LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

# URBAN WATER CHALLENGES

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Urban water unit
Hydraulics and Environment Dept.
LNEC – National Civil Engineering Laboratory

4th June 2019

# LNEC in 1 minute…

> National Civil Engineering Laboratory

> State owned R&D institution

> Founded in **1946**

> 22 ha campus, in Lisbon, close to the airport

> Unique **multidisciplinary** perspective in civil engineering

> Innovative R&D, **best practices** in civil engineering, with a key role in advising the government, as an unbiased and independent body

> **28 M€** annual budget, 40% from the National Budget and other sources, 60% own revenue through Sci. & Tech. contracts

> **498 total staff** (researchers, technicians, admin) + research fellows

# LNEC in 1 minute…

Scientific Board

BOARD OF DIRECTORS

Advisory and Control Bodies

Finance and Property Services

Human Resources and Facilities Services

Concrete Dams Department

Buildings Department

Structures Department

Geotechnique Department

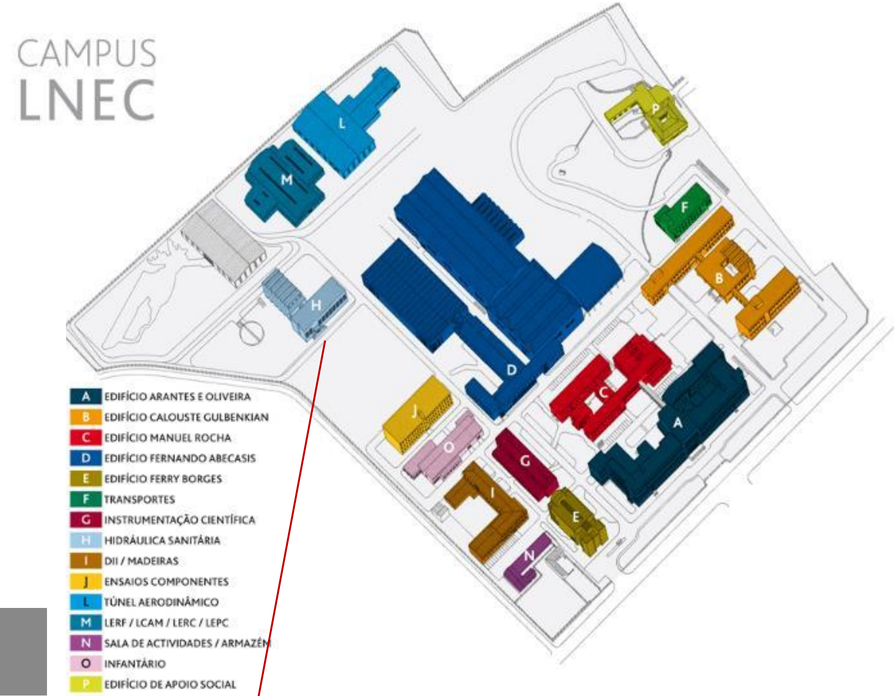
Hydraulics and Environment Department

Materials Department

Transportation Department

Scientific Instrumentation Centre

Information Technologies in Civil Engineering Division




- **Urban water unit**
- **Estuaries and coastal zone unit**
- **Ports and maritime structures unit**
- **Water resources and hydraulic structures unit**
- **Information Technol. in Water & Environ. Research Group**

# Urban water management

## ▼ Challenges

- **More demanding requirements ...**
  - Health and public safety, incl. contaminants of emerging concern
  - Environment protection
  - Circular economy and resource efficiency
  - Infrastructure asset management
    e.g. in PT: 25 000 M€ total
    2000 M€ green-field + 2000 M€ rehab in the next 10-years
  - Economic sustainability and affordability
  - ...
- **Climate dynamics**
  - Natural hazards > cascading effects
- **Collaborative processes**
  - Resources' management
  - Alignment between land management and water management
  - Alignment between different services, organizations, partners

# Urban water management

## Key aspects


- **Water essential to life and socio-economy**
  - “Natural monopoly"
  - Most infrastructures buried (out of sight ...)
  - High value infrastructures
  - Degradation of infrastructure higher than rehabilitation
  - High temporal / spatial variability
- **Recognition of interdependencies**
  - Water - territory
  - Between urban services (water, energy, transport, waste, ...)
- **Water availabilities, uses and functions**
  - Quantity and quality, time-space asymmetries
  - Social / natural uses / functions

# Water in urban areas

## Acting for change

- Capacity building, innovation, co-creation
- Circular economy and resource efficiency (water, energy, …)
- Adaptive management, promotion of change
- Responsible investments and water pricing
- Integrating water management into territorial management, multi-stakeholder

- Transfer of know-how to users, including methods and technologies (hardware and software) and information
- Integrated approaches: systemic, multi and trans disciplinary
- Changing behaviors and practices: responsible consumption, naturalization of urban areas ...
- Portfolio of procedures and solutions directed to multiple objectives
- Infrastructure asset management: performance, cost and risk
- Bridging the gap in water management and spatial planning

# Urban water unit | NES/DHA

- Problem-driven, leading-edge **R & D & innovation** on urban water systems and services - **water supply**, **wastewater** and **stormwater**
- **European** and **national funds** from competitive calls and **industry funds** from **peer-to-peer innovation projects (national initiatives)**, an in-house developed model of project with researchers, IT providers and utilities
- **Advanced consultancy** of water services
- **Regulation** - policy documents, codes, best practice manuals (ERSAR, 2004-…)
- **Standardization** - ISO TC224, TC251, TC282 - CEN 164, 165
- **Capacity building** (institutions and individuals) through **collaborative projects**, advanced courses and training programs for water professionals, PhD and Master students
- 23 total staff, 20 researchers: 12 PhD + 7 PhD students + 1 MSc research grantee

# **R&D&I areas** & ongoing/recent related **projects**

- **Infrastructure asset management (IAM)**
  water networks & WTPs/WWTPs; decision support tools based on a performance-cost-risk integrated approach http://igpi.aware-p.org/, www.trust-i.net, http://icitage.lnec.pt/

- **Water and energy**
  water losses & energy management in water supply systems http://iperdas.org/
  ICT www.i-widget.eu, big consumers (e.g. hotels http://adapt-act.lnec.pt/), hydro-agriculture projects agir, energy efficiency in urban water cycle http://avaler.lnec.pt/

- **Reliability, safety and resilience of urban water systems**
  assessment & control of undesirable inflows into sewers http://iaflui.lnec.pt
  resilient cities, climate change adaptation www.resccue.eu (H2020)

- **Water quality, treatment and reuse**
  natural waters, drinking water, wastewater, water reuse (urban and rural areas)
  conventional, advanced and nature-based treatments (centralized/decentralized)
  process development and pilot prototype demonstration, performance assessment and benchmarking of full-scale plants www.trust-i.net, www.life-aware.eu, www.life-hymemb.eu, www.life-impetus.eu, democon, www.marsol.eu/, http://ieqta.lnec.pt/

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UQTA Water Quality and Treatment Laboratory

