv file format
- Remote configuration and updates through 3G
- Protocols supported: Modbus RTU, Modbus TCP/IP, M-Bus, MQTT, FTP server/client

Approximate dimensions (mm):



### 7.2 Electromechanical Enclosure

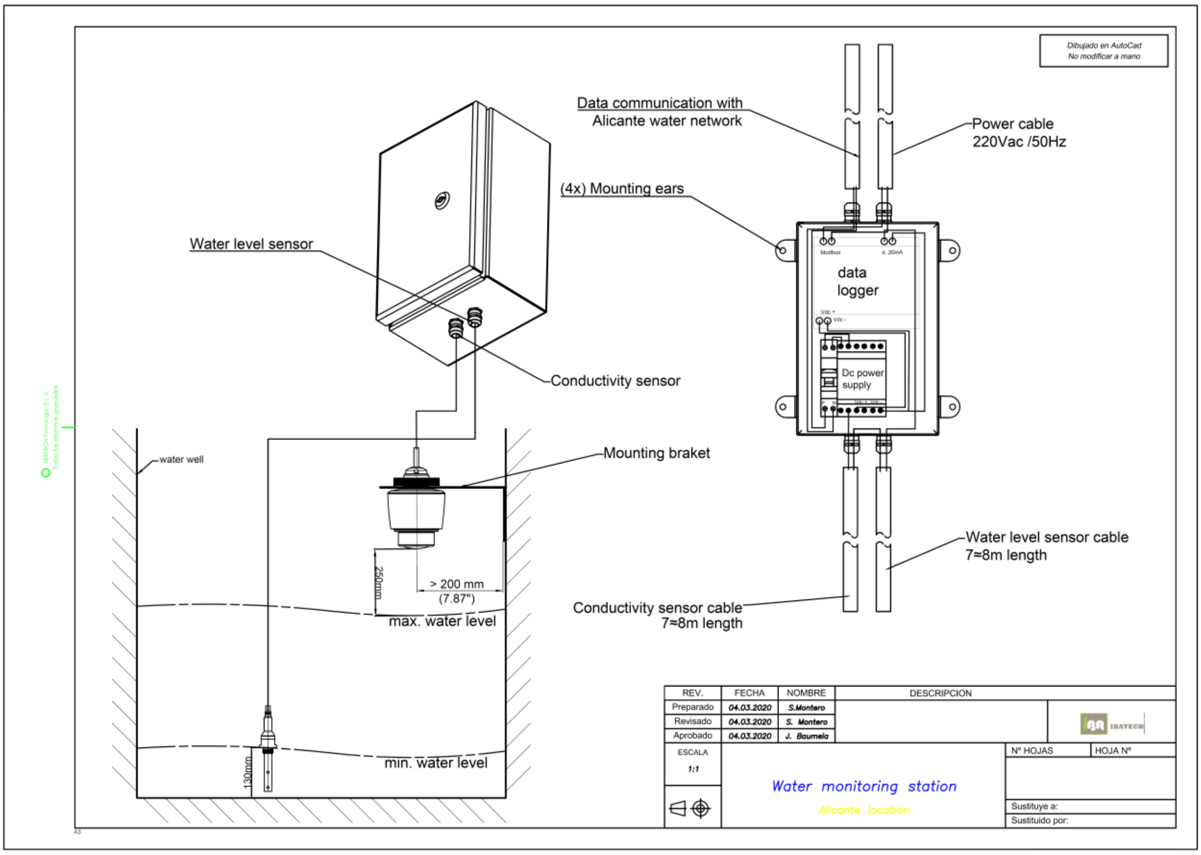
The purpose of the electromechanical enclosure is to protect electronics (data logger, power supply transformer, circuit breakers, etc) from potential water intrusions. The water-well application use case states that the electromechanical enclosure should be manufactured from a stainless steel monobloc offering 100% hermetic sealing and maximum resistance according to EN 62208 and EN 60529 IEC standards. Additionally the enclosure will come with 4 fitted cable glands made of stainless steel: 2 at the bottom (to secure the water level and conductivity sensor points) and 2 at the top to secure the data communication and power supply cable entry points which in turn link up with the Alicante water management network. Four (4) ears will be included for wall installation. See below a schematic drawing:




Internally it shall provide electronics. See next chapter for further details.

### 7.3 Water monitoring station layout

The Alicante water monitoring station use case will consist of an electromechanical enclosure from which the two (2) sensors (conductivity and water level) will be deployed into each water well.




The purpose of the enclosure-encased electronics is to convert data from sensors to a format recognised by the Alicante water management network So, the communication protocol output from Data-logger, as commented in the previous paragraph 7.1, comes with MODBUS RTU which is easily integrated into SCADA (Alicante water management communication system).

# 8 Water Monitoring Station - Carouge Use case 1: Fountains.

The main need, in this case, is to analyse water monitoring of fountains to improve water management in the city in response to the water shortages of recent years. Additionally, maximizing water management in fountains and public spaces is considered an improvement in citizens' quality of life.

Accordingly, public employees need:

- to be informed if there is a water quality problem within the fountain
- to save water. Currently, 2 million litres of water are used per year
- to take action if water quality deteriorates
- Chlorate is a complicated problem with no easy solution

Use case 1 will use one fountain: **Fountain des Tours**. The other fountain (**Promenade**) is shut down due to recurrent problems, highlighting the importance of efficiency for the Fountain des Tours. The Promenade fountain, with the Carouge swimming pool of Carouge, is replaced because chlorate problems were found.

