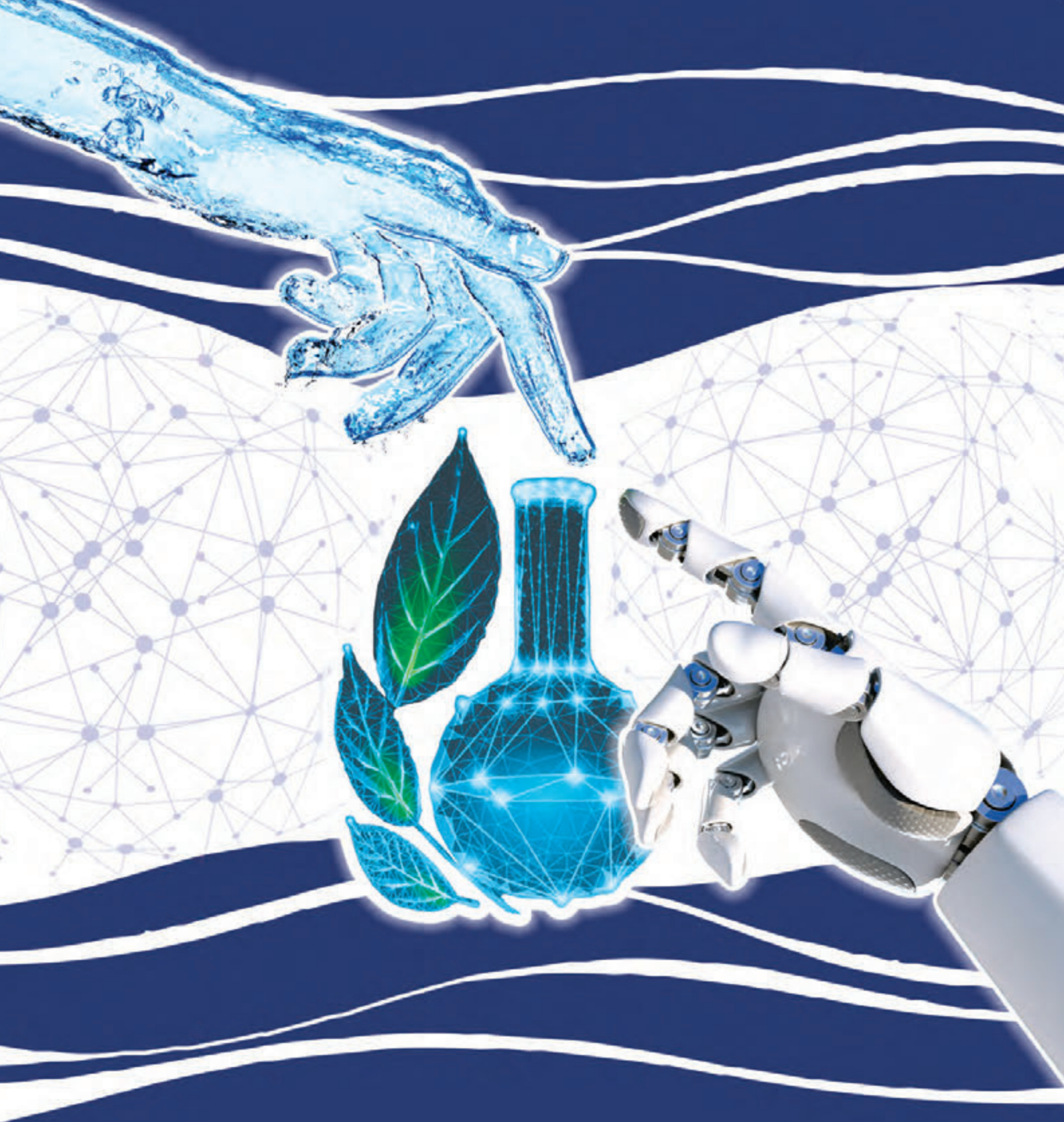

Research activities 2022 2023

SMAT Research Center

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smat
CENTRO RICERCHE

CENTRO RICERCHE

Research Activities

YEAR 2022/2023

The SMAT Research Center for Sustainability, Mitigation and Adaptation

The sixth IPCC 'Assessment Report' condenses the best scientific knowledge of climate change to date and identifies among the four key risks for Europe, the risk of water scarcity and the increased frequency and intensity of flooding, in addition to rising temperature extremes.

All these factors are elements that have a significant impact on SMAT's activity and must therefore be taken into adequate consideration with a first level objective that is part of the current climate change adaptation policy.

The historical series of rainfall and temperature measurements recorded in North-West Italy indicates 2022 as an unprecedented year in terms of climate, and the drought that is continuing to affect the area even in the first part of 2023 confirms this trend.

'Business-as-usual' is no longer an available option for those who, like SMAT, manage the integrated water service in an area so incisively impacted by the effects of the drought, and effective and innovative measures are needed, and it is precisely in this area that the many activities developed by the SMAT Research Centre fall.

In addition to the completion of major projects, new lines of research were pursued to increase the efficiency and effectiveness of treatment, reduce the use of reagents and process energy, the PNRR project to digitise networks and reduce leakage, the use of artificial intelligence and machine learning, and the reuse of treated wastewater in agriculture.

In addition, the need to strengthen the resilience line to the effects of climate change, the focus on the carbon footprint of the activities developed by SMAT, the optimisation of technologies applied to the search for network losses, and the opportunities offered by the circular economy in a sector where circularity is inherent in the service provided have never been lost sight of.

Armando Quazzo

CEO

Paolo Romano

President

March, 2023

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Projects closed in 2022

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Ongoing projects

Projects closed in 2022

Energy/Environment/Climate Change

Taxonomy

STATUS	Closed
STARTING DATE	May 2022
DURATION	6 months
FUNDING	No
PARTNERS	Ref Ricerche
SMAT REPRESENTATIVE	Beatrice Coloru

Taking into account the Paris Agreement (2015), the 2030 Agenda for Sustainable Development, and the Green New Deal, the European Commission has approved EU Regulation 2020/852 (Taxonomy) on the establishment of a framework to encourage sustainable investments. The Taxonomy (Article 3) establishes the criteria for determining whether an economic activity can be considered environmentally sustainable, i.e. whether it substantially contribute to the achievement of one, or more, of the six environmental objectives defined in Article 9, without causing harm to others, while respecting minimum social safeguards (Article 18). The Taxonomy provides for mandatory reporting in Non-Financial Statement as of January 1, 2022 for fiscal year 2021.

The project, entirely implemented in the second half of 2022 with the support of Ref Ricerche, is the first application of the EU Taxonomy to SMAT's activities. The applied methodology is based on the requirements and criteria outlined in Regulation 2020/852 and declined in the "Climate Delegated Act" published on June 4, 2021 for technical aspects and in the "Disclosure Delegated Act" published on July 6, 2021 for reporting aspects.

Initially, we performed a screening of SMAT's activities through the analysis of the 2021 Preliminary Financial Statements and the 2020 Sustainability Report. The analysis of economic and financial data started from the 2021 budget, prepared in accordance with IFRS. The increases in tangible and intangible assets, broken down by contract, were analysed. The analytical detail of accounts and control objects were used as key elements to achieve the necessary granularity of information to link economic data with taxonomic activities and, where possible, with individual assets. The activities carried out by SMAT are almost entirely eligible for the Taxonomy (more than 90 percent of turnover, CapEx and OpEx are attributable to activities considered as potentially contributing to the Climate Change mitigation objective by the Taxonomy). In addition, 48% of turnover, 50% of OpEx and 31% of CapEx are attributable to activities that meet the technical screening criteria demonstrating a substantial contribution to climate change mitigation. An additional research project was initiate, in collaboration with CMCC, to implement a Climate Change Adaptation Plan, which is essential to passing the DNSH criteria.

"More than 90 percent of SMAT's revenues, CapEx and OpEx are attributable to activities considered as potentially contributing to the Climate Change mitigation objective by the EU Taxonomy"

Greenhouse gases emissions

STATUS	Closed
STARTING DATE	May 2020
DURATION	24 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
SMAT REPRESENTATIVE	Beatrice Coloru

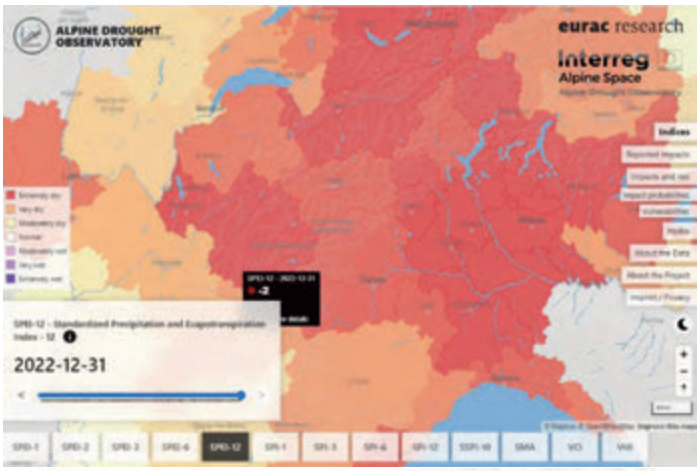
The project led to the development of a data-mining and data processing tool for automatically assessing the carbon footprint of SMAT's plant and settlements, taking into account national and international guidelines, such as ISO 14064-1, which incorporates the requirements of the GHG Protocol, and methodological guidance outlined by the IPCC. Given the complexity of wastewater treatment processes, the dynamic nature of methane and nitrous oxide production mechanisms and the resulting high uncertainty in estimating emission factors, it was necessary to directly measure off-gases from biological treatment, in order to estimate the carbon footprint of such systems with due accuracy.