# Differentiating factors

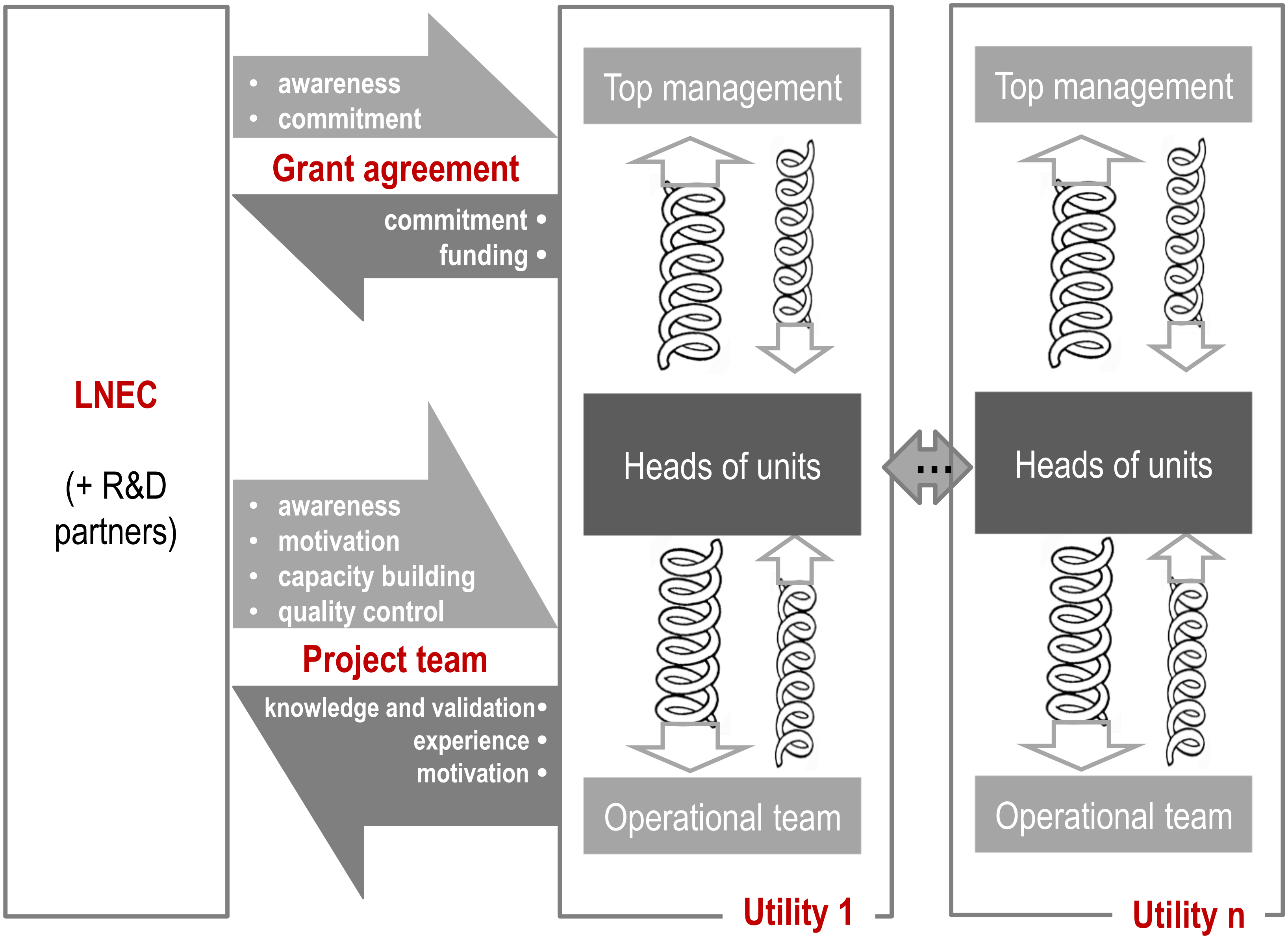
+ Urban water cycle as a whole – "**system approach**"
+ **Knowledge** transformed **into** management and decision **tools**
+ Lab and experimental competences and modelling competences
+ **Multidisciplinary**
+ LNEC "ecosystem" (within the dept., between depts., with hosted organisations)
+ Several solutions offered (e.g. treatment) – impartial advise, **effective benchmarking**
+ Lab-pilot-full scales
+ National and international networking – sound network of partnerships
+ The **full innovation cycle**

# NES strategy


- European projects
- National projects P2020 (FCT, FAI)
- **National initiatives**

- Participation in advisory boards, associations, standardization committees (ISO, CEN)
- Partnerships with consultants and technology providers
- **National initiatives**
- Training/lecturing actions

# **National initiatives.** Peer-to-peer innovation projects



# **National initiatives.** Peer-to-peer innovation projects

**IAM**

| Project | Utilities |
|---|---|
| PI-waters 2000 | 16 |
| iGPI 2012 | 19 |
| iGPI 2015 | 18 |
| iCitage … | 11 |

**Water and energy**

| Project | Utilities |
|---|---|
| INSSAA 2004 | 11 |
| iPerdas 2014 | 17 |
| iPerdas 2016 | 14 |

**Reliability safety and resilience**

| Project | Utilities |
|---|---|
| iAflui 2016 | 13 |
| iAflui 2019 | 7 |

**Water quality, treatment and reuse**

| Project | Utilities |
|---|---|
| PASt21 2009 | 15 |
| iEQTA 2017 | 11 |

LIS-Water
Lisbon International Centre for Water

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Cranfield University

UNIVERSITÉ PARIS 1 PANTHÉON SORBONNE
IAE PARIS
SORBONNE BUSINESS SCHOOL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 763562

Intertwined areas


1+4

# LIS-Water: The new centre of excellence for water

*Better water governance for a better world!*

# A few examples of R&I projects

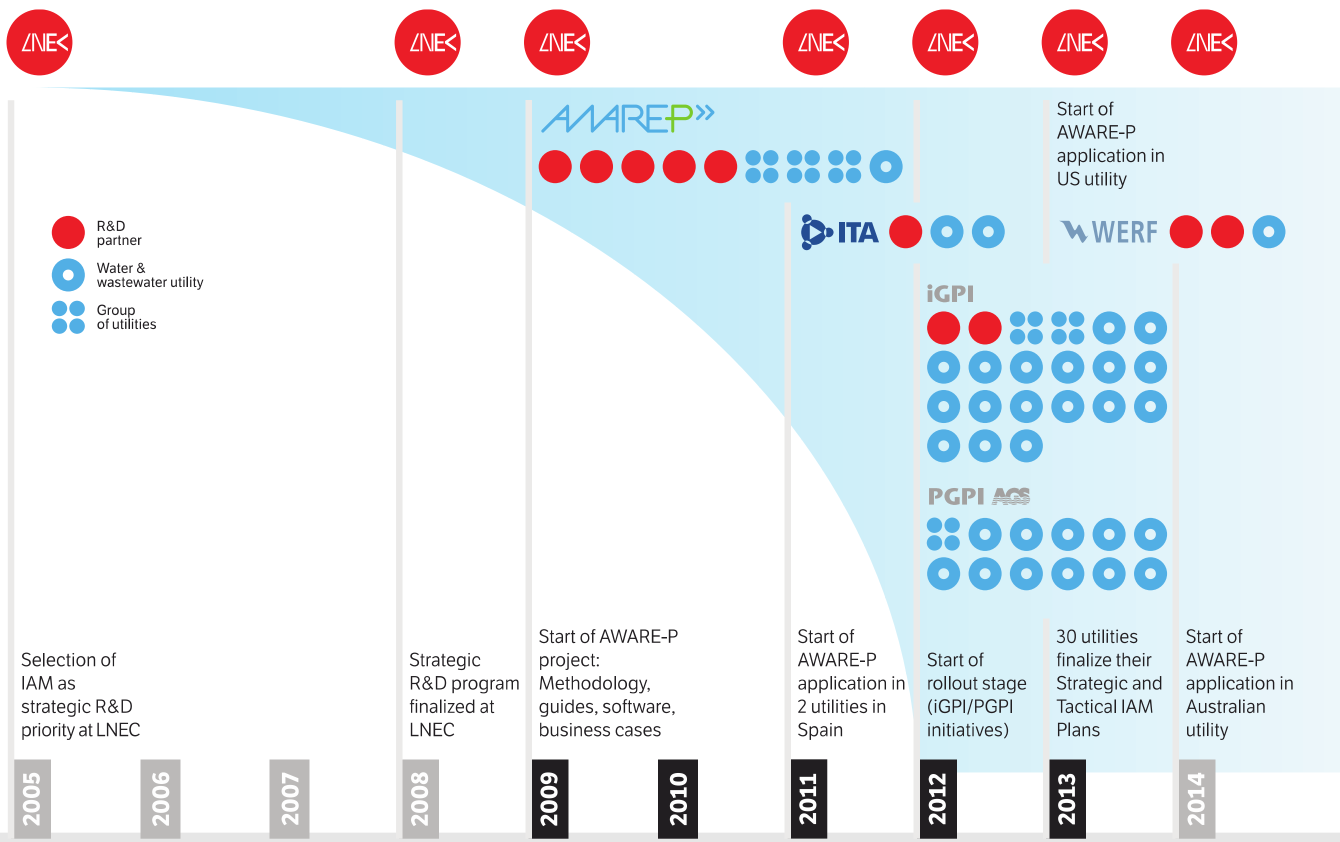
http://www.lnec.pt/hidraulica-ambiente/en/core/urban-water-unit/activity-2/