Generic information

- The Fountain des Tours has a capacity of 150,000l. It consumes about 2 million litres of water per year.
- The Fountain des Tours has a large technical designated space where we can install the bacteria system
- In the Fountain des Tours, it is easy to install and to conceal sensors in the fountain (pH, Cl, chlorine)
- It is open from May until October

A public fountain was selected as a demo location for the water monitoring system as it complies with the use-case scenario:


The parameters to be measured according to specifications are the following:

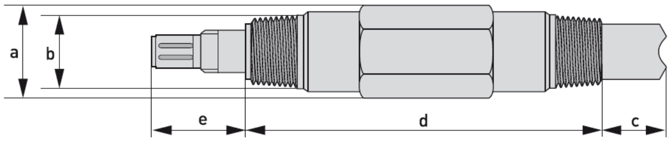
- Temperature.
- PH.
- Free Cl ($Cl_2$)
- Combined Cl ($ClO_2$)
- Total Cl
- Bacteria
- Chlorate ($ClO_3^-$)

Bacteria monitoring needs to be considered for reasons of budget constraints. Total organic carbon and/ or turbidity sensors (in combination) might be effective in the collection of data as an indirect indicator of organism levels. Chlorate ($ClO_3^-$) is a very complex issue and its effective monitoring requires further research. Therefore, the implementation of this sensor may be outside the scope of the project. Taking in account these premises, the presented report shall describe a water monitoring station prototype which can be subject to modification in further reviews.

### 8.1 PH and Temperature sensor

The PH sensor shall be specially designed for water monitoring in pressure pipes with a complete measuring range of (0-14pH) and a temperature range of about 0-80ºC (to be confirmed). The sensor integrates a transmitter with bidirectional communication (4…20Ma/HART) sending the information to the data-logger device.

Dimensional diagram (below):




| | Approximated dimensions (mm) |
|---|---|
| a | 33ø |
| b | To be defined |
| c | 24 |
| d | 128 |
| e | 34 |

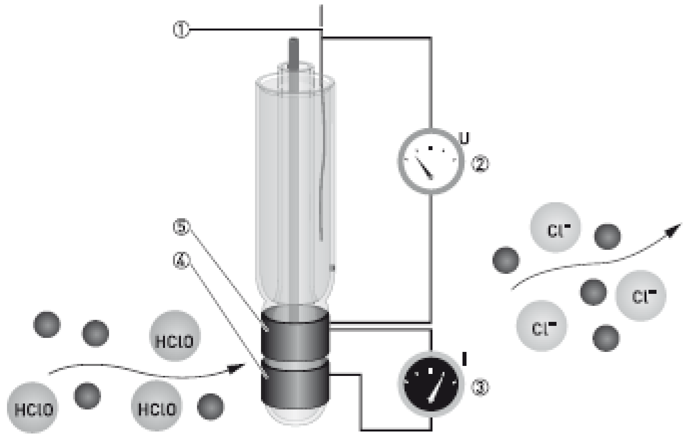
The pH shall provide a large ceramic diaphragm for reliable pH measurement with a double junction for extended lifetime offering a wide range of applications. Low maintenance is required owing to the field of application (public fountains) offering high potential cost savings with offline calibration under controlled conditions and integrated Pt100 for temperature readings.

### 8.2 Free chlorine/chlorine dioxide

Free and combined Cl ($ClO_2$) is another parameter specified in user case 1: Carouge Fountains. In order to meet this requirement, a high-quality CL sensor comprising gold electrodes for precise usage in water analysis is envisaged. It shall have a membrane-free sensor enabling a wide range of applications, low maintenance costs and a long life cycle. It is also able to measure Ozone ($O_3$).

The data logger shall be able to send both free chlorine and chlorine dioxide values from the fountain pipeline to the Carouge communication network (LORA or 3/4G).

### 8.2.1 Free chlorine measurement principle:



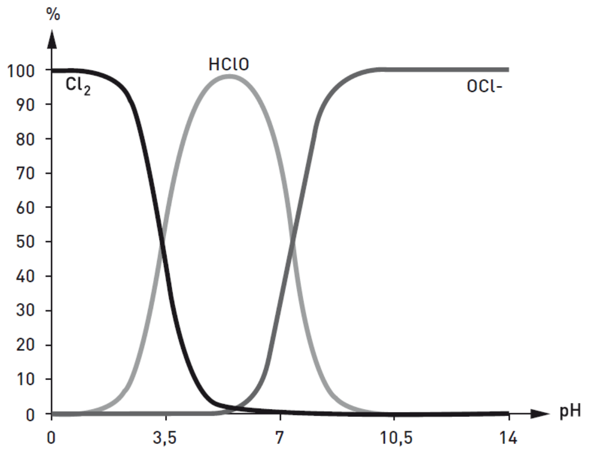

| | |
|---|---|
| **1** | Reference electrode |
| **2** | Applied chlorine specific potential |
| **3** | Current needed to maintain the constant potential |
| **4** | Counter electrode |
| **5** | Measuring electrode |

Material for sensor electrodes are the following: gold for the measuring and counter electrodes and Ag/AgCl for the reference electrode. When a precise potential is applied between the reference and the measuring electrode, reference one starts polarising. At that moment ions move close to the electrode to neutralize the electrical field. Then, the current decreases down to 0mA while the polarising layer does not change and free chlorine molecules are polarized (negative) when hitting the measuring electrode and take portions of the total charge with them. This turns into a change of measuring potential and therefore the signal converter immediately readjusts the potential as soon as it begins to change. In this manner the current, that always needs to maintain a constant potential, is directly correlated to the free chlorine concentration.

As free chlorine values are directly correlated to the pH of the medium, the CL sensor parameter shall correlate with pH sensor values. The pH value has consequences for the disinfection strength: when increasing pH, the disinfection strength decreases.

- Below pH 3: Chlorine gas ($Cl_2$)
- Between pH 3 and pH 8: Hypochlorous acid (HClO)
- Above pH 8: Hypochlorite (ClO-)

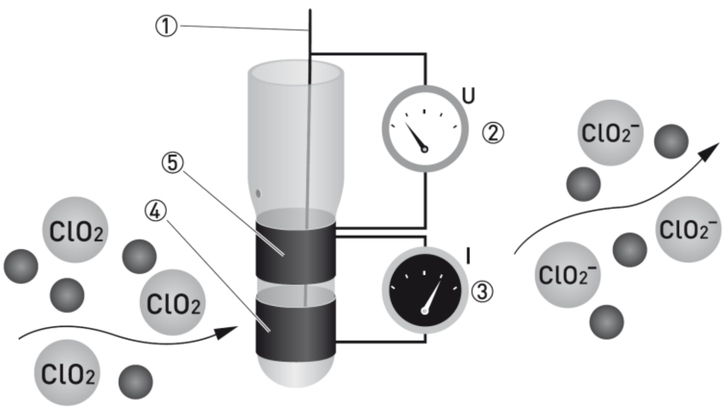
So, to get a reliable free chlorine measurements, pH values must be correlated with Chlorine ones according to the following dependence graph:




NOTE: It must be reminded that pH is also temperature dependant, therefore PH sensor should have an integrated temperature sensor (PT 100 or similar as described in the previous chapter), as recommendation.