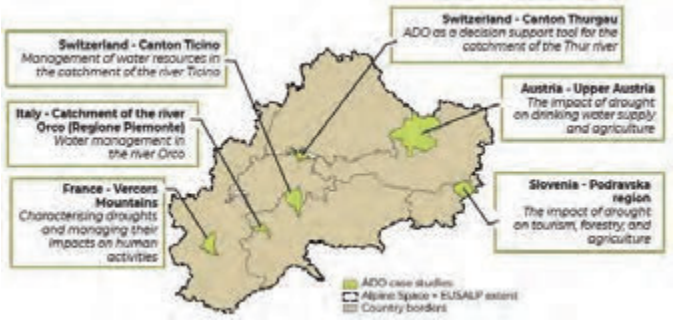
DIATI of the Polytechnic University of Turin designed and built an experimental apparatus for capturing emitted gases and measuring low concentrations of CH_4 and N_2O. It consists of a floating chamber and a system of valves and piping that flows the gases to a portable gas chromatographer. For sampling under anaerobic or anoxic conditions, the system uses a flow of air generated by a compressor. The system was tested during three campaigns on the Castiglione Torinese plant. Measurements were conducted on the biological treatment tanks with intermittent aeration and on the anaerobic tanks for biological phosphorus removal. Spot measurements were also carried out on the denitrification tanks for effluents from the sludge line (Anammox system). The measurements showed that the CH_4 and N_2O emissions could be much lower than those calculated using the IPCC guidelines (and could decrease further after the ongoing refurbishment of the aeration system). On the other hand, the Annamox process alone could result in N_2O emissions comparable to those calculated using the IPCC method. Given the high spatial and temporal variability of CH_4 and N_2O concentrations in the emitted gases, in relation to process operating conditions and outdoor temperature, further measurement campaigns would be necessary to define the plant emission factors with a good level of confidence.

"Measurements showed that CH4 and N20 emissions from biological treatment tanks could be much lower than those calculated using IPCC guidelines"

Alpine Drought Observatory (ADO)

STATUS	Closed
STARTING DATE	January 2021
DURATION	18 months
FUNDING	No
PARTNERS	EURAC Research, Piedmont Region, Arpa Piemonte and 8 international partners
LEADER	EURAC Research
SMAT REPRESENTATIVE	Elisa Brussolo





Fonte immagini: hiips://www.alpine -space.eu/project/ado/ hiips://ado.eurac.edu/

The Alpine Drought Observatory (ADO) project is a European project funded within the Interreg Alpine Space program. It provides a tool for a quick and easy overview of the current drought situation in the Alpine region and past drought situations in the last 12-48 month. The platform in online at the following link hiips://ado.eurac.edu/ and its results may be used to better implement policies for drought management and to create coordinated governance tools for more efficient use of water resources.

ADO integrates data from climate models, satellite observations and ground station data from all Alpine countries as well as historical records. All data are openly accessible, ADO provides the following data for the whole Alpine space on political and hydrological relevant borders:

- Meteorological indicators such as SPI (precipitation), SPEI (evaporation), and SSPI (snow conditions)
- Satellite based vegetation indicators VHI, VCI
- Hydrological data from monitoring stations along most rivers in the Alps
- Historical database of drought impacts from scientific articles and media reports
- Vulnerability analysis and relevant data for its assessment

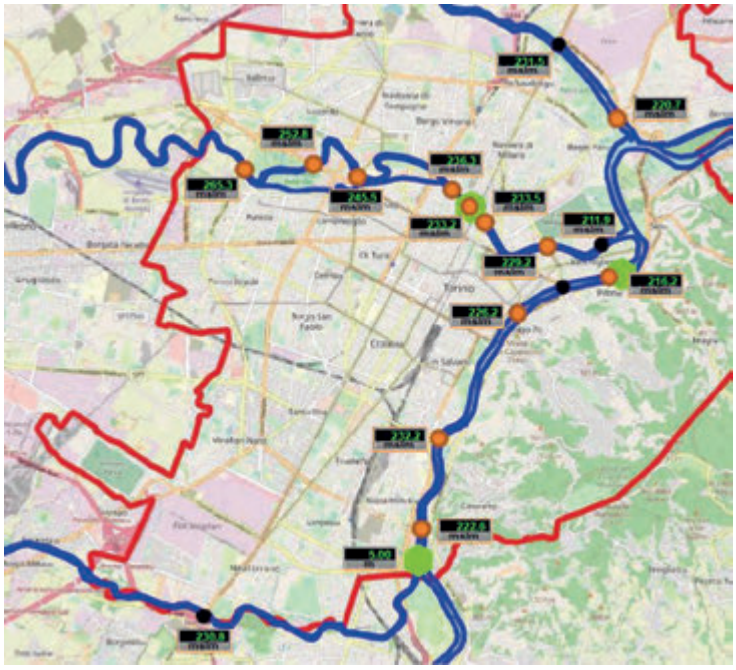
In this context, SMAT participates in the Italian case study on the Orco River Basin, which focuses on the management of water resources in a basin where multiple water uses and significant management practices exist and coexist. SMAT Research Centre, in the framework of the activities foreseen in WP5 (Case Studies, Drought Management and Policies), supported the Piedmont Region and ARPA Piemonte in the critical data analysis and identification of water supply system crises in the study area, contributing to the drafting of the "Recommendations and Guidelines for Improving Drought Management" document, one of the project deliverables, and a document that will be used by the Piedmont Region in the framework of climate change adaptation strategies.

In addition, the technical contributions required to SMAT included knowledge of the dynamics of the groundwater resource for potable use and concrete experience in the field of research into alternative sources of supply, also in relation to the multiple use of the water extracted, in accordance with the regional water protection plan.

"Create an online platform for monitoring and developing guidelines for the implementation of proactive drought management models in Alpine regions"

River4U – REACH European incubator, 2nd round

STATUS	Closed
STARTING DATE	February 2022
DURATION	12 months
FUNDING	No
PARTNERS	MobyGIS SRL
SMAT REPRESENTATIVE	Edoardo Burzio



REACH is a second-generation European incubator for startups and SMEs that use Big Data and aims to facilitate the development of reliable and secure innovative solutions based on industrial data.

REACH aims to be the main innovation mechanism supporting the experimentation of secure and reliable data value chains in different sectors and the launch of new data-driven products and services on the market. Over its duration, REACH will support +100 business ideas from SMEs and select 30 solid business cases through a total of three open calls in the next three years, distributing a total amount of €3.5 million. The funding mechanism provides economic support to a startup (Waterjade®) or SME, which deals with solving a challenge proposed by a third party (SMAT).

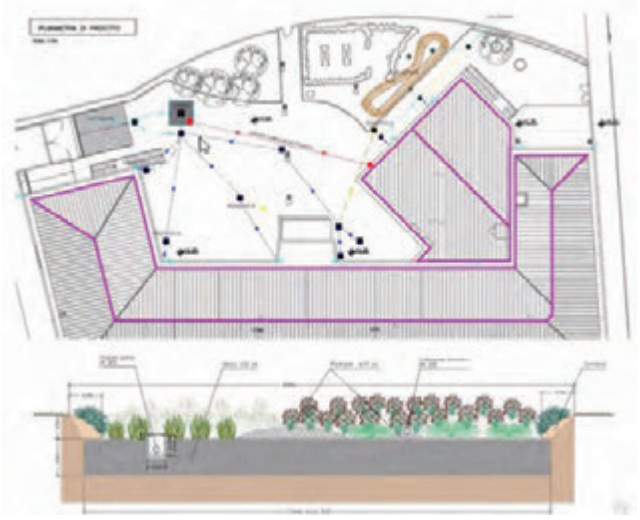
SMAT CHALLENGE: develop a Decision Support System (DSS) for an informed management of wastewater and drainage waters. In particular, SMAT's request is to have, in strategic points and areas of interest, a river monitoring system that provides an interpretive and predictive tool for current and future riverbed dynamics, of particular interest in points of interaction between the drainage network and surface water bodies.

The solution proposed by MobyGIS to address the challenge identified by SMAT involves the implementation of a short-term prediction system. The system will be developed using a Machine Learning (ML) model that will enable the reconstruction of levels in the chosen sections using different data sources (satellite images, weather forecasts, data from ARPA hydrometers). The use of ML algorithms within the modeling allows for excellent results to be obtained without necessarily setting up a complex hydrological model in anthropic contexts such as the proposed case study.
The proposal illustrated here was selected among the 30 participants in Phase 1 (EXPLORE) of the REACH incubator. The initial funding allowed for the development of the Minimum Viable Product (MVP) version of the system, which was positively evaluated during the final event (datathon) of the EXPLORE phase. The project then made it among the 10 finalists of the call and was refueled, accessing the EXPERIMENT phase. The complete model of the prediction system has been implemented in the company's telecontrol and provides a +6 hour prediction of the level of urban rivers in the 5 sections of interest for SMAT.

"develop a Decision Support System (DSS) for an informed management of wastewater and drainage waters"

City Water Circles (CWC)

STATUS	Closed
STARTING DATE	April 2019
DURATION	30 months
FUNDING	Yes
PARTNERS	Municipality of Turin and 10 international partners
LEADER	Municipality of Budapest
SMAT REPRESENTATIVE	Edoardo Burzio



Hydrological hazards caused by climate change are making cities increasingly vulnerable to flooding, while at the same time exacerbating the problem of water scarcity. Given the increasing consumption of drinking water and the consequent increase in the volume of water to be treated, the implications for water service providers are extremely serious.