# IAM. Infrastructure Asset Management

AWARE-P

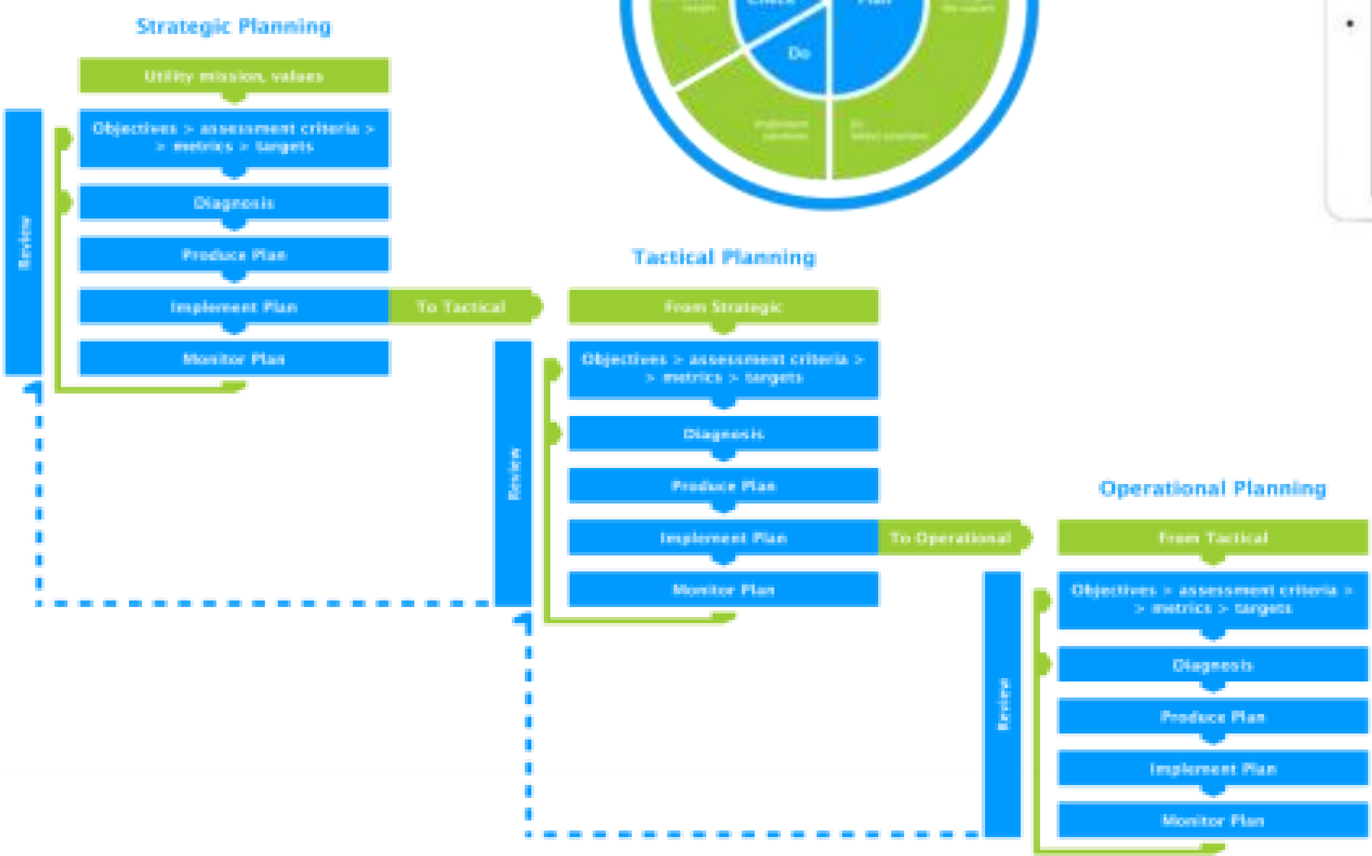
**from incipient to leading-edge IAM planning in Portugal**