### 8.2.2 Chlorine dioxide measurement principle (Combined Cl: $ClO_2$)

The molecule is made up of one chlorine and two oxygen atoms. It is a very reactive, neutral chemical compound. Chlorine dioxide is very different from elemental chlorine, both in its chemical structure and in its behaviour. Chlorine dioxide does not hydrolyse when it comes into contact with water; it remains as a gas in solution and is approximately 10 times more soluble in water than chlorine



The molecule is made up of one chlorine and two oxygen atoms. It is a very reactive, neutral chemical compound. Chlorine dioxide is very different from elemental chlorine, both in its chemical structure and in its behaviour. Chlorine dioxide does not hydrolyse when it comes into contact with water; it remains as a gas in solution and is approximately 10 times more soluble in water than chlorine

Chlorine dioxide is less corrosive than chlorine. It is not negatively impacted by pH, does not lose effectiveness over time (bacteria will not grow resistant to it) and it is not negatively impacted by silica and phosphate, which are generally used as inhibitors of corrosion in drinking water.

The disinfection effect of $ClO_2$ is due to the transfer of oxygen instead of chlorine, so that no chlorinated by-products are formed. $ClO_2$ is used as disinfectant against biofilm, bacteria, spores, and viruses. Today it is believed that the molecule's unpaired electron is transferred to the DNA of the microorganism which cracks and causes cell necrosis. $ClO_2$ has a long-term effect of several days. In contrast to chlorine, the disinfection strength of $ClO_2$ does not depend on pH, and neither does the measurement show a pH influence in the range of pH 6 to pH 9. It is more effective as a disinfectant than chlorine in almost all circumstances against pathogens present in water, such as viruses, bacteria and protozoa - including Giardia cysts and Cryptosporidium oocysts.

The use of chlorine dioxide in water treatment involves the formation of chlorite as a byproduct, which is currently limited to a maximum of 1 ppm in drinking water. The EPA standard limits the use of chlorine dioxide to relatively high quality water or treated with iron-based coagulants (iron can reduce chlorite to chloride).

Both measuring and counter electrodes are potentio-static connected to measure $ClO_2$ by applying a precise drop of voltage. When ions are collected around the measuring electrode, this means polarising has begun. $ClO_2$ molecules start hitting the electrode surface and take away a portion of charge. Henceforth, the controller starts measuring the potential between the measuring and reference electrode to readjust the charge on the electrode surface.

### 8.3 Turbidity sensor

Turbidity is understood as the degree of transparency lost by water or some other colourless liquid due to the presence of suspended particles. The greater the amount of solids suspended in the liquid, the greater the degree of turbidity. In water purification and wastewater treatment, turbidity is considered a good parameter to determine water quality, the higher the turbidity, the lower the quality.

There are several parameters that influence water turbidity. Some of them are:

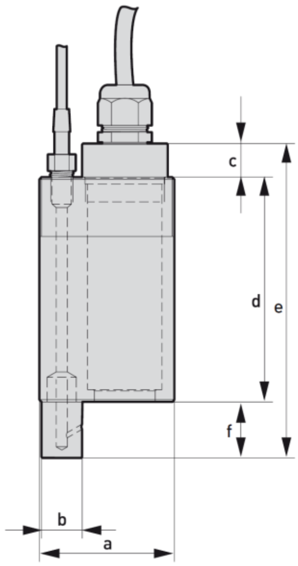
- Presence of phytoplankton, or algae growth;
- Presence of sediments from erosion;
- Presence of re-suspended sediments from the bottom (often scrambled by fish that feed on the bottom, such as carp);
- Effluent discharge, such as urban runoff mixed in the water being analyzed

Suspended particles absorb heat from sunlight, causing cloudy waters to become hotter, and thus reducing the concentration of oxygen in the water (oxygen dissolves better in the colder water). In addition some organisms cannot survive in hotter water, while the multiplication of others is favoured. Suspended particles disperse the light, thereby decreasing photosynthetic activity in plants and algae, which contributes to lowering the oxygen concentration even more. As a consequence of the sedimentation of the particles at the bottom, the shallow lakes fill faster, the fish eggs and the larvae of the insects are covered and suffocated and the gills of the fish are tucked or damaged.

The main impact of high turbidity is merely aesthetic: nobody likes the appearance of dirty water. But in addition, it is essential to eliminate turbidity to effectively disinfect water that you want to drink. This adds extra costs for surface water treatment. Suspended particles also help the adhesion of heavy metals and many other toxic organic compounds and pesticides.

Consequently turbidity values can be easily correlated to the presence or disinfection of organisms in water suspension. Turbidity and TOC sensors are reliable and indirect indicators of the absence or presence of bacteria and can substitute direct bacteria indicator sensors when budgets cannot accommodate the latter.