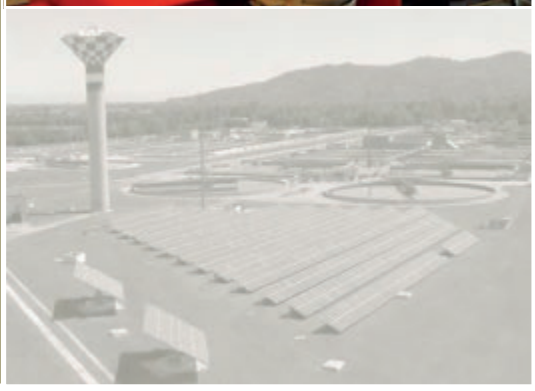
In this context, the CWC (City Water Circles) project, a three-year project funded by the European Union under the INTERREG Central Europe programme, is aimed to introduce water efficiency measures and promote the reuse of unconventional local water resources (rainwater and grey water) in order to reduce water consumption and relieve pressure on overexploited water resources.

Through a circular economy approach, Nature-Based Solutions (NBS) and the promotion of a water-saving culture, urban cooperation models have been developed to promote a culture of resilience, efficiency and re-use in those urban areas most vulnerable to the impacts of climate change.
The CWC project involved 11 partners from 6 countries and the implementation of 5 pilot projects. The partners have developed, through a major involvement of local stakeholders, a set of innovative methods and tools (state-of-the-art technological solutions and NBS, smart governance tools exploring new cooperation and financing schemes) that can be replicated at European level.
The Italian pilot project, installed at Open 011 - Casa della Mobilità Giovanile e dell'Intercultura - consisted in the creation of a roof garden and an aeroponic greenhouse, where the plants are fed by a misting system that uses rainwater: its recovery creates a beneficial cycle for the life of the garden and the greenhouse itself, where fruit and vegetables are grown for the hostel, and the terrace has become a meeting place for the hostel's guests.
SMAT's role in this project included:

- Participating in the work of the Italian stakeholder group, as stakeholder group leader;
- Supporting the drafting of strategies for water reuse in urban areas;
- Providing technical support for rainwater harvesting, sampling and monitoring at the site identified for the Italian pilot.

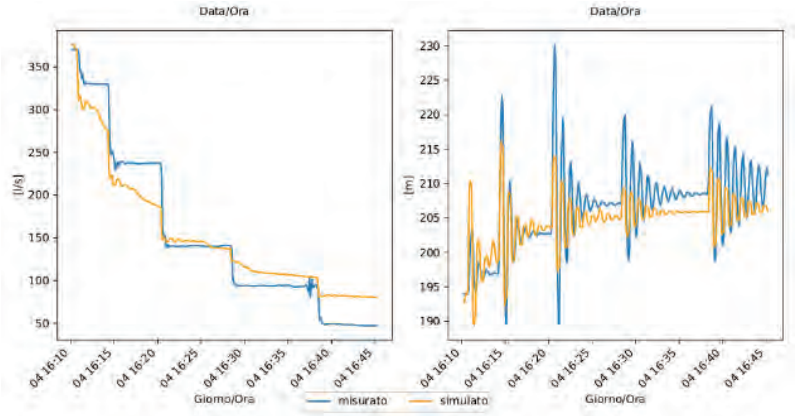
"Urban cooperation models to improve water efficiency and reuse with an integrated circular economy approach"

Supervision

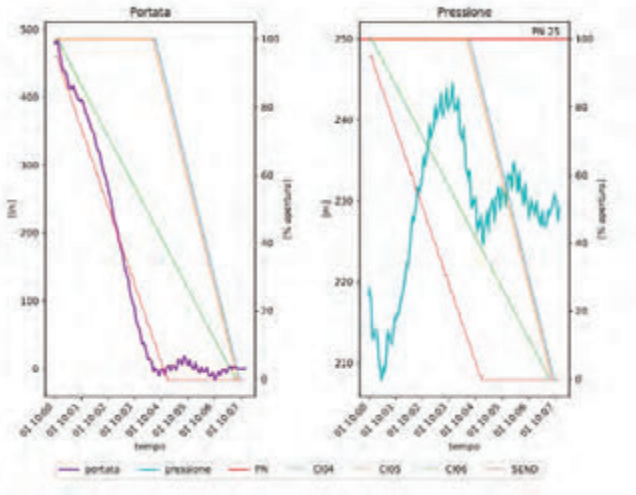


Design of an intelligent automation for the management of the Susa Valley aqueduct

STATUS	Closed
STARTING DATE	May 2021
DURATION	12 months
FUNDING	No
PARTNERS	\\
SMAT REPRESENTATIVE	Marco Scibetta



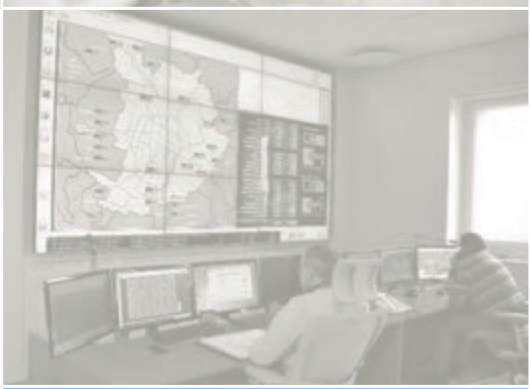
The new Susa Valley aqueduct is designed to meet the water needs of the area by supplying a significant quantity of water of high natural quality. The project involves 27 municipalities, from Bardonecchia to Caselette, through the construction of 96 km of pipelines with a flow rate of 600 litres per second.
This is a highly technologically advanced plant which, through a sophisticated remote control and remote monitoring system, features a high level of automation.



The Susa Valley Aqueduct safety system was developed in this project. It consists of the automatism that governs the system for shutting down the various sections of the aqueduct main line in the event of a pipe break. The automatism consists of two phases.
The first phase has concerned the detection of the conditions that determine the start of the out-of-service procedure. These conditions must be defined for each site, and updated according to the condition of use, since they depend on the deviation between the usual behaviour of the physical and hydraulic quantities and the possible anomalies resulting from a rupture.
The second phase has been represented by the definition of the choice of the valves to close and the sequence to adopt, in order to avoid dangerous pressure drops, and the verification of the maximum and minimum pressure resulting from pressure transient (i.e. water-hammer effect).

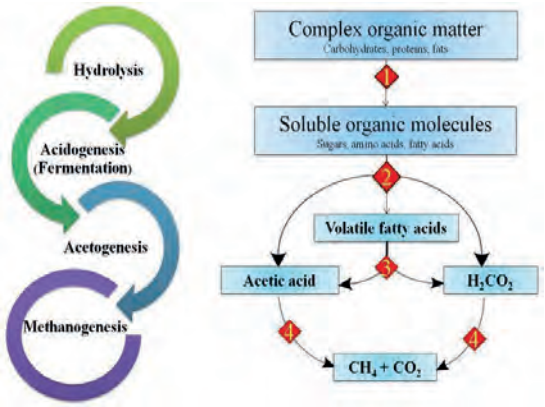
"The new Susa Valley aqueduct is a very technologically advanced plant with a high level of automation"

Treatment



Sludges

STATUS	Closed
STARTING DATE	June 2020
DURATION	24 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
LEADER	Polytechnic University of Turin
SMAT REPRESENTATIVE	Gerardo Scibilia



The optimisation of sewage sludge treatment processes is a theme of primary importance, not only for the reduction of sludges to be managed, but also for the maximisation of energy and material recovery in a circular economy perspective.
The purpose of this project is a pilot scale experimental test of the performances, in terms of biogas production increase and organic substances recovery, of different 2-stage configurations for primary and waste activated sludge anaerobic digestion.

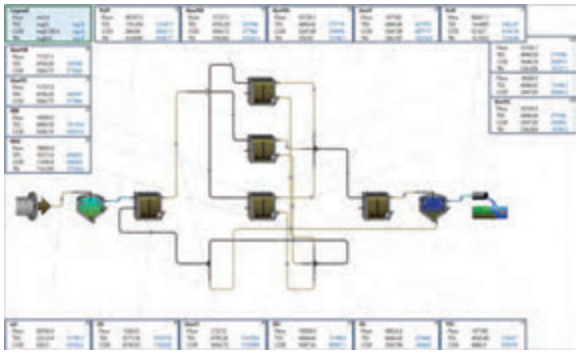
We investigated the 2-stage anaerobic digestion of primary sludge. In the first stage the primary sludge was subject to an acid fermentation with a limited retention time (3-4 days), with the aim of fostering hydrolysis and acidogenesis (trough the inhibition of methanogenesis) achieving interesting production of volatile fatty acids (VFA). These latter are extremely useful compounds as they can be used for biopolymer production or, in future, as raw feedstock for chemical industry or, more simply, for biological phosphorus removal in wastewater treatment processes.
At the same time, we performed a pilot scale experimental test devoted to biological pretreatment of waste activated sludge in thermophilic condition followed by mesophilic anaerobic digestion. Experimental results showed that thermophilic biological pretreatments, as compared to already tested thermo-alkali pretreatments, could achieve comparable methane production increase with thermal energy and chemical savings.