## From R&D to the industry

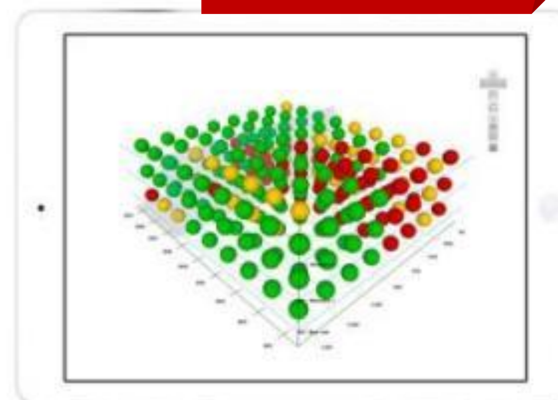


# **IAM.** Infrastructure Asset Management

Knowledge Methodology

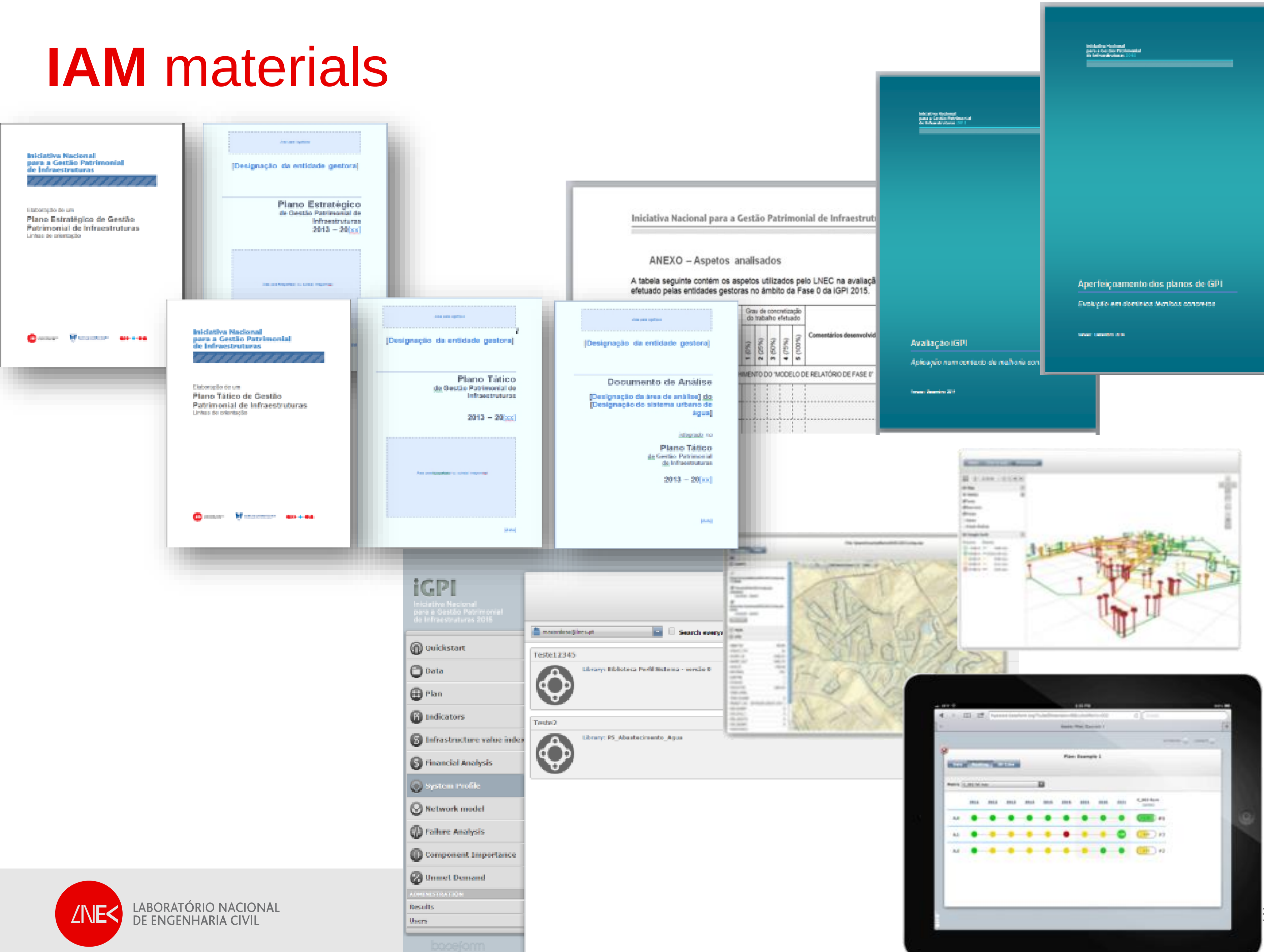




Software and tools

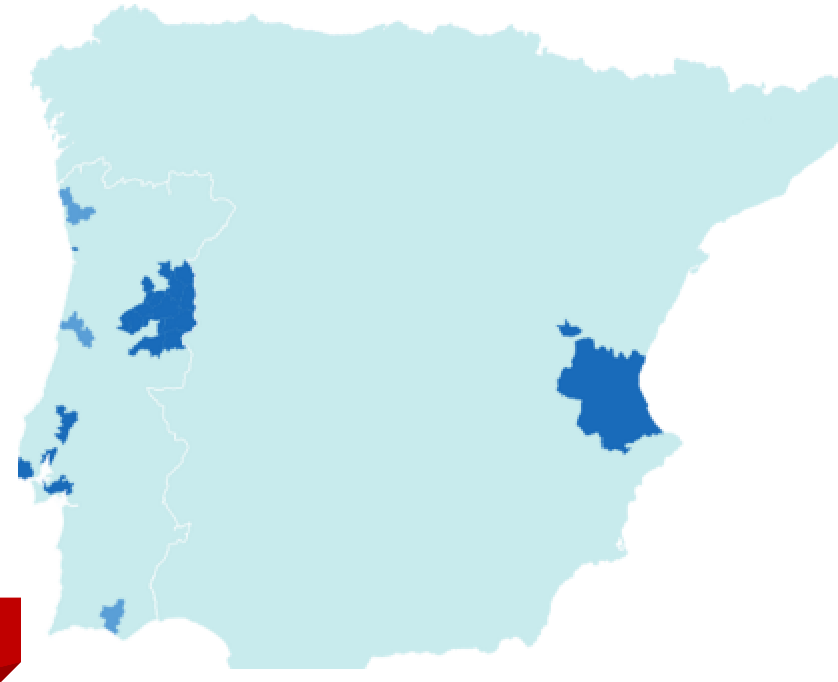


performance-cost-risk

# IAM materials



# IAM results



iGPI 2015

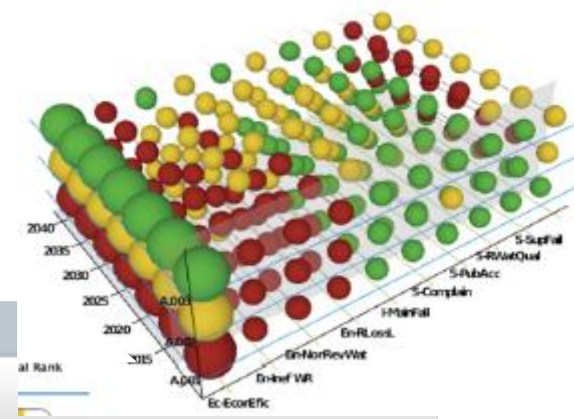
**Direct results of the utilities (IAM plans)**

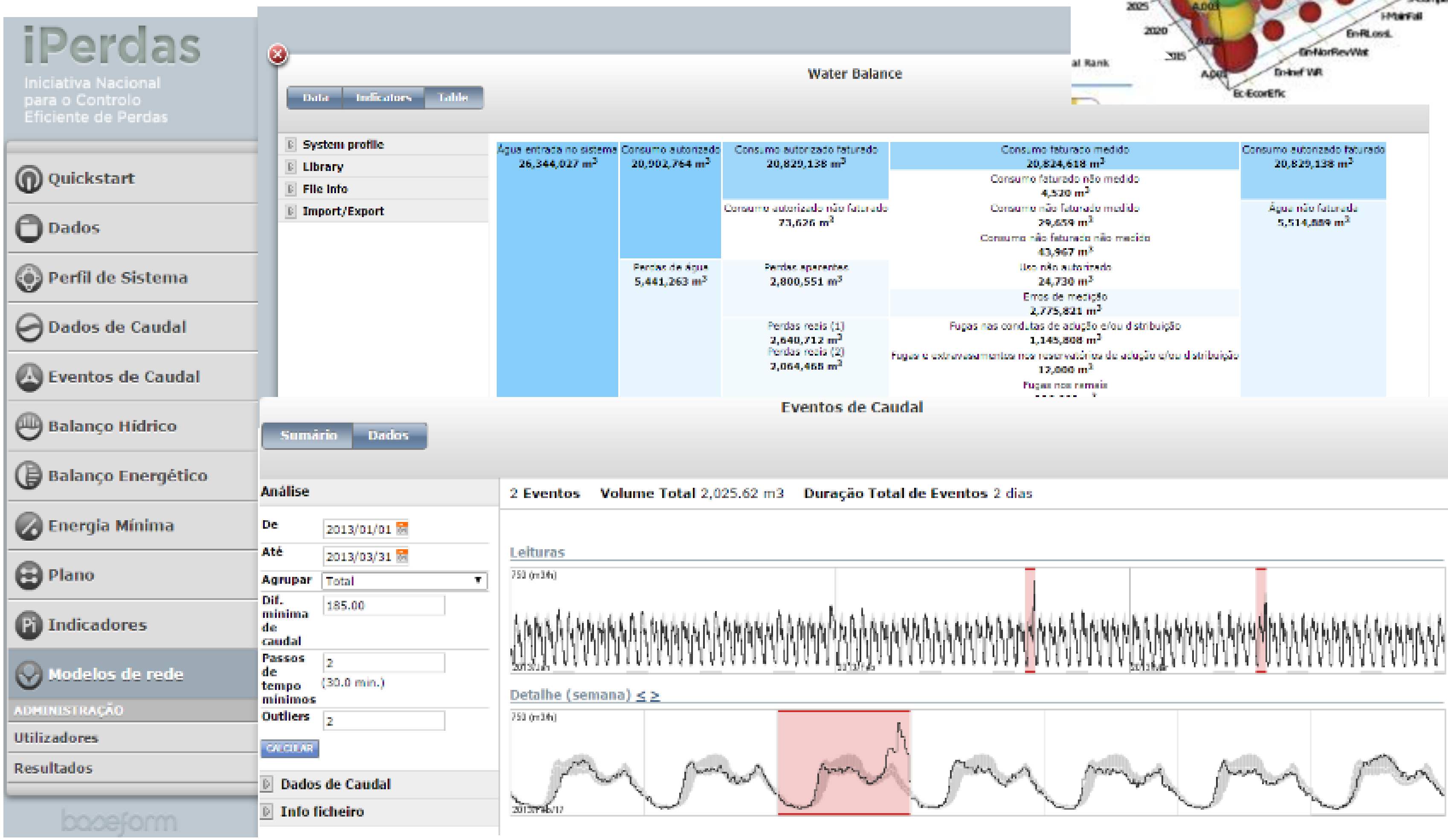
iGPI 2012

**Training and capacity building**

# iPerdas

- Software and instructions
- Supporting documents
- Quick start guides
- e-learning: metering course





# AGIR | Efficiency assessment of water and energy in collective irrigation systems

## In Portugal…

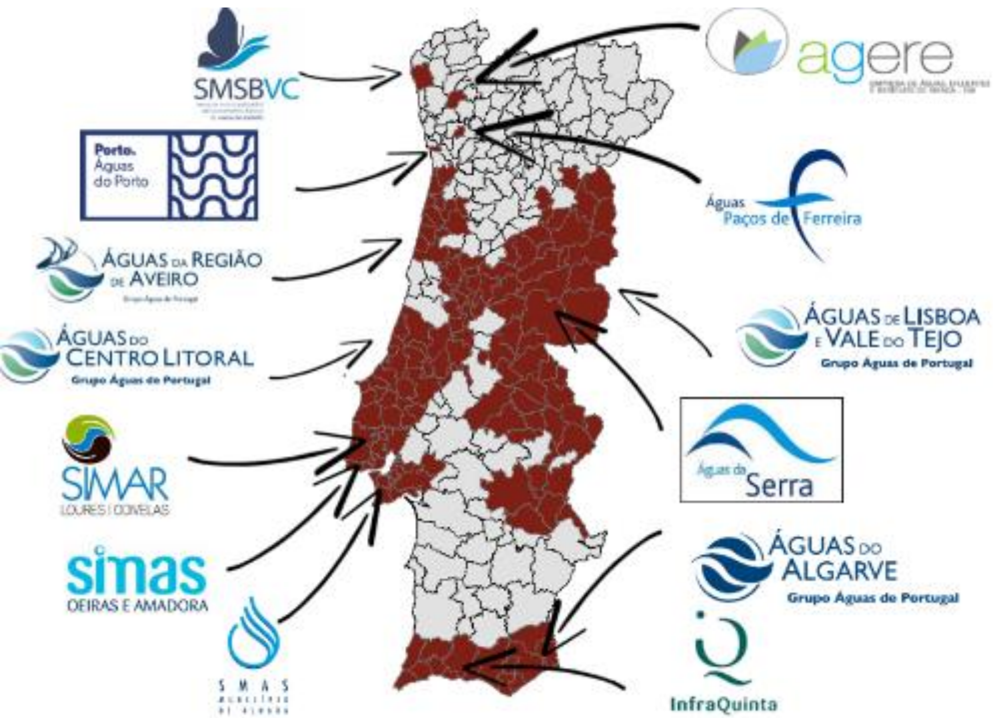
- Water use efficiency in irrigation systems ~ 60-65% (DGADR, 2014)
- Energy consumption in irrigation systems increased from 200 kWh/ha to 1500 kWh/ha between 1960 and 2017 (SIR, 2017)
- Collective irrigation infrastructures in poor condition and labour-intensive (PDR 2020)