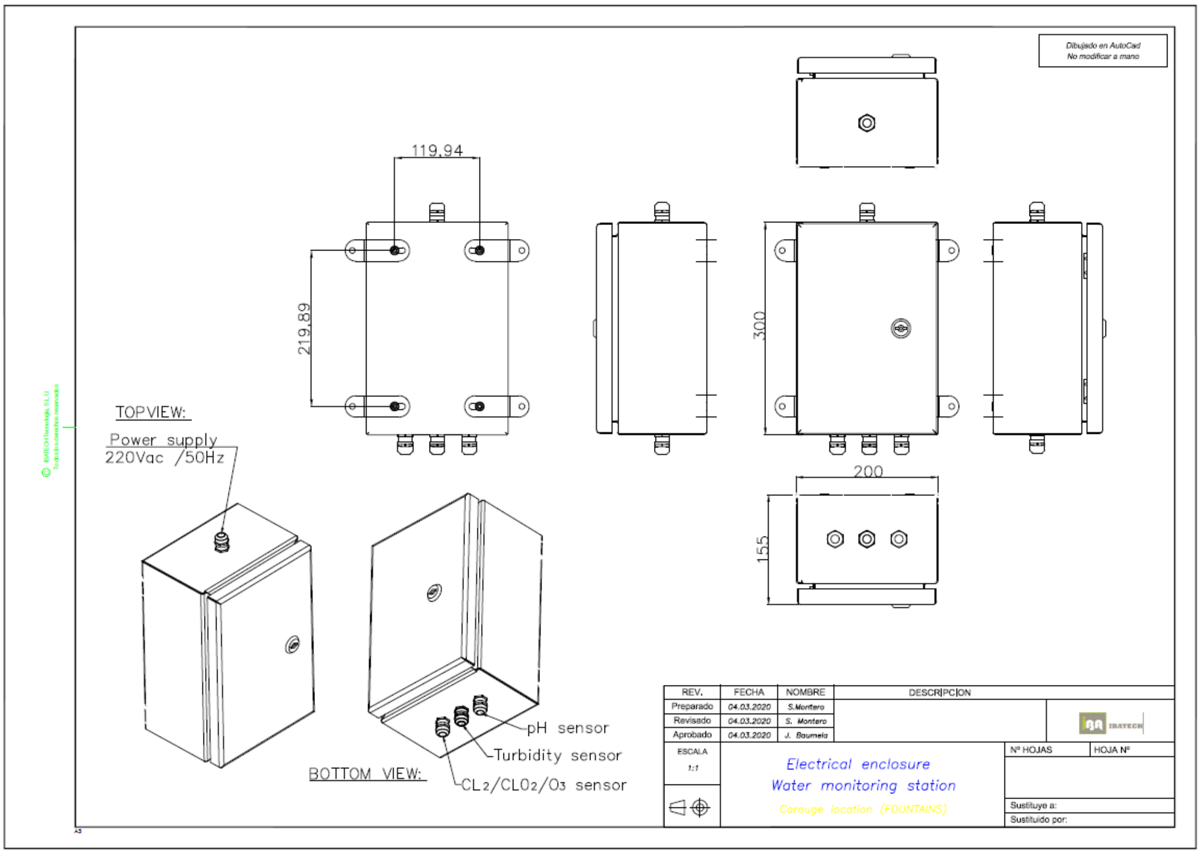
A proposed sensor with dimensions is shown below:




| | Approximated dimensions (mm) |
|---|---|
| a | 60 |
| b | 18 |
| c | 15 |
| d | 100 |
| e | 140 |
| f | 25 |