"The purpose of this project is a pilot scale experimental test of the performances of different 2-stage configurations for primary and waste activated sludge anaerobic digestion"

Innovative wastewater treatment process modelling

STATUS	Closed
STARTING DATE	June 2020
DURATION	24 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
LEADER	Polytechnic University of Turin
SMAT REPRESENTATIVE	Gerardo Scibilia

Mathematical models of physical, chemical and biological processes of wastewater treatment are instruments of great importance for plant management, since they give the opportunity to simulate the operation and foresee the plant's behaviour in response to changes in operational parameters.
The models (for sure the most renowned is ASM – Active Sludge Model) allow to optimize operational management, in terms of treatment performance, sludge production, energy consumption and chemicals consumption.



During the first phase of the project, we analysed the deammonification process (DEMON) recently installed at Castiglione T.se plant and we identified the best regulation strategies and the actions for potential troubleshooting.
Following the introduction of the intermittent aeration logic and biological phosphorus removal process in wastewater treatment line of Castiglione T.se, it was necessary to update the mathematical model of the classical MLE denitrification-nitrification process, that we developed during past research projects, with a more sophisticated model.
Therefore, we performed sampling campaigns and experimental tests, also based on respirometry techniques, aimed at wastewater characterization (fractioning) and estimation of process kinetic parameters and their variation as a function of operative parameters. Based on these data we set up and calibrate the model, that will be used for the optimization of the process and for the assessment of control and regulation strategies.

"Mathematical models of physical, chemical and biological processes of wastewater treatment are instruments of great importance for plant management"

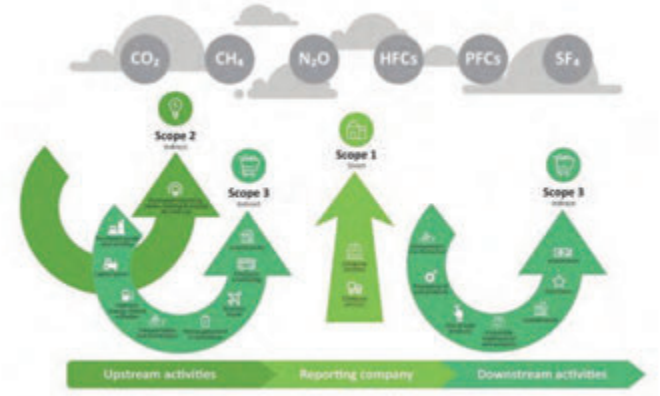
Ongoing projects

Energy/Environment/Climate Change

Greenhouse gas emission reporting: identification of shared methods for applying international guidelines (GHG protocol, IPCC) to the integrated water service and quantification of emissions from biological wastewater treatment

STATUS	Ongoing
STARTING DATE	April 2022
DURATION	24 months
FUNDING	No
PARTNERS	Hera SpA, Iren SpA, A2A ciclo idrico
SMAT REPRESENTATIVE	Camilla Burdizzo

GREENHOUSE GAS PROTOCOL



The project is part of the Partners' initiatives to share experiences and develop common methodological approaches.
The objective of the project is the identification of a shared methodology among the Partners for reporting greenhouse gas emissions in order to obtain comparable results.

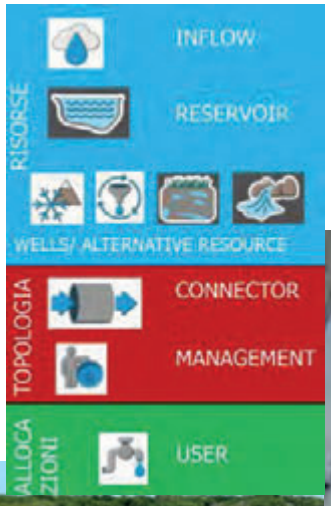
The carbon footprint of integrated water service companies is closely linked to a not entirely standardized declination of reference guidelines.
One of the reference standards, also referred to in the ARERA resolution (917/2017/R/idr), indicates that the calculation must follow the 2012 UNI EN ISO 14064-1 standard, which expresses the emissions in terms of CO2 equivalent. However, this standard contains general prescriptions, not specifically declined for the SII or for the wastewater service, and therefore requires assumptions and hypotheses in order to contextualise its application to the reference production context.

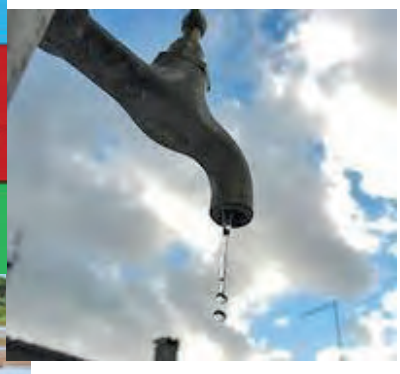
The project aims to define a common approach, for the integrated water service sector, that will make it possible to overcome the variability associated with the calculation methodologies applied, the emission factors used, the scope categories taken into consideration and the organisational and operational boundaries which, in the various applications, may have taken on different dimensions. Particularly interesting for partner companies could also be the joint promotion of different perspectives for assessing the emissions actually attributable to wastewater treatment service operators: for example, in the face of anthropogenic activities that result in unavoidable GHG emissions, the existence of centralized and optimized systems for wastewater treatment actually allows a reduction in emissions of about 80%, compared to the alternative scenario in which the management of manure is entrusted, at most, to on-site systems (imhoff pit latrines). In addition, the contribution of sewage products (dried sludge) to reducing fossil fuel consumption could be valued in terms of reducing overall GHG emissions.

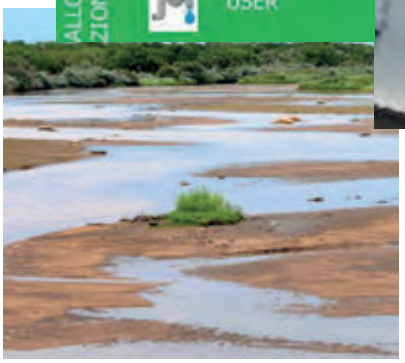
"The project aims at defining, for the integrated water service sector, a common line of approach for the calculation of greenhouse gas emissions"

INOPIA: customisation of a water crisis early warning and decision support tool

STATUS	Ongoing
STARTING DATE	June 2022
DURATION	24 months
FUNDING	No
PARTNERS	CNR-IRSA, Civil Protection, Arpa Piemonte
SMAT REPRESENTATIVE	Elisa Brussolo







In the last two decades, the national and regional territory has been affected by numerous water crises, which have affected the main water-using sectors, exacerbated conflicts between these sectors in different territories (over priority use of the resource) and required the implementation of emergency procedures to manage the impacts.
The term water crisis refers to the phenomenon of water scarcity reaching a level of severity that requires a set of procedures to manage the phenomenon.

The identification of early warning indicators of water scarcity, understood as the inability of a system to meet the water needs of its connected users, must take into account the variability of meteorological forcings and medium- to long-term climatic trends, as well as the specific infrastructure and management characteristics of each system.
The decision support tool called INOPIA^{QGIS}, developed within the framework of the collaboration agreement between the Department of Civil Protection and the Water Research Institute of the National Research Council, allows for an immediate assessment of the risk of failure to meet demand (water shortage) caused by conditions of significant resource depletion as a result of persistent precipitation anomalies.

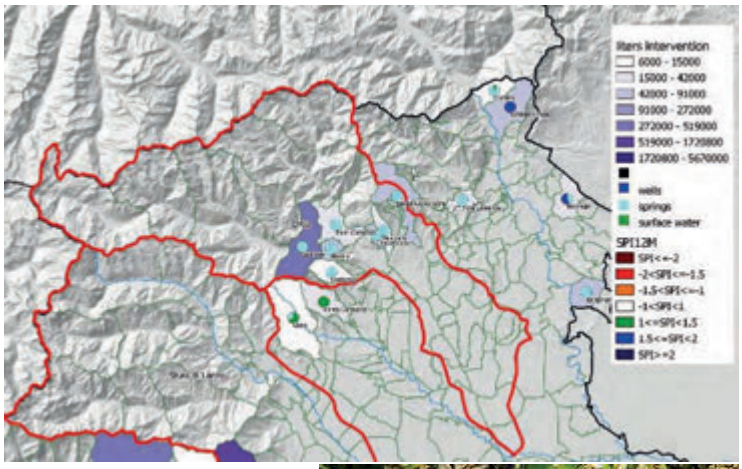
The subject of the INOPIA^{QGIS} analysis is a multi-resource-multiutility system that allows the implementation of the topological scheme of any water system that draws on different types of resources (surface reservoirs, underground reservoirs, springs, drinking water treatment plants, etc.) and feeds a multiplicity of resources. INOPIA^{QGIS} implements the indications of the Guidelines on Water Drought and Scarcity Indicators to be used in the activities of the District Observatories for the Use of Water Resources, prepared by ISPRA.

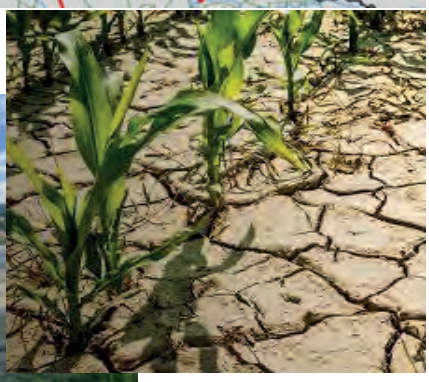
In this context, this research project foresees the application and customisation of the INOPIAQGIS operational decision support system on three initial case studies, in order to have an early warning system for water crises, in order to increase the risk anticipation and management capacity of the Turin area. Within the framework of the collaboration with IRSA-CNR, the Civil Protection Department and ARPA Piemonte, the feasibility of using within INOPIA^{QGIS} the indices for quantifying the precipitation deficit already calculated by ARPA and used to issue monthly hydrological bulletins will be evaluated.
The case studies identify the city of Turin and the municipalities of the Susa and Orco valleys as priority areas for this type of project.