## What's necessary?

- Adapt existing and well succeed methodologies from the urban water system to collective irrigation systems
- Develop tools to support diagnosis and decision-making about alternatives to improve efficiency
- Develop an assessment system to promote water and energy management in collective irrigation systems and the definition of public policies

# National Initiatives for the Control of Undue Inflows
2016-2018, 2019-2021

iAFLUI




## Objectives

**Capacity building** of the utility's team

Internalization of a **structured process** for the undue inflows

Development of a **Plan for the Control of Undue Inflows**

# iEQTA

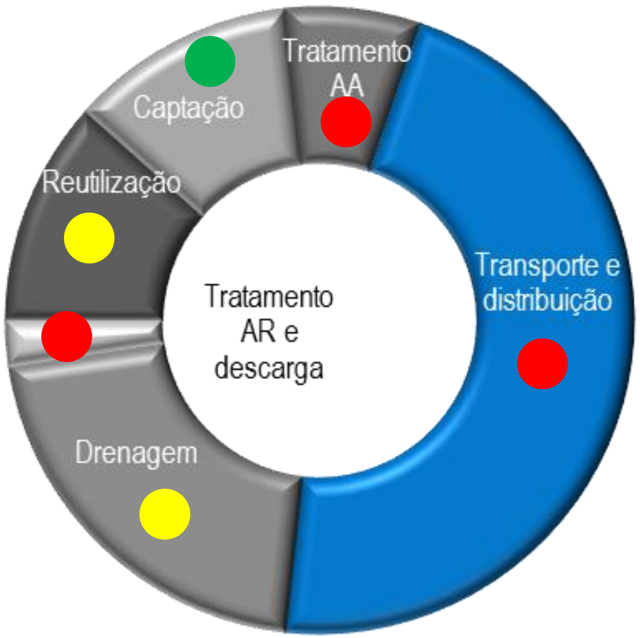
**iEQTA.** Initiative on energy, water quality and treatment | 2017-2019

**WWTP** **IAM** **Tutorials**

| | |
|---|---|
| **Benchmarking WWTPs** (**23 *ETAR***) | AGS, SMAS Município de Almada, Luságua, Águas de Barcelos, Tratave, Porto. Águas do Porto, efacec |
| **Infrastructure asset manag. IAM** (***GPI***) | AGS, SMAS Município de Almada, Aquapor, Águas de Santo André Grupo Águas de Portugal, vimagua |
| **Tutorials** (***Formação***) | AGS, SMAS Município de Almada, Aquapor, Hidurbe |

# Energy efficiency assessment and sustainability of urban water services

- Rational for diagnosis




Energy consumption &
Performance per **stage of the urban cycle, component, process or equipment**

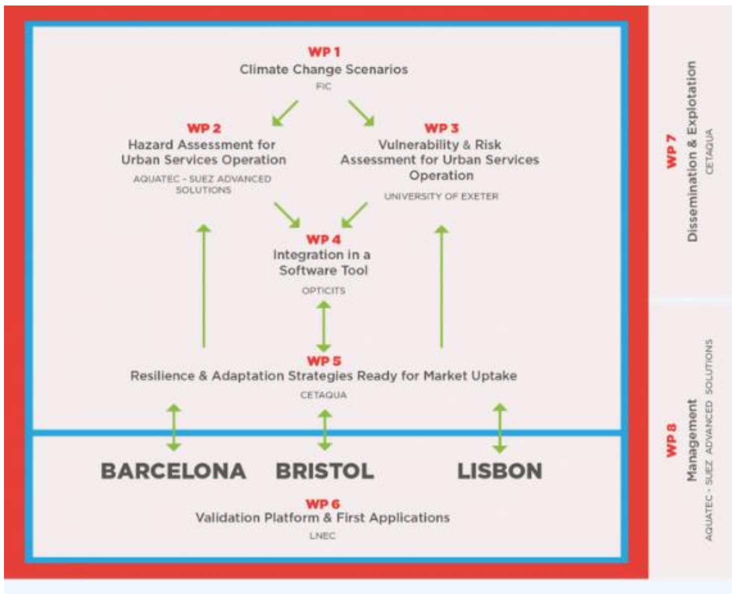
## Expected results

- *Baseline* of the water sector and identification of energy drivers in each stage
- Assessment system for diagnosis and decision support
- Action plan to improve energy efficiency in multiple utilities
- **Energy efficiency measures implemented and monitored**
- **Direct contribution to national energy efficiency targets**

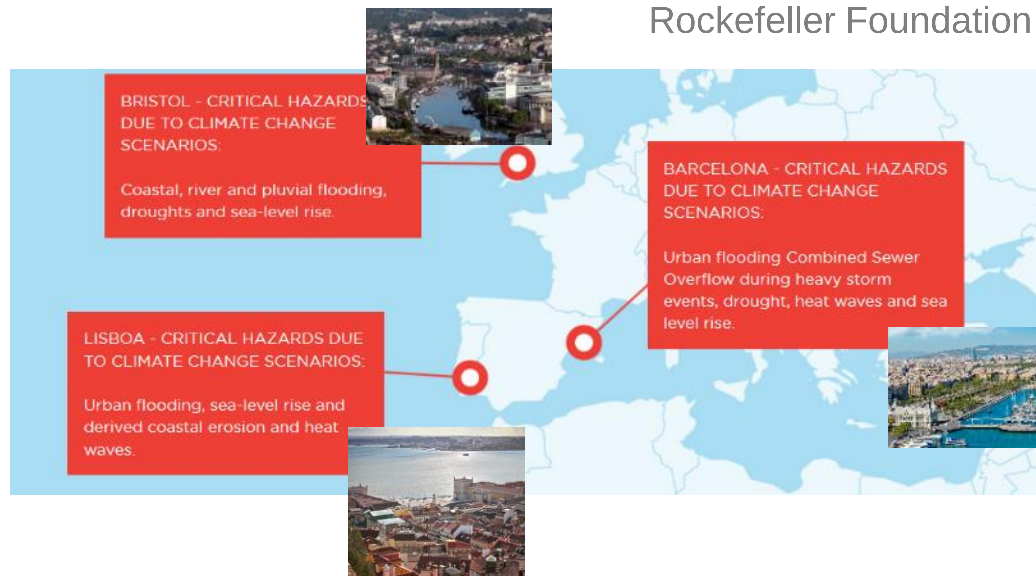
# RESCCUE

RESILENCE TO COPE WITH CLIMATE CHANGE IN URBAN AREAS.

8 M€ H2020 project, 18 partners, 2016-2020
Coordinator: Aquatec (Pere Malgrat)




100 resilient cities,
Rockefeller Foundation




To help cities to become **more resilient** to physical, social and economic challenges by generating **models** and **tools** to bring this objective to practice and make them applicable to different types of cities, with different climate change pressures.

www.resccue.eu

RESCCUE will also assist cities preparing their **resilience plans**.