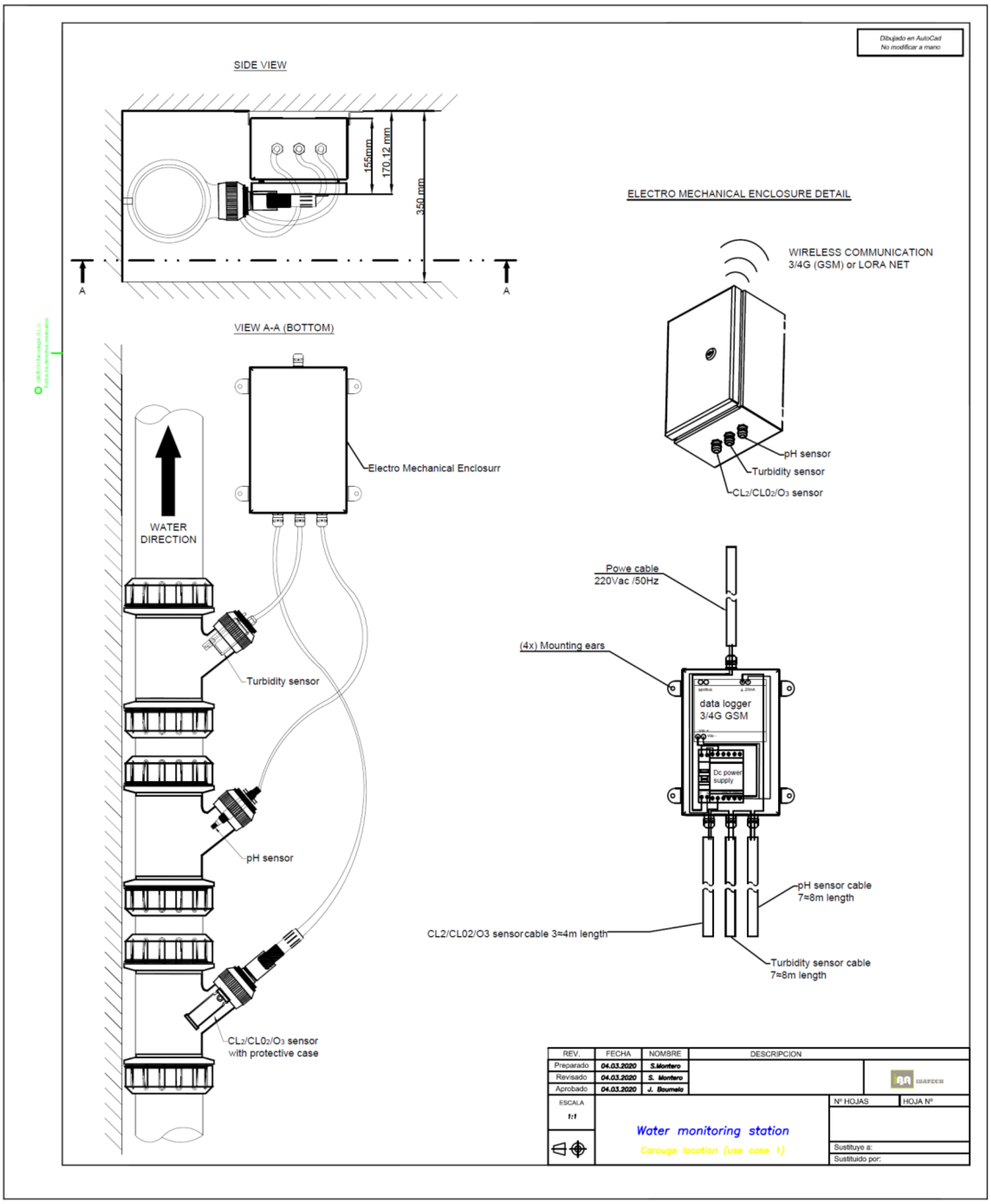
### 8.4 Electromechanical Enclosure

The purpose of the electromechanical enclosure is to protect the electronics i.e., the data logger, power supply transformer, circuit breakers, etc. from potential water intrusion. The water-well application use case states that the electromechanical enclosure should be manufactured from a stainless steel monobloc offering 100% hermetic sealing and maximum resistance according to EN 62208 and EN 60529 IEC standards. Additionally the enclosure will come with 4 fitted cable glands made of stainless steel: 2 at the bottom (to secure the water level and conductivity sensor points) and 2 at the top to secure the data communication and power supply cable entry points which in turn link up with the Alicante water management network. Four (4) ears will be included for wall installation. See below a schematic drawing:



### 8.5 Water monitoring station layout

The use case 1 fountains water monitoring station will consist of an electromechanical enclosure from which the three (3x) sensors (PH-Temp, Cl and turbidity sensor) will be installed on the water pipes and connected to the electromechanical enclosure placed in the surroundings. See below a proposal drawing of the Carouge water station and its physical installation:




The purpose of the enclosure-encased electronics is to convert data from sensors to a format recognised by the Carouge Fountains management network. (Case of Use 1)

<u>IMPORTANT NOTE: Design of UCC2 prototype is still being studied, therefore it is susceptible to further modifications.</u>

# 9 Water Monitoring Station - Carouge Use Case 2 (Watering)

## 9.1 Water monitoring sensors

This paragraph has been revised in MAY 2021.

At the submission of D3.3, this paragraph was still under evaluation. The consortium had not been able to fully define the UCC2 requirements because different options and configurations were possible; so, the design and details of the related prototype have been exhaustively detailed and defined in the following deliverable D.3.4 Integrable WATER MONITORING SENSOR PLATFORM (mid-term).

Regarding the incompletion of this paragraph, It is worth mentioning that the structure of deliverables D3.3, D3.4 and D3.5 is conceived as a review and refinement of design and development concepts of the prototypes throughout the execution of the project. Although the D3.3 is the catalogue and Design of water monitoring sensors; the D3.4 is focused on the integration of water monitoring sensors at mid-term; and D3.5 is the final version of integration of water monitoring sensors.

A posteriori, the preliminary design of fountain use case for Carouge is summarized below.

### 9.1.1 URBAN BOX PROTOTYPES

This section describes the urban box (UB) prototypes developed to improve watering efficiency through measurement of soil moisture tension. To this end, a tensiometer (temperature compensated) has been used in the water scheduling of Use Case: Carouge 2 (UCC2). Prototypes also include a LoRaWAN connection so the soil moisture can be monitored remotely.

*Figure 1 Urban Box prototype*

### 9.1.2 PROTOTYPE GENERAL DESCRIPTION

Prototypes have been designed in line with end user requirements. The main requirements are listed below:

- Tensiometer sensor to measure soil moisture tension to determine plant water status
- Ability to access data from current LoRaWAN city network
- One-month power guarantee with provision for at least 2 daily data collection connections
- Prototype must be fully interred to avoid possible tampering

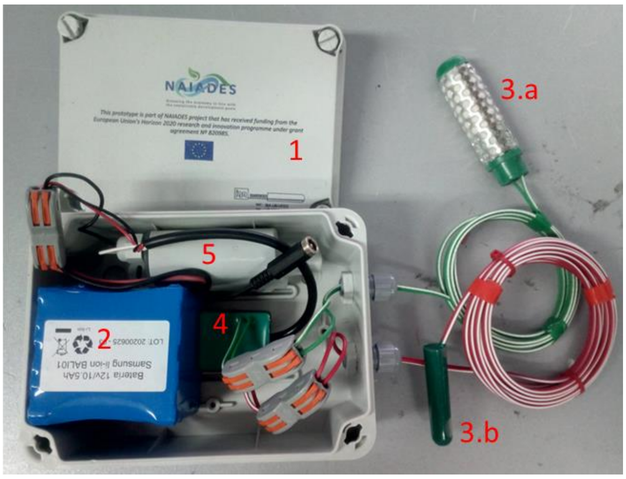



*Figure 2 Urban Box prototype internal components*

1) **Enclosure/ casing:** provides IP67 degree to protect each internal element when buried. To avoid electrical conductivity when the prototype is buried, a techno-polymer halogen-free material for the casing has been selected providing external electrical insulation. Besides, the degree of protection and impact-resistance properties makes it ideal for below-the-surface operations. It provides two (2x) M12 cable glands for tensiometer and temperature sensor fastening.

   Technical data

   - Protection grade IP65-IP67*
   - Impact resistance IK07
   - Incandescent wire resistance 650 oC
   - Ambient temperature range -25 oC / +40 oC
   - Maximum operating voltage 1000 V AC / 1500 V DC
   - Double insulation Class II

Dimensions:

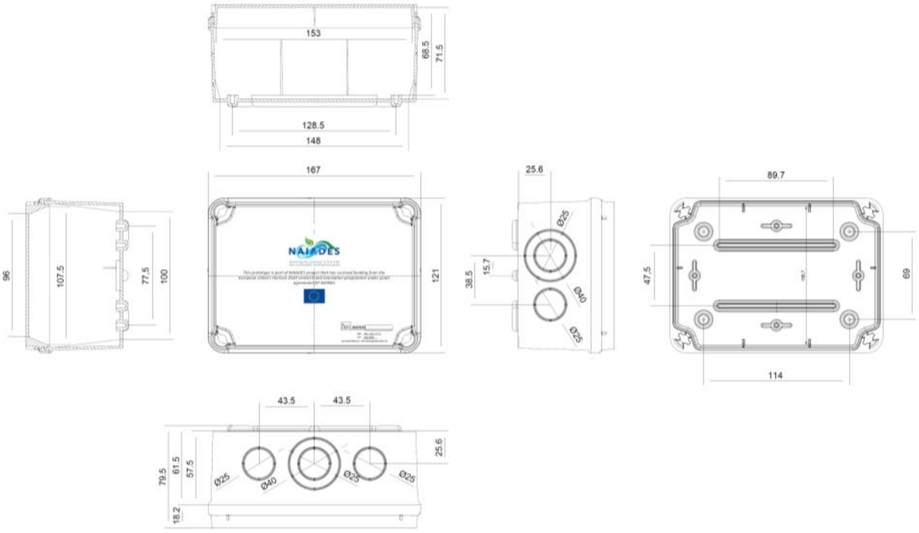


*Figure 3 Urban Box prototype dimensions*

2) **Rechargeable Lithium Battery:** coming with 10500mAh to provide continuous monitoring for at least a year (12 months) permitting up to 4 daily connections.


*Figure 4 Urban Box rechargeable lithium battery*

This type of battery is especially designed for charging or feeding any portable device with a 12v output and has a high storage capacity. They do not suffer from the so-called "memory effect".

Its discharge is linear and hardly changes when discharging.

It has high discharge, up to 10Ah, and protection CHIP with anti-short circuit, anti-overload, anti-current and anti-overload functions.

Characteristics

- Battery capacity: 10.5A (10500mAh)
- Maximum output current: 10 Amps
- Maximum continuous discharge current: 5ah
- Discharge cut: 9.6v - 12.6v
- Input voltage: 12.6v
- Output voltage: 12.6v

- Size: 70x60x55mm
- Weight: 598 grs.
- Electric energy charging time: 10h
- Battery life: 48 months
- Working temperature: minimum: 0ºC / maximum: 45ºC

Charger Features

- Input: 110-240AC / 50-60Hz
- Output: 12.6v DC / 1000mAh

Benefits

- Lithium battery
- Low energy consumption
- Designed to charge electronic devices at 12v

Content

- 1 x 2.6A 12V Rechargeable Lithium Battery
- 1 x Transformer to charge the 1000mAh battery

3) **Sensors:**

a. **Tensiometer:** Each prototype provides a tensiometer to measure soil tension in cBar. It is a resistive device that responds to changes in soil moisture. The sensor consists of a pair of highly corrosion resistant electrodes that are imbedded within a granular matrix. As the soil water tension changes with water content, the resistance changes as well. The sensor adapter translates the resistance value into a linear voltage output which can be read by a compatible reading device. The reading device can then be configured to display the voltage output in centibars (cb) or kilopascals (kPa) of soil water tension. Once planted in the soil, it exchanges water with the surrounding soil thus staying in equilibrium with it. Soil water is an electrical conductor thereby providing a relative indication of the soil moisture status. As the soil dries, water is removed from the sensor and the resistance measurement increases. Conversely, when the soil is rewetted, the resistance lowers.

*Figure 5 Urban Box tensiometer sensor*

It takes its resistive measurement within a defined and consistent internal matrix material, rather than using the surrounding soil as the measurement medium. This unique feature allows the sensor to have a stable and consistent calibration that does not need to be established for every installation.

The relationship of ohm of resistance to centibars (cb) or kilopascals (kPa) of soil water tension is constant and built into the reading devices that are used to interrogate the sensor. The sensor is calibrated to report soil water tension, or matric potential, which is the best reference of how readily available soil water is to a plant.

Specifications:

- ABS plastic caps with stainless steel body over a hydrophilic fabric covered granular matrix.
- dimensions – diameter: .875 in. (22 mm)
- length: 3.25 in. (83 mm)
- weight: .147 lb. (.067 kg) – with 5 ft. lead

Use the following readings of the tensiometer as guidelines:

- 0-10 Centibars = Saturated soil
- 10-30 Centibars = Soil is adequately wet (except coarse sands, which are drying)
- 30-60 Centibars = Usual range for irrigation (most soils)
- 60-100 Centibars = Usual range for irrigation in heavy clay
- 100-200 Centibars = Soil is becoming dangerously dry- proceed with caution!

b. **Temperature sensor:** is responsible to compensate the measures of the tensiometer sensor. Therefore, there is not a temperature value collected by the prototype. Temperature sensor is a resistive device that responds to changes in temperature. As the temperature gets warmer, the resistance lowers. Once planted in the soil, it will change its resistive value as the soil temperature changes.

*Figure 6 Urban Box temperature sensor*

The protective encapsulating material will tend to insulate and slow the response time if used for ambient measurements. The relationship of ohms of resistance to temperature is constant and built into the reading devices that are used to interrogate the sensor. Temperature Sensor is a precision thermistor encased in epoxy potting compound for direct burial applications.

Specifications:

- maximum power rating: 30 mw at 25°c
- maximum operating temperature = +150°c
- maximum storage and operation temperature
- for best long-term stability = +120°c
- accuracy: ±0.2°c

- materials: epoxy potting compound with a corrosion
- resistant plastic sleeve
- dimensions – diameter: .4375 in. (12 mm)
- length: 2.25 in. (57 mm)
- weight: 2.7 oz. (75.7 g)

4) **Voltage adapter:** Basically a gateway which converts the tensiometer output signal into an analogue signal (0-3V) recognised by the LoRaWAN module bridge. This electronic adapter provides a linear voltage output which makes most data loggers or devices that can read a voltage signal. The voltage output signal is directly proportional to the soil water tension measurement which represents the energy a plant's root system uses to draw water from the soil. It can be temperature compensated with the addition of a soil temperature sensor.