"The numerous water crises in recent years have affected the main water-using sectors and required the implementation of emergency procedures to manage the consequences"

A bottom-up approach for water scarcity risk management

STATUS	Ongoing
STARTING DATE	July 2021
DURATION	24 months
FUNDING	No
PARTNERS	Arpa Piemonte
SMAT REPRESENTATIVE	Elisa Brussolo





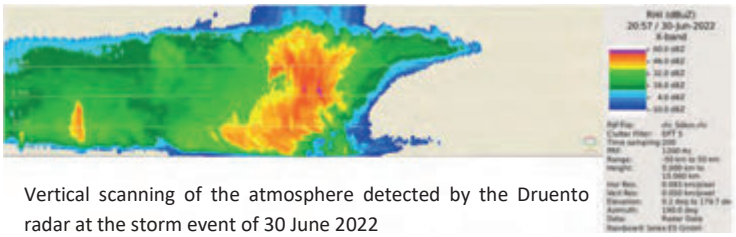
The Piedmont region is located between the Alps and the Mediterranean area, two territories that are recognized as climate hotspot regions, showing amplified climate change signals and associated with environmental, social and economic impacts.
A number of water crisis that affected the Italian territory in the last twenty years exacerbated conflicts in different territories with regard to the priority use of water resource. The recent drought events (2017, 2021, and 2022) have seen areas not normally characterized by this type of phenomenon, such as the Piedmont region, go into crisis, involving all water users and human activities.

In this framework, there is a renewed urgency for improved drought monitoring, forecasting and assessment methods, that will allow for better anticipation and preparation and will lead to better management practices, in order to reduce the vulnerability of Society to drought and its subsequent impacts. As drought can be defined in a number of ways and the determination of drought magnitude and impacts can be quite complex, the top scientific priority and social challenge are the identification of meteo-hydrological precursors of water crises, in order to go from meteo-hydrological drought to socio-economic drought and to drive water management and decision-making with a strong scientific basis.
In this work, focusing on the area managed by SMAT, after identifying the events that have sent in crisis the drinking water supply sources, the meteorological data and appropriate drought indexes have been analyzed. In particular, standardised indices related to the so-called “effective precipitation”, i.e. the difference between precipitation and evapotranspiration (SPEI, Standardised Precipitation-Evapotranspiration Index), hydrological processes (SRI index, that is based on the probability of observing a certain average monthly flow) and snow resource accumulation (SSPI, an index based on the probability of observing a certain snow water equivalent value) were evaluated.
Analyses have shown a delay in the response of the supply system, particularly for networks supplied by sources, which go into crisis following moderate to extreme indices.
In this way, the entire hydrological cycle has been taken into account, critical thresholds and parameters have been identified, and an initial combined index of the above-mentioned "individual" parameters has been proposed, in order to develop an operational chain capable of alerting all stakeholders in the area reasonably in advance.

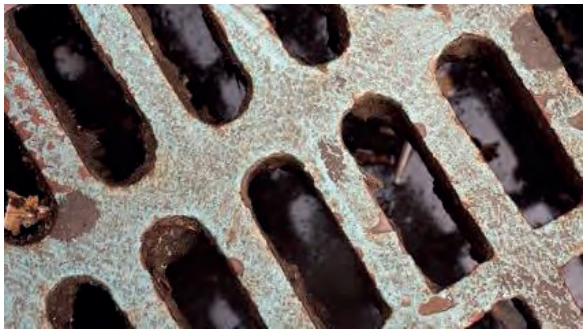
“Prediction and management of water crises through a bottom-up approach based on the analysis of the risk of supply failure for drinking water use”

PrecipiTO: monitoring and nowcasting high-impact precipitation phenomena

STATUS	Ongoing
STARTING DATE	October 2022
DURATION	24 months
FUNDING	No
PARTNERS	Arpa Piemonte
SMAT REPRESENTATIVE	Elisa Brussolo



Vertical scanning of the atmosphere detected by the Druento radar at the storm event of 30 June 2022



Precipitation phenomena capable of creating criticality and risk situations can be divided into: (i) meteo-pluviometric events with a wide spatio-temporal extension and longer forecast times (flood-type phenomena); (ii) meteo-pluviometric events that are highly localised in space, of short duration, strongly convective in nature, with very rapid evolution and associated with destructive phenomena (hail, flash floods, downbursts, ...).
Events of the latter type, which are becoming more frequent in a changing climate and in areas heavily influenced by human activity, are less predictable and require high and very high resolution models in order to develop truly effective early warning systems.

In this context, SMAT manages some infrastructures that are particularly critical to intense and localised precipitation events, such as road underpasses (about 20 points in the city of Turin and in some municipalities of the first belt). In order to improve the management and safety of these infrastructures, with this project we intend to provide the company with an alert system for the best possible management of meteo-hydrological criticalities related to intense and rapid precipitation events.
To this end, it is intended to develop a short-term forecast service (nowcasting), integrating high-resolution numerical models and observed precipitation data with an equally high spatial resolution, homogeneous over the territory and accurate, in order to carry out an appropriate validation (and calibration) of the modelling chain.
The project, developed with the Natural and Environmental Risks Department of ARPA Piemonte, consists of three phases:

1. Construction of spatially uniform, high-precision precipitation fields: to this end, data from the ARPA Piemonte radar mosaic (resolution 800 m, frequency 5 minutes), the X-band research radar installed at the SMAT well field in Druento (resolution 150 m, frequency 2 minutes), the ARPA Piemonte rain gauges network and the SMAT rain gauges network will be cross-referenced;
2. Development of a nowcasting model on the areas/points of greatest interest to SMAT;
3. Integration of the early warning system into SMAT's Scada.

"For highly localised convective rainfall phenomena, very high resolution models are required in order to be able to develop truly effective early warning systems"

Climate risk analysis and adaptation plans

STATUS	Ongoing
STARTING DATE	June 2022
DURATION	18 months
FUNDING	No
PARTNERS	CMCC
SMAT REPRESENTATIVE	Elisa Brussolo

It is now accepted by the scientific community that the Mediterranean is a climate change hotspot.
Available climate scenarios indicate that the Mediterranean basin will experience a progressive worsening of climatic conditions during the current century, with strong changes in seasonal rainfall patterns and an increase in extreme phenomena related to both precipitation and intense temperatures.
The climate changes expected from these projections will have a direct impact on, for example, the availability of water resources (both surface and groundwater), floods and heat waves, with worrying consequences for the environment and the well-being of society.

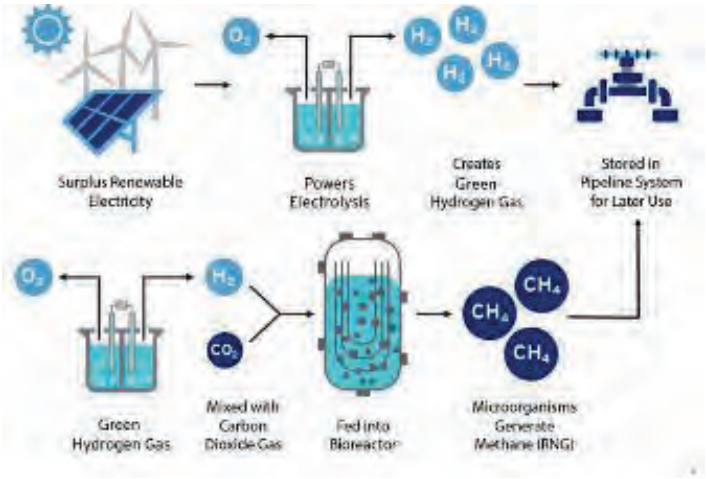
Given the multiplicity of elements and actors involved and the importance of the ultimate goal, the Integrated Water Service (IWSS) is highly vulnerable to possible disruptions, including those that may be caused directly or indirectly by climate change. It is therefore vital to quantify and analyse the risks posed by climate change and to take appropriate adaptation measures.
The aim of this research project is to provide elements that can support SMAT in the definition of climate change adaptation and risk reduction strategies, also in response to EU requests for alignment with the EU taxonomy regarding the climate change adaptation objective.

In this first part of the project, with the support of the Euro-Mediterranean Center on Climate Change (CMCC), the climate hazards to which SMAT's activities are mainly exposed have been identified and the spatio-temporal assessment of these hazards through specific climate indicators is underway.
For this assessment, the highest resolution climate model ensemble available from the EURO-CORDEX programme was considered, analysing three different CMIP5 emission scenarios (i.e. RCP2.6, RCP4.5 and RCP8.5) for two time horizons: 2050 and 2065.
In the second phase of the project, this information will be cross-referenced with SMAT data and spatial vulnerability maps to assess the relevance of physical climate-related risks and prepare adaptation plans where necessary.

"Provide elements to support SMAT in defining climate change adaptation and risk reduction strategies"

Hydrogen production and methanation

STATUS	Ongoing
STARTING DATE	June 2020
DURATION	36 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
LEADER	Polytechnic University of Turin
SMAT REPRESENTATIVE	Gerardo Scibilia



"Power-to-gas" is a promising approach as a solution to the lack of programmability of renewable energy sources, especially photovoltaic and wind power. This is the possibility to convert the renewable source energy over-productions into combustible gas (therefore transforming the electrical energy into chemical energy) that can be stored and transported.
An example is the electrochemical production of hydrogen which is, however, an energy vector with a still limited diffusion because of the lack of infrastructures.