# Contaminants of emerging concern

- Chemical compounds found in
  - **pharmaceutical compounds** (2012 - …)
  - personal care products
  - pesticides
  - flame retardants
  - surfactant products
  - industrial additives and solvents
  - manufactured nanoparticles
- Natural substances
  - **Hormones** (2012 - …)
  - **Cyanotoxins** (2002 – 2012)
- Biological material
  - antibiotic resistance genes

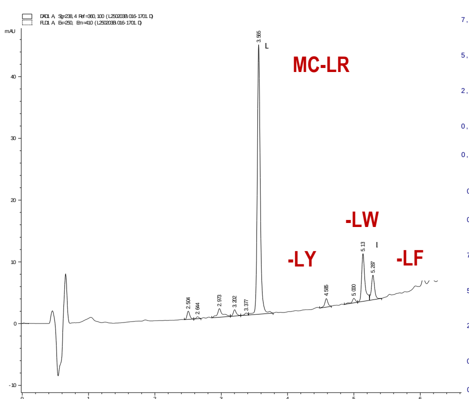
**examples of CECs**

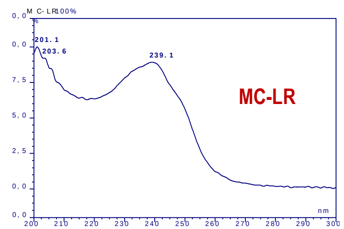
# Cyanotoxins and pharmaceuticals

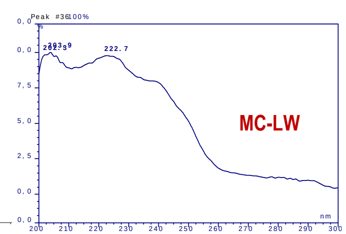
## Cyanobacterial bloom

## Water sample processing

## HPLC quantification

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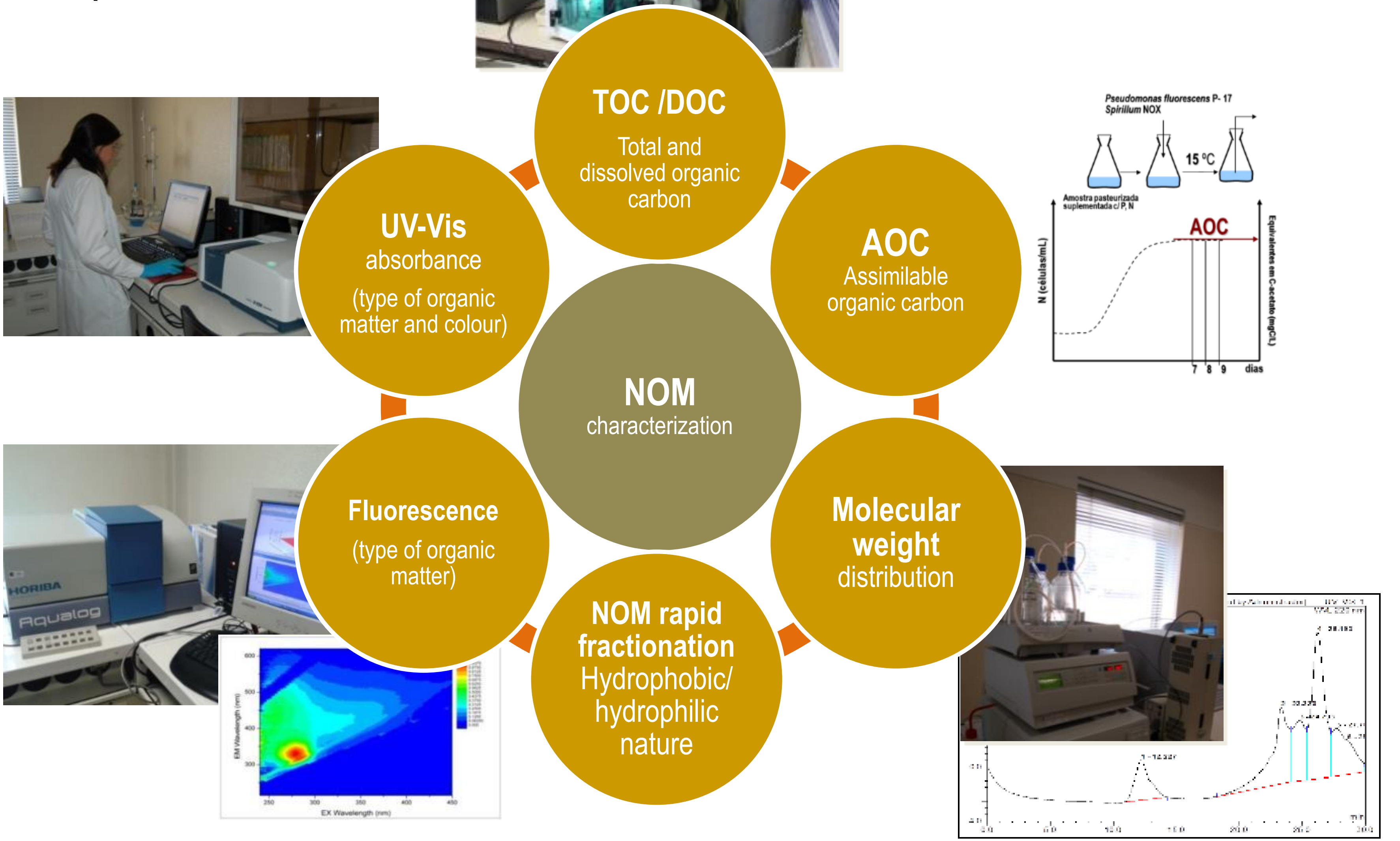
UQTA
Water Quality and Treatment Laboratory

# Monitoring beyond requirements

## NOM - natural organic matter

- Affects CEC control
- DBP precursor



# WATER TREATMENT
## Strategies for climate change adaptation

Prepared
enabling change

Assessment of current treatment works to handle climate change related pollutants and options to make current multi-barrier systems climate change proof – Summary of Prepared Research

Prepared
enabling change

**Adapted operation of drinking water systems to cope with climate change**


Prepared
enabling change

**Resilient Water Supply**

*Feedback from validation and demonstration in partner cities WP5.2*

Prepared
enabling change

**Guidelines for improved operation of drinking water treatment plants and maintenance of water supply and sanitation networks**

LIFE IMPETUS

## Improving current barriers for controlling pharmaceutical compounds in urban wastewater treatment plants

## www.life-impetus.eu

- To produce valuable **knowledge for water resource protection from PhCs** and associated **environmental  policy** on PhC occurrence, concentration and control in WWTPs, bacterial antibiotic resistance and PhC bioaccumulation in clams
- To demonstrate **low capex measures for improving the control of pharmaceutical compounds** (PhCs) in urban wastewater treatment plants (WWTPs) with conventional activated sludge (CAS) treatment

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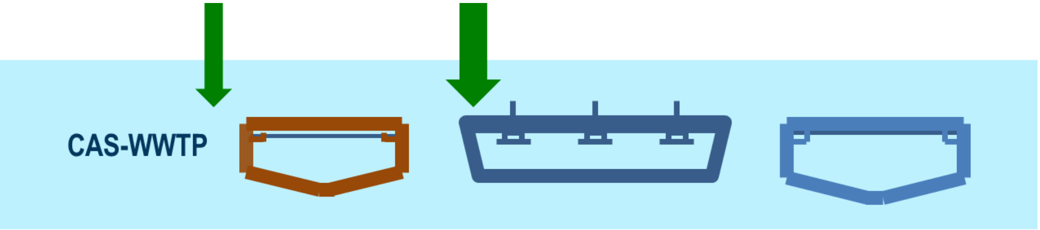
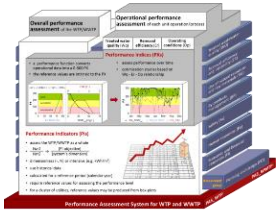
EPAL Grupo Águas de Portugal · ÁGUAS DO ALGARVE Grupo Águas de Portugal · ÁGUAS DO TEJO ATLÂNTICO Grupo Águas de Portugal · ehs Consulting

LIFE IMPETUS

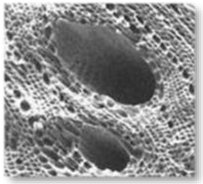



**enhanced treatment**
Low CAPEX

a) OPERATIONAL MEASURES
b) ECO-FRIENDLY ADSORBENTS AND COAGULANTS



Operational improvement of the current barriers using benchmarking tools (KPIs, indices)

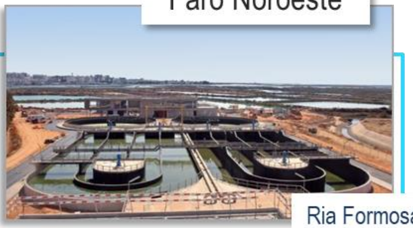


Chemical enhancement of clarification barriers by adding commercial vs new adsorbents from (local) wastes (**circular economy**)


**Full scale**
2 Portuguese urban WWTPs, conventional activated sludge

Beirolas

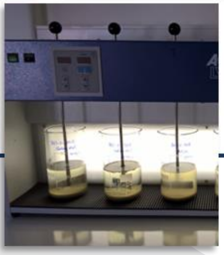
Faro Noroeste



Ria Formosa, clams

**Pilot scale**
3 coagulation/flocculation/ /sedimentation pilot prototypes

**Lab scale**
jar-tests



## Monitoring PhC occurrence in urban WWs

- Wastewater samples were analysed for 24 PhCs and hormones.
- Caffeine and acetaminophen are the most abundant PhCs and are highly removed (> 99%).
- Other PhCs (e.g. erythromycin, sulfamethoxazole, propranolol and bezafibrate) present variable removals (~30-80%).
- Carbamazepine and diclofenac are (almost) not removed in the WWTPs → target for PAC adsorption.