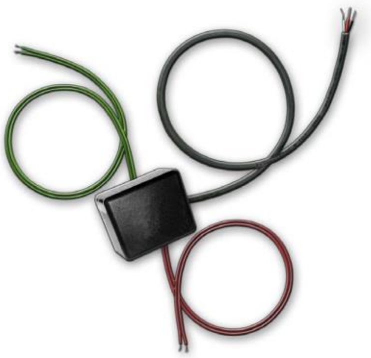


*Figure 7 Urban Box temperature sensor*

5) **LoRaWAN Bridge:** converts the 0-3V signal in the voltage adapter into LoRaWAN network recognisable format for Carouge city. LoRaWAN 863-870 ANALOG PWR is a ready-to-use radio transmitter enabling any type of 0-10V or 4-20mA sensor to be converted into a wireless communicating sensor. It allows to integrate the LoRaWAN 863-870 ANALOG PWR into any network that is already deployed. Two sensors can be supported by a single LoRaWAN 863-870 ANALOG PWR transmitter. In NAIADES project is necessary one analogue input but the two channels have been configured for 0-10V analogue. The configuration of the transmitter is accessible by the user via a micro-USB port, allowing in particular a choice of modes of transmission. The LoRaWAN 863-870 ANALOG PWR is powered by an external power supply independently.

IMPORTANT NOTE 1: the user needs to declare his/her product to a LoRaWAN operator.
IMPORTANT NOTE 2: the LoRaWAN 863-870 ANALOG PWR can transmit measurements from the sensors but does not feed them.

General description:

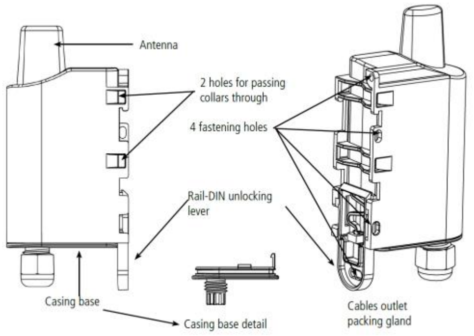



*Figure 8 Urban Box LoRaWAN Bridge general description*

Dimensions

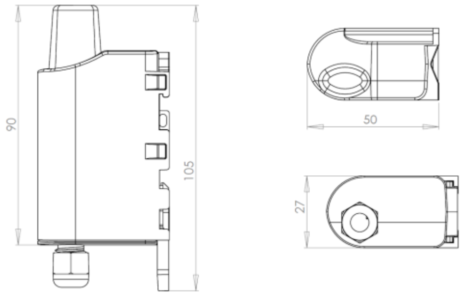



*Figure 9 Urban Box LoRaWAN Bridge dimensions*

Electronic board:

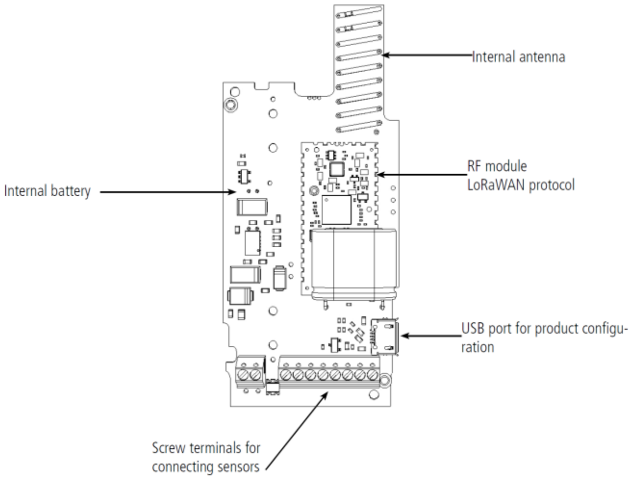



*Figure 10 Urban Box LoRaWAN Bridge electronic board*

## ELECTRICAL WIRING DIAGRAM

Electrical wiring diagram is shown below for integration works at pilot use case place:

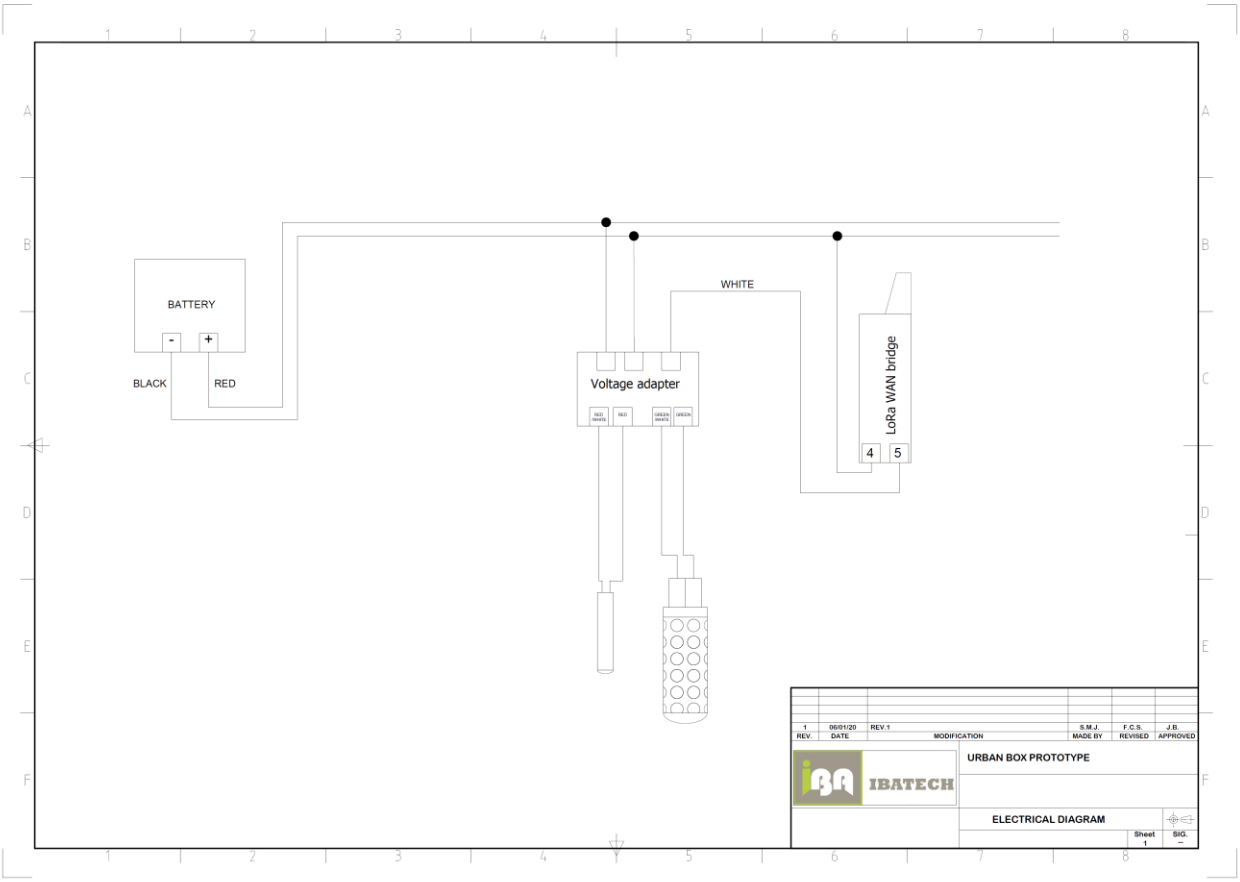



*Figure 11 Urban Box electrical wiring diagram*

## 9.1.3 WATER TRUCK CONSUMPTION PROTOTYPE

This prototype is focused on monitoring the water consumption when watering the urban box plants. Such monetarization of the water volume irrigated will ease to improve create better plans to improve the watering and therefore reduce the water consumption of the irrigation of plants.

<u>According to last meetings this prototype is still under end user requirements.</u> Only the flow meter device (sensor) has been acquired and customized with GEKA hose connectors for its integration with water truck hoses.

## WATER VOLUME METER

The device operates according to the electromagnetic measurement principle. According to Faraday's Law of magnetic induction a voltage is induced in a conductor moving through a magnetic field. The electrically conductive measuring agent acts as the moved conductor. The voltage induced in the measuring agent is proportional to the flow velocity and is therefore a value for the volumetric flow. The flowing media must have a minimum conductivity. The induced voltage is picked up by two sensing electrodes which are in contact with the measuring agent and sent to the measuring amplifier. The flow rate will be calculated based on the cross-sectional area of the pipe.

*Figure 12 Water volume meter*

The measurement is not depending on the process liquid and its material properties such as density, viscosity and temperature. The device may be equipped with a switch, frequency or analogue output. Moreover, there is a compact electronic system to be selected from, which contains a switch and an analogue output.

The device series is completed by an optionally obtainable dosing and counter electronic system. The counter electronics system shows the current flow rate on the first line of the display and shows the partial or overall volume on the second line. A dosing electronic system controls simple filling duties and also measures the flow rate, overall volume and filling volume. The analogue output and two relay outputs can be utilised for the further processing of signals.

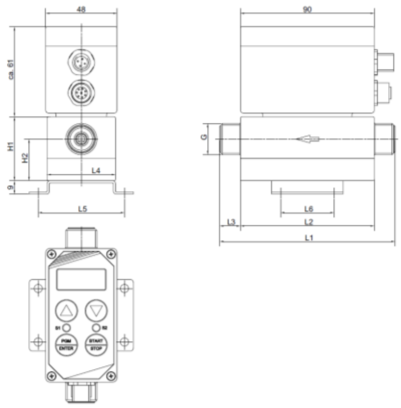


*Figure 13 Water volume meter dimensions*

| Connection | Inside diameter | Flow velocity at full scale | Range |
|---|---|---|---|
| G 1 male | 15 mm | approx. 3.0 m/s | 1.6 ..32.01/min |

*Table 1 Water volume meter technical details*

- Accuracy: ±2.0 % of full scale Repeat accuracy: ±1.0 % of full scale Measurement process: electromagnetic
- Electrical conductivity: min. 30 µS /cm (at MIK- ...08 and 10: min. 200 µS /cm) Mounting position: in all directions, flow in direction of the arrow
- In-/Outlet: 3 x DN / 2 x DN
- Media temperature: -20 .. +80 °C (max. +60 °C with PVC-connection set) Ambient temperature: -10 .+60 °C
- Max. pressure: 10 bar

- Max. pressure loss: max. 250 mbar at full scale Max. medium viscosity: 20 cSt ≤ G1; 70 cSt ≥ G1½
- Sensor housing: PPS or PVDF, fibreglass-reinforced
- Connection set: PVC-glue connection or hose connection, weld-on ends stainless steel 1.4404
- Electrodes: stainless steel 1.4404, Hastelloy® C4 or Tantalum
- Seal: NBR, FPM or FFKM
- Response time t90: approximately 1 s (at flow changes >10% FS)
- Protection: IP 65

# 10 Water Monitoring Station - Carouge Use case 3: CANCELLED

Use case 3 is no longer studied owing to time consuming and large amount of resources needed for Carouge end user. This end user has clearly renounced to the implementation of use case number 3.

## 11 Conclusions

In the first part of this deliverable, a catalogue of technological solutions available on the market aimed at defining water quality parameters, as set out in current EU regulation. This equipment has been divided into sections covering every regulatory parameter. A specific focus was put on technologies that can provide online data so that these can be injected in (near-) real time to the NAIADES system. This catalogue of solutions will serve to assist in the final selection of sensors for the monitoring station, depending on NAIADES use case requirements.

In the second part, a study and design of the water monitoring station prototypes for the Alicante location and Carouge use case 1 were put forward. In the case of the Alicante pilot, there is significant progress with the water monitoring prototype, but otherwise Carouge monitoring prototypes must be further studied to meet the whole range of the two use case specifications/requirements. Such Requirements of UCC1 and UCC2 are currently being defined and prototypes designs will be revised and provided when they are completely specified.

The consortium agreed to hold weekly teleconferences to address both use cases. In these teleconferences, Carouge will present the problems they are having with, and subsequently partners will propose potential solutions to these problematic issues including specifications, design review, and all needed for the development of the water monitoring stations. It is estimated that in about 2 or 3 months, we will be able to offer further solutions with a final design of prototype water monitoring stations for both use cases.

NOTE: The content of this deliverable feeds back into Task 3.2 and, after the production of requirements in WP2, will be used for the final design of the stations. The next step in terms of D3.3 deliverables is the production of the first physical monitoring stations, due in month 16 of the project.