Until hydrogen economy will be fully developed, combining "green" hydrogen with biogenic CO2, to produce renewable methane enables the use of natural gas distribution grid for storing and transporting, in chemical form, the excess of renewable energy in case of overproduction.
With this perspective, wastewater treatment plants represent an excellent location for power-to-gas installations, for at least a couple of reasons:

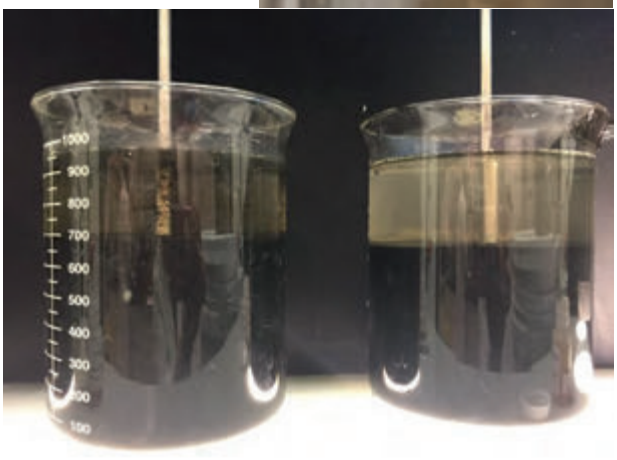
- in plants equipped with anaerobic digestion, CO2 in biogas could be combined with hydrogen in order to produce additional renewable methane (biological methanation).
- besides hydrogen, also oxygen is generated from water hydrolysis, which can be favourably used for the aeration of aerobic biological processes of water treatment.

In the first phases of the project, we set up two laboratory reactors and we performed tests of biological in-situ and ex-situ methanation of hydrogen. Next activities will be aimed at the optimisation of operative process parameters and energetic yield, and at technical-economic feasibility assessment of the solution.

"Wastewater treatment plants represent an excellent location for power-to-gas installations"

Resource recovery and consumption reduction

STATUS	Ongoing
STARTING DATE	September 2022
DURATION	24 months
FUNDING	No
PARTNERS	\\
SMAT REPRESENTATIVE	Gerardo Scibilia



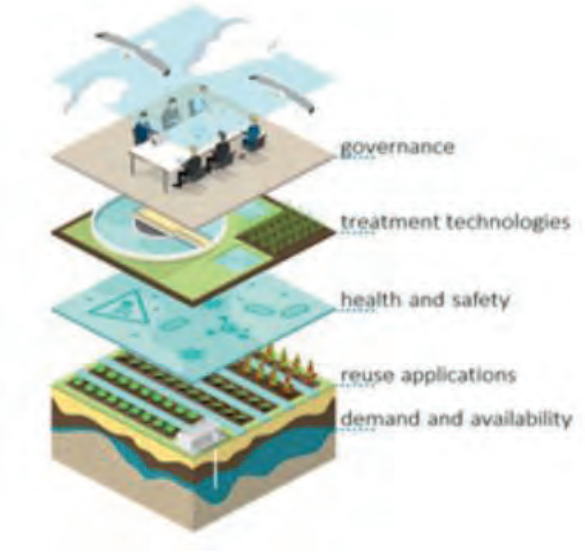
This research project, following two parallel research/experimental lines, is focused on studying plant and process solutions for chemical use optimization in wastewater treatment (in particular those used for phosphorus removal), biogas production maximization and nutrient recovery

The first phase of the project is focused on an assessment for the introduction of a phosphorus crystallization process in the form of struvite (phosphorus and ammonium salt) from sewage sludge after anaerobic digestion. This approach is coupled with the ongoing experimentations on biological phosphorus removal.
Some tests will be dedicated to the optimization of chemical dosage, even different from the traditionally used ferric chloride, in order to chemically bound the phosphorus released by phosphorus accumulating bacteria (PAO) during anaerobic digestion.
The second phase of the project will be dedicated to the chemically enhanced primary sedimentation (CEPT) process by inorganic and/or organic coagulants/flocculants dosage. These chemicals will be able to remove colloids and increase COD in primary sludge sent to anaerobic digestion. The objective is to increase the organic load addressed to biogas production, rather than to biological oxidation, reducing at the same time the energy consumption for aeration.
In order to keep unchanged denitrification performance, we will study a primary sludge fermentation process for the production of readily biodegradable COD.

"The research project is focused of studying solution aimed at chemical use reduction, biogas production maximization and nutrient recovery"

Water reuse: solutions and opportunities to adapt to a changing climate

STATUS	Ongoing
STARTING DATE	December 2022
DURATION	24 months
FUNDING	No
PARTNERS	UNITO, Butterfly Area, UTILITALIA
LEADER	UNITO
SMAT REPRESENTATIVE	Rita Binetti

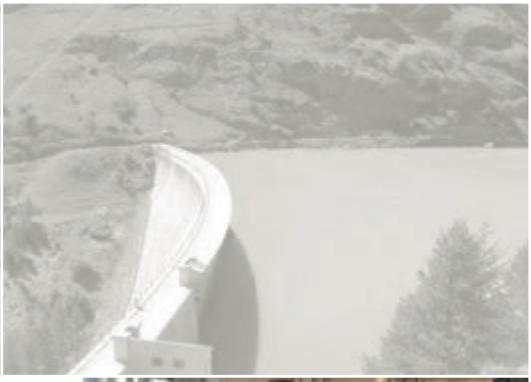


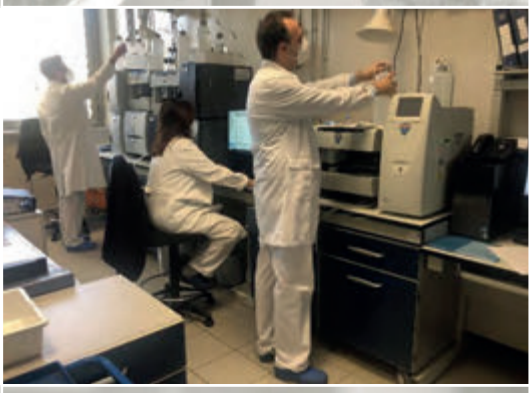
To respond to increasing water stress, reduce pressure on resources and increase their availability, wastewater reuse represents an opportunity, also in the context of the transition to a circular economy. Compared to the potential, only a few percent of water is reused in both Europe and Italy; agriculture is the most water-intensive sector, and rising temperatures and droughts favour a further increase in water demand.
To address these critical issues and facilitate adaptation to climate change, Regulation 2020/741 was adopted by the European Parliament and the Council on 13 May 2020, laying down minimum requirements for the reuse of treated wastewater in agriculture for irrigation purposes, which will apply from 26 June 2023.
The main objective of the Regulation is to promote the wider use of this practice in agriculture in countries and areas where it is appropriate and cost-effective.

In addition to setting minimum requirements, the regulation bases safety guarantees on the assessment and management of risks along the entire supply chain: from the production of purified water to its transport, storage and use. In Italy, a new presidential decree is currently being adopted to harmonise national regulations with European regulations on the reuse of purified and refined wastewater for different purposes and to introduce the new site-specific risk management method.
With the aim of tackling the issue of water reuse from a multidisciplinary approach, the University of Turin, through the Butterfly Area (the science and technology hub dedicated to companies and research institutions - City of Science and Environment in Grugliasco), in collaboration with Utilitalia, SMAT and the various stakeholders, has set up a working table. The Water Reuse Table proposes itself as an interlocutor to create collaborations, synergies and projects to face and combat the water crisis. A wide range of issues will be discussed in depth, from the criteria for allocating funds to infrastructure, to the correct distribution of responsibilities, to the need to ensure adequate coverage of operating costs.
By identifying the needs, criticalities, drivers and restraints of institutions, managers and potential users, it is possible to outline a virtuous policy involving all stakeholders for the proper management of an increasingly precious commodity such as water, including its reuse.

"Identifying models and solutions for water reuse in a scenario of water scarcity caused by the effects of climate change"

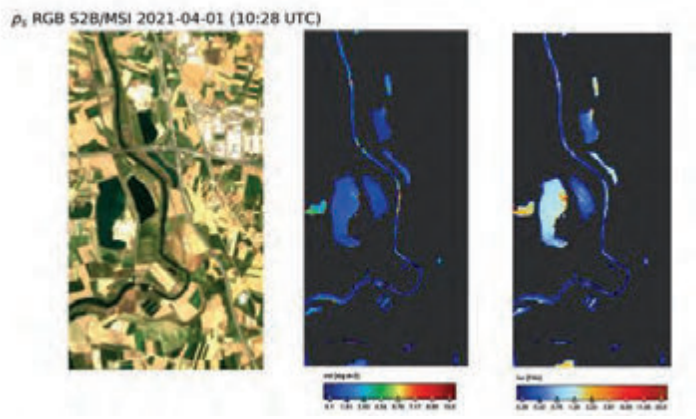
Analysis/Quality





CALLISTO: Copernicus Artificial Intelligence Services and data fusion with other distributed data sources and edge processing to support DIAS and HPC infrastructures

STATUS	Ongoing
STARTING DATE	January 2021
DURATION	36 months
FUNDING	Yes
PARTNERS	16 international partners
LEADER	Serco S.p.A.
SMAT REPRESENTATIVE	Beatrice Coloru



Created in line with the European Commission's Destination Earth Initiative, the CALLISTO project will develop Artificial Intelligence solutions to integrate data from heterogeneous sources (including Copernicus satellite data) and facilitate their use for (1) EU Common Agricultural Policy (CAP) monitoring, (2) surface water quality assessment, (3) journalism, and (4) border monitoring.