## Monitoring PhC accumulation in clams

- Caged clams were exposed to realistic conditions, in an area influenced by the WWTP.
- These clams were analysed for 24 PhCs and hormones.
- The most abundant PhC in clams is caffeine (in the ng/g range); in water samples from the exposure sites, it is diclofenac, followed by caffeine.

**knowing**

## Physicochemical enhancement strategies

Lab and pilot adsorption results show that the new waste-based PACs developed (10-15 mg/L) and the commercial PACs selected can remove 80% (or more) of the target PhCs (carbamazepine, diclofenac and sulfamethoxazole) present in the WWs. New eco-PAC better than the best commercial PAC.

## Operating strategies

PAC addition to secondary treatment or as post-treatment tested at pilot scale and PAC addition to secondary treatment tested at full scale. Aeration and solids retention time conditions tested at full scale.

**innovating**

A **low-capex and easy-to-implement solution** for improving PhC removal in WWTPs, while keeping operating costs to a minimum and maximising recovery of resources and energy efficiency.

Wealth of **data on PhC occurrence in WWTPs** which may be used in decision support systems and future EU policy and legislation.

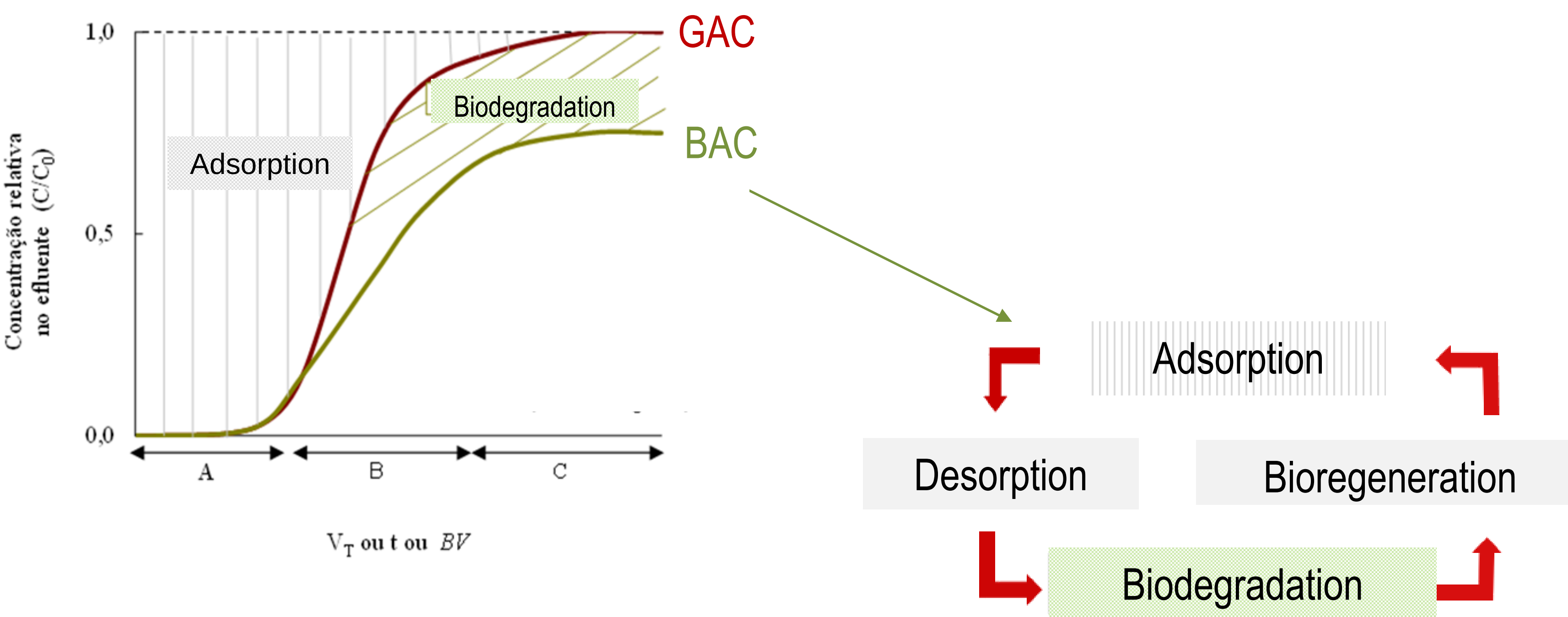
A **cost-benefit analysis** using an innovative integrated approach including inputs from stakeholders.

**replicating**

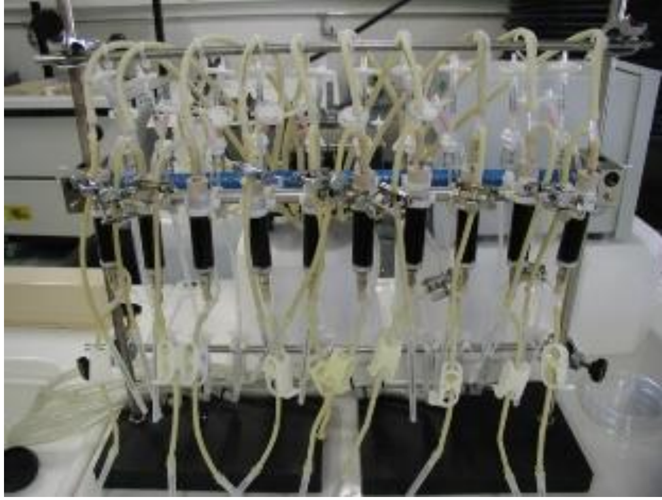
# Biologically active carbon (BAC) filtration
## for **drinking water production** and water reuse

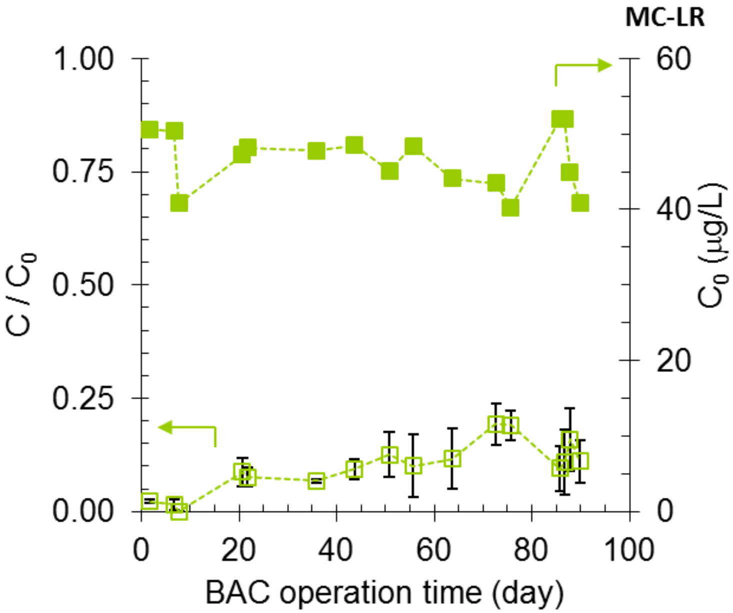
When a permanent barrier against organics is required → GAC filters