Operators of plants that treat surface water for drinking purposes need sensors for water quality variables that have high spatial and temporal resolution, and remote optical sensors could meet these requirements by detecting changes in backscattered light spectra from the water surface. The products to be developed by the technical partners of CALLISTO project, to be integrated into a single, easy-to-access user-interface platform, are the following: i- an automated processing data chain with near real time validated atmospheric corrected water reflectance products that leads to novel and fine-tuned water quality products (Suspended Particulate Matter, Chlorophyll-a, phytoplankton groups); analysis ready datasets for future AI models training, validation and testing; iii- a multicorrelation analysis between algal blooms and environmental data, for the identification of possible causal relationships; iv- a tool capable of predicting the evolution of algal bloom events, to correlated parameters and satellite data; v- a tool capable of generating hyperspectral signals from multispectral signals, using deep neural network techniques, to provide advanced water quality products from Sentinel 2 images even in relation to unmonitored basins. During the first year of the project, satellite data from two basins (Blankaart in Belgium and La Loggia Lagoon on the Po River) were collected and processed. Autonomous hyperspectral radiometers were installed at Blankaart to obtain continuous data essential for calibrating atmospheric correction algorithms and improving the accuracy of water quality monitoring products. During the second year of the project, some sampling campaigns were carried out on the La Loggia basin, in conjunction with the satellite passage, in order to collect some analytical data that could be compared with the results obtained from satellite image analysis.

"The sampling campaigns on the La Loggia basin were carried out in conjunction with the satellite passage, in order to collect analytical data comparable with the results of satellite image analysis"

Extension of legionella risk assessment to all SMAT workplaces

STATUS	Ongoing
STARTING DATE	May 2022
DURATION	13 months
FUNDING	No
PARTNERS	\\
SMAT REPRESENTATIVE	Sara Steffenino

Legionella, as expressly indicated also by the WHO, is the waterborne pathogen that produces the highest health burden in Europe.

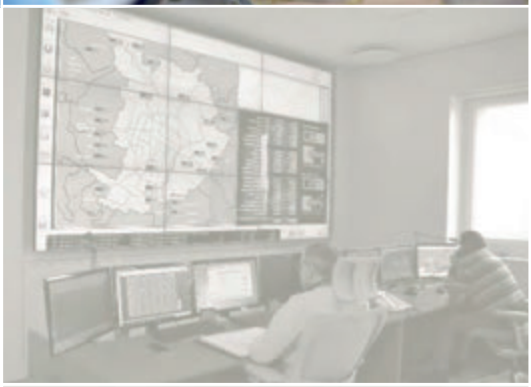
As part of the prevention of legionellosis, risk assessment is the first step to identify and evaluate the critical aspects in order to be able to proper manage them, identifying the most suitable preventive and corrective measures useful to reduce the risk.

A first project, "Legionella risk assessment in the workplace" (LRC_AC_2021_07), had the objective of defining a method for risk assessment and management to be applied progressively to all SMAT workplaces.

The project ended with the definition of the Risk Assessment Protocol of one of the most complex SMAT workplace, both in terms of size and plant layout; the defined and applied methodology proposes a risk assessment based on three factors: 1) the plant proliferation potential, 2) the aerosol exposure potential, 3) the susceptible population potential. The first factor is the one that requires greater knowledge of the analyzed system as it is evaluated taking into account the characteristics of the water supply, the presence of any incoming water treatment systems, the characteristics of the internal water system (both cold water and domestic hot water), the maintenance activities already underway and the presence of a monitoring plan. In this second phase of the project, the analysis will be extended to all SMAT manned sites.

"Risk assessment is fundamental in the prevention of legionellosis"

Water Networks



Resilience CSUD: improving drought resilience in municipalities in the southern area of Turin

STATUS	Ongoing
STARTING DATE	May 2022
DURATION	12 month
FUNDING	No
PARTNERS	\\
SMAT REPRESENTATIVE	Edoardo Burzio

The aim of the project is to model the interconnections between the water supply networks of the municipalities in the southern area of Turin. The connection of different networks aims to improve the quality and quantity of the water supply sources and increase the resilience of the related water supply systems with respect to the availability of the resource and the continuity of the service.

Mathematical modeling can provide an important contribution to the interconnection of independent water networks, particularly with regards to system optimization.
Firstly, mathematical modeling can be used to analyze the performance of interconnected water networks, predicting how the system will respond to different operational conditions and emergency scenarios. This can enable system operators to identify critical areas and improve their emergency response capacity.
Secondly, mathematical modeling can be used to optimize the operation of the water system, for example by determining the optimal network configuration or control strategy to ensure a balance between water quality, available quantity, and system resilience.
In addition, mathematical modeling can be used to determine the best control strategies for pumping systems, reducing energy costs and improving the overall efficiency of the system. For example, mathematical modeling can be used to determine the ideal time for turning pumps on and off, or to establish optimal pumping speeds, in order to minimize energy consumption without compromising the quality and quantity of water supplied.
Overall, mathematical modeling can provide an important tool for the optimization and management of interconnected water networks, enabling system operators to make more informed, data-driven decisions to ensure adequate supplies of high-quality water for all consumer needs.

"Mathematical modeling is the optimal tool to optimize the interconnection of independent water networks, improving the quality, quantity, and resilience of the water supply"

Methods and tools for optimising leak detection and water network replacement plans

STATUS	Ongoing
STARTING DATE	March 2022
DURATION	22 month
FUNDING	No
PARTNERS	Hera SpA, Iren SpA, A2A ciclo idrico
LEADER	Hera SpA
SMAT REPRESENTATIVE	Marco Scibetta

The project is part of the initiatives envisaged by the partnership agreement between A2A - Hera - Iren - Smat aimed at management effectiveness and efficiency, favoring the adoption of innovative solutions in terms of technology and management practices.
The project aims to analyze and select the best practices and the most effective tools for optimization:

- the scheduled search plans for leaks;
- network replacement plans.

The activity underlying the project consists of sharing significant experiences related to:

- tests (of any level and extension) of innovative technologies proposed by the market;
- methods and algorithms developed in-house.
-

The project intends to develop the following macro-themes:

- methods and technologies for pre-localization and localization of losses;
- algorithms and tools for selecting and prioritizing "critical" sections in support of the definition of planned loss research plans and water supply network replacement plans.

The following topics, although related to the project, are considered outside the scope of the project as they are adequately covered by the partners with a different and progressive level of development:

- criteria and methods for designing, implementing and managing districts;
- technologies for advanced control, regulation and pressure management.

The activities related to the project are expected to be developed without the need for specific external specialist support. Each partner is free to use external support of any nature, disseminating the content of the related activities to the extent permitted by intellectual property agreements.

"The project is part of the Partners' initiatives oriented towards effectiveness and management efficiency, favouring the adoption of innovative solutions in terms of technology and management practices."

Feasibility study for providing a remote monitoring service for water distribution network leak detection

STATUS	Ongoing
STARTING DATE	November 2021
DURATION	20 months
FUNDING	No
PARTNERS	DigiSky, ESA, EnelX, e-Geos
LEADER	DigiSky
SMAT REPRESENTATIVE	Marco Scibetta

The ever-increasing availability of satellite data acquired by various space missions, often made available to users in an open and free way, combined with the growing ability to transform these data into information, makes it possible to create innovative services useful in different framework. The approach currently used for the assessment of water losses in distribution is expensive because it must be carried out step by step to cover the whole distribution network.

This is why SMAT is participating in a feasibility study, promoted by DigiSky in collaboration with ESA and EnelX, together with e-Geos, with the aim of evaluating the effectiveness of three different technologies: i) survey with a thermal camera mounted on an airplane; ii) survey with L-band SAR radar mounted on an airplane; iii) survey with X-band SAR radar from a satellite. The first technology was tested with the aim of verifying temperature anomalies in areas with known leaks; with the L-band SAR radar, instead, variations in the dielectric constant of the terrain are intended to be detected; with the last technology, on the other hand, ground subsidence (even millimetric) that could be correlated with water pipe leaks can be identified. At the moment, no significant correlations have been found with the first technology tested, while the data acquired with L-band SAR radar are being processed. The data acquired with X-band SAR radar (an hystorical series of 3 years, from 2019 to 2022) have instead been processed and are currently available for consultation on a dedicated platform.

"The satellite data, combined with the data acquired from aerial systems, will be processed in order to identify water leakages in the water distribution network"

Monitoring and remote control of sewerage network connected to Castiglione Torinese treatment plant

STATUS	Ongoing
STARTING DATE	December 2021
DURATION	24 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
SMAT REPRESENTATIVE	Marco Scibetta

The project aims to analyze and improve the management of the waste water network (WWN) connected to the waste water treatment plant located in Castiglione Torinese. The WWN analyzed in this study allows the transport of wastewater produced by users distributed in 48 municipalities in a safe and controlled manner.

It is intended to improve the management of the WWN, consisting of three main channels, (North, West and South), in addition to the channel that collect Turin waste water, through an approach that allows to know the status in real time of all the physical variables involved in order to guide the operational management choices using a scientific-based methodology.

It will be possible to obtain this result through the use of data collected by flow and water level monitoring stations that will be installed along the channels. These data will be integrated with the results of mathematical modeling of the whole system. Mathematical modeling will also allow verifying the functionality of the system by simulating particular situations in order to predict any critical issues.

The project, currently under development, sees collaboration with the hydraulic research group of the Turin Polytechnic, which is dealing with the aspects related to mathematical modeling, and involves, in addition to the Research Center, which is entrusted with the coordination of various activities, the Operations Centers and the Central Technical Services.

"The project aims to analyze and improve the management of the waste water network that allows the transport of wastewater produced by users distributed in 48 municipalities in a safe and controlled manner"

Modelling and criticality analysis of the Turin urban drainage system

STATUS	Ongoing
STARTING DATE	December 2020
DURATION	24 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
SMAT REPRESENTATIVE	Marco Scibetta

The last analysis of Turin's urban drainage system dates back to about 50 years ago. Since then, three events have occurred that have greatly changed the hydraulic situation: (i) increase in waterproofed urban soil in exiting areas, (ii) the construction of new urbanized areas and (iii) climate change.

The urban change that the town has undergone in the last 50 years is evident, with a sharp increase in the waterproofing of the surfaces and the growth of the drainage areas. In several areas of the Turin area, the situation is so compromised that the establishment of new residential and / or industrial areas could be fatal for the urban drainage system.

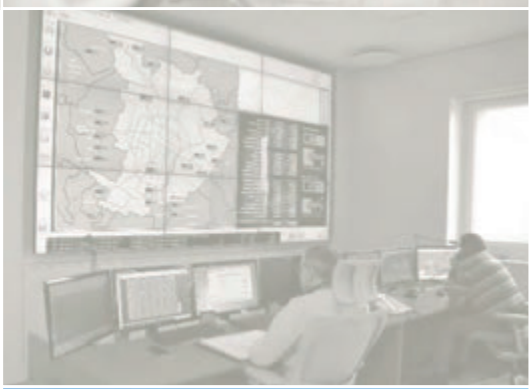
Another key aspect is the imminent construction of the new Turin median collector. This is a work destined to have a strong impact on the structure of the urban outflow and which, if properly harmonized with the hydraulic context of the existing network, can make a fundamental contribution to making the Turin drainage system safe in future decades.

Finally, there are climate changes, which are evident to everyone in daily experience. In particular, the increase in very intense events, precisely those that most create problems for the drainage network.

Faced with this picture, an accurate and complete analysis of the current network is therefore urgent, of how it will respond to the growing pressure in the coming years, of what actions can be taken to mitigate the risks of flooding and breakdowns and how it can hydraulically interact with the new median manifold. This study is trying to answer these questions.

"An accurate and complete analysis of the current network is therefore urgent, of how it will respond to the growing pressure in the coming years, of what actions can be taken to mitigate the risks of flooding"

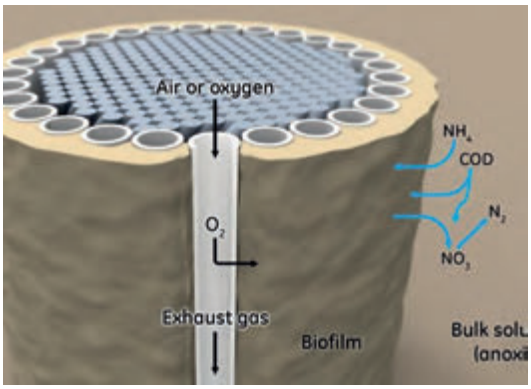
Treatment



MABR

Membrane Aerated Biofilm Reactor

STATUS	Ongoing
STARTING DATE	June 2020
DURATION	36 months
FUNDING	No
PARTNERS	Polytechnic University of Turin
LEADER	Polytechnic University of Turin
SMAT REPRESENTATIVE	Gerardo Scibilia



Biological waste water treatment processes are notoriously energy intensive, especially the aerobic ones that consume oxygen for the oxidation of organic and nitrogen substances. In facts oxygen transfer from gas phase to liquid phase (namely the dissolution) is a relatively limiting factor.
Common aeration systems, based on the production of small air bubbles trough diffusers installed at the bottom of the tanks, are characterised by an oxygen transfer efficiency generally in the order of 20%.

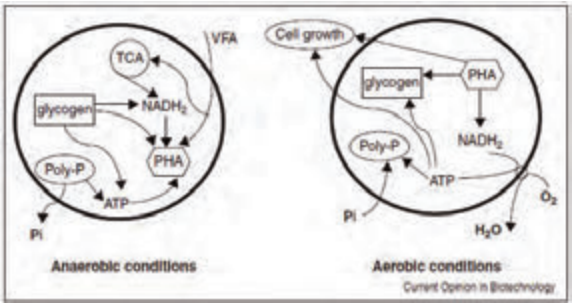
A recent and really promising technological innovation, called MABR (Membrane Aerated Biofilm Reactor), provides for the use of hollow fibre membrane for oxygen transfer in liquid phase. Air is blown inside the hollow fibres immersed in oxidation tanks and oxygen is directly consumed by biomass developed on membrane external surface. By this way there is not more need for producing air bubbles to achieve oxygen transfer, and aeration energy efficiency is greatly increased. Moreover, oxidising conditions develop only inside the biofilm at membrane interface, making possible the denitrification, in anoxic conditions, in the same biological reactor.
In the framework of the project, we set up a laboratory pilot MABR and we performed experimental tests for the measurement of oxygen transfer efficiency, and fed batch tests with synthetic wastewater. Lately we started experimental test with continuous stirred tank reactor configuration (CSTR). The purpose of the research project is the experimental test of MABR technology performances, as well as assessing strengths and possible weaknesses and their applicability to SMAT plants.

"The purpose of the research project is the experimental test of MABR technology performances"

Biological phosphorus removal

STATUS	Ongoing
STARTING DATE	May 2022
URATION	24 months
FUNDING	No
PARTNERS	HERA, IREN, A2A, Polytechnic University of Marche
LEADER	A2A
SMAT REPRESENTATIVE	Gerardo Scibilia

Phosphorus removal is of primary importance in wastewater treatment processes, for the protection of receptor water bodies.



Besides the traditional process of phosphorus removal by chemical precipitation, increasing attention is being focused on biological removal process that, in addition to chemical savings, allows to recover phosphorus in form of struvite that can be used as a fertilizer in a circular economy vision.

The purpose of this research project, in collaboration with HERA, IREN, A2A and Polytechnic University of Marche, is studying the process configuration for biological phosphorus removal implementation in wastewater treatment plant, assessing management, technical and economic aspects.
Particular attention will be focused on monitoring/control parameters and systems, on limiting and inhibiting factors, as well as on the identification of optimal process management strategies.
Then we will perform a technical-economic feasibility assessment of the implementation of this process in some wastewater treatment plants managed by the utilities involved in the project, identifying the optimal plant configuration and considering the effects on sludge line reject waters, following a phosphorus recovery perspective.
The first project activities have been dedicated to the identification of wastewater treatment plants to be analysed and to the collection of plant and process data for feasibility assessments.

"The purpose of this research project is studying the process configuration for biological phosphorus removal implementation in waste water treatment plant"

Research articles and proceedings

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G. Campo, B. Ruffino, A. Cerutti, G. Scibilia, M. De Ceglia and. M.C. Zanetti: Combined production of biogas and volatile fatty acids from a pure primary sludge: preliminary results of a pilot test, 9th International Conference on Sustainable Solid Waste Management. Corfu, Greece, 15 - 18 June 2022.

G. Campo, A. Cerutti, M.C. Zanetti, G. Scibilia, M. De Ceglia and B. Ruffino: Toward the energy self-sustainability of a WWTP. Thermophilic Temperature-Phased Anaerobic Digestion (TPAD) as biological pretreatment to increase the WAS anaerobic biodegradability, 6th Symposium on circular economy and urban mining 10th anniversary. Capri, Italy 18-20 May 2022.

D. Papagiannaki, D. Palma, A. Cedrino, G. Molinari, M. Lai, M. Minella, R. Binetti: Degradation of PFASs in Aqueous Solutions by Non-thermal Plasma Water Treatment Process, 11th European Conference on Solar Chemistry and Photocatalysis: Environmental Applications (SPEA), Turin, Italy, June 6-10, 2022.

Presentations

Binetti R. Master II Livello in Virologia Ambientale, Università degli Studi di Torino, 1 aprile 2022. Presentazione orale: "Le matrici ambientali coinvolte nella diffusione dei patogeni: l'esperienza di SMAT".

Binetti R. UNITRE, Pino Torinese, 3 novembre 2022. Presentazione orale: "Acqua: un bene prezioso da salvaguardare"

Brussolo E. Celebrazioni per la Giornata Mondiale dell'Acqua 2022, Torino, 22 marzo 2022. Presentazione orale: "Gestione e salvaguardia della risorsa idrica: dalla storia dell'acqua che alimenta i campi pozzi agli impatti dei cambiamenti climatici".

Brussolo E. ADO project meeting, 31 Marzo 2022. Presentazione orale: "River Orco Valley: a bottom-up approach".

Brussolo E. Workshop "City Water Circles closing conference", Spalato, 9 giugno 2022. Roundtable discussion on stakeholder involvment to develop circular water management in Europe.

Burzio E. Festival dell'Acqua, 23 settembre 2022, Torino. Presentazione orale: "Industrial and applied research" (meeting Utilitalia – IWA about the young water professional (YWP) initiative)

Scibetta M. Festival dell'Acqua, 23 settembre 2022, Torino. Presentazione orale: "L'esperienza di SMAT nel contenere le dispersioni idriche: aspetti critici, tecnologie e possibili soluzioni«

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