Breakthrough curves



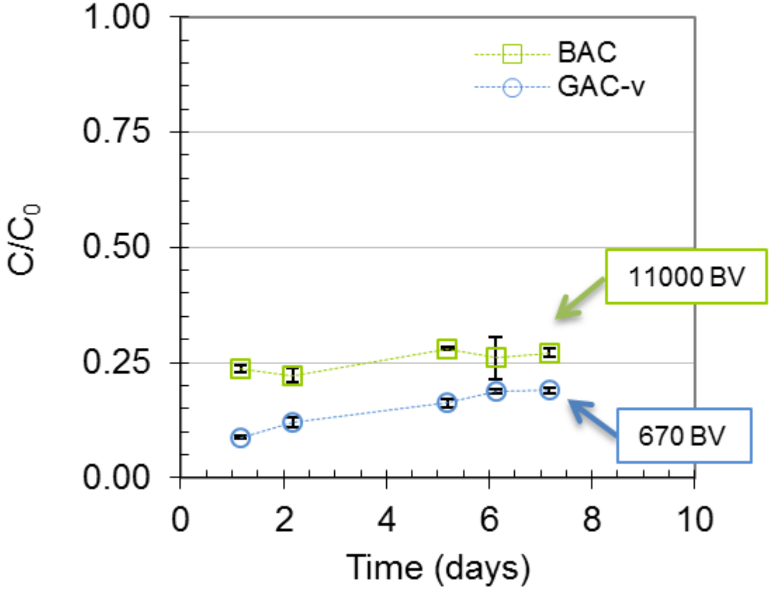
# Biologically active carbon (BAC) filtration for **drinking water production**






- ✓ Low and stationary breakthrough of **microcystin-LR** (MC-LR) in **BAC filters**

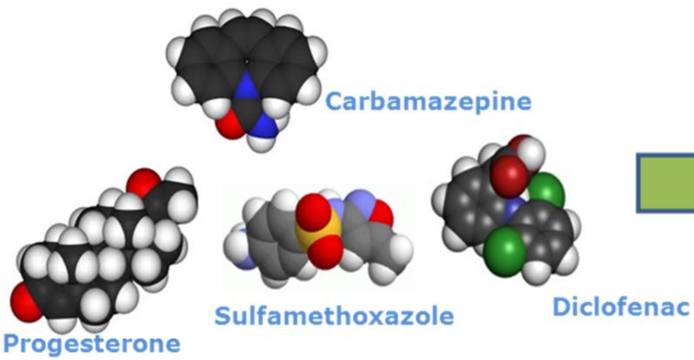
NOM – Tannic acid

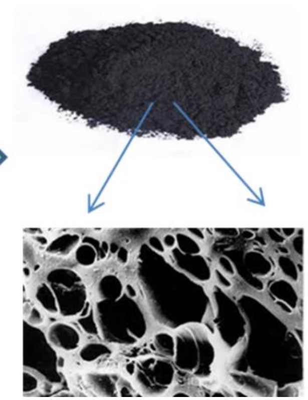


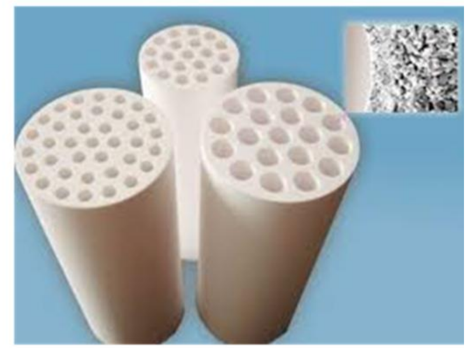

- ✓ Biological activity extends the lifetime of **BAC filters**. Tannic acid removal efficiency of **BAC** (4 months) ~ **virgin GAC** (8 days)

# The concept...

**An innovative PAC/MF hybrid process**
powdered activated carbon/microfiltration





**Target contaminants**
pharmaceuticals, pesticides and other endocrine disruptor compounds, cyanotoxins, viruses and protozoa

**PAC can be tailored** for a wide range of contaminants targeted

**MF** is a safe barrier against protozoa, turbidity, bacteria and fine-PAC

**Ceramic membranes** are emerging in water treatment, in many European countries but not in Portugal; they have superior lifetime and low energy consumption.

**Hymemb** Tailoring Hybrid Membrane Process for Sustainable Drinking Water Production

**Best LIFE ENV project 2016-17**

## Ceramic Membranes

Emerging in Europe but not yet in Portugal:
+ chemical resistance
+ membrane lifetime
+ ability for heavy loads of particles

## PAC/MF prototype

Benchmarking PAC/MF vs. conventional treatment

## INNOVATION

When, where and how using PAC/MF?

## Tailoring

+ PAC dosing for specific contaminants
+ PAC/MF for different water qualities and pretreatments

## Social Indicators

Cost benefit analysis crossing technical, environmental, economic and social dimensions (stake--holders resistances and believes)

This research has received funding from European Union LIFE programme under grant agreement LIFE12 ENV/PT/001154, 2014-2016.

www.life-hymemb.eu

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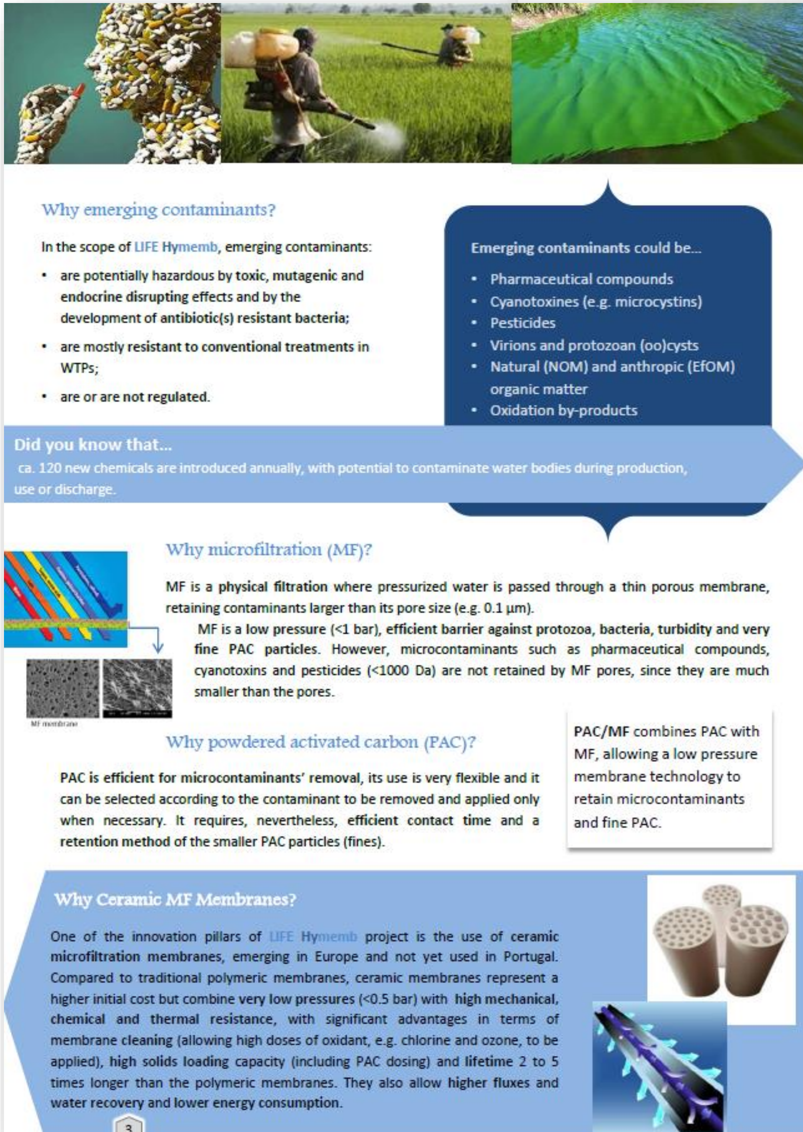
ÁGUAS DO ALGARVE


Why emerging contaminants?

In the scope of LIFE Hymemb, emerging contaminants:

- are potentially hazardous by toxic, mutagenic and endocrine disrupting effects and by the development of antibiotic(s) resistant bacteria;
- are mostly resistant to conventional treatments in WTPs;
- are or are not regulated.

Emerging contaminants could be…

- Pharmaceutical compounds
- Cyanotoxines (e.g. microcystins)
- Pesticides
- Virions and protozoan (oo)cysts
- Natural (NOM) and anthropic (EfOM) organic matter
- Oxidation by-products

Did you know that…

ca. 120 new chemicals are introduced annually, with potential to contaminate water bodies during production, use or discharge.

Why microfiltration (MF)?

MF is a physical filtration where pressurized water is passed through a thin porous membrane, retaining contaminants larger than its pore size (e.g. 0.1 µm).

MF is a low pressure (<1 bar), efficient barrier against protozoa, bacteria, turbidity and very fine PAC particles. However, microcontaminants such as pharmaceutical compounds, cyanotoxins and pesticides (<1000 Da) are not retained by MF pores, since they are much smaller than the pores.

Why powdered activated carbon (PAC)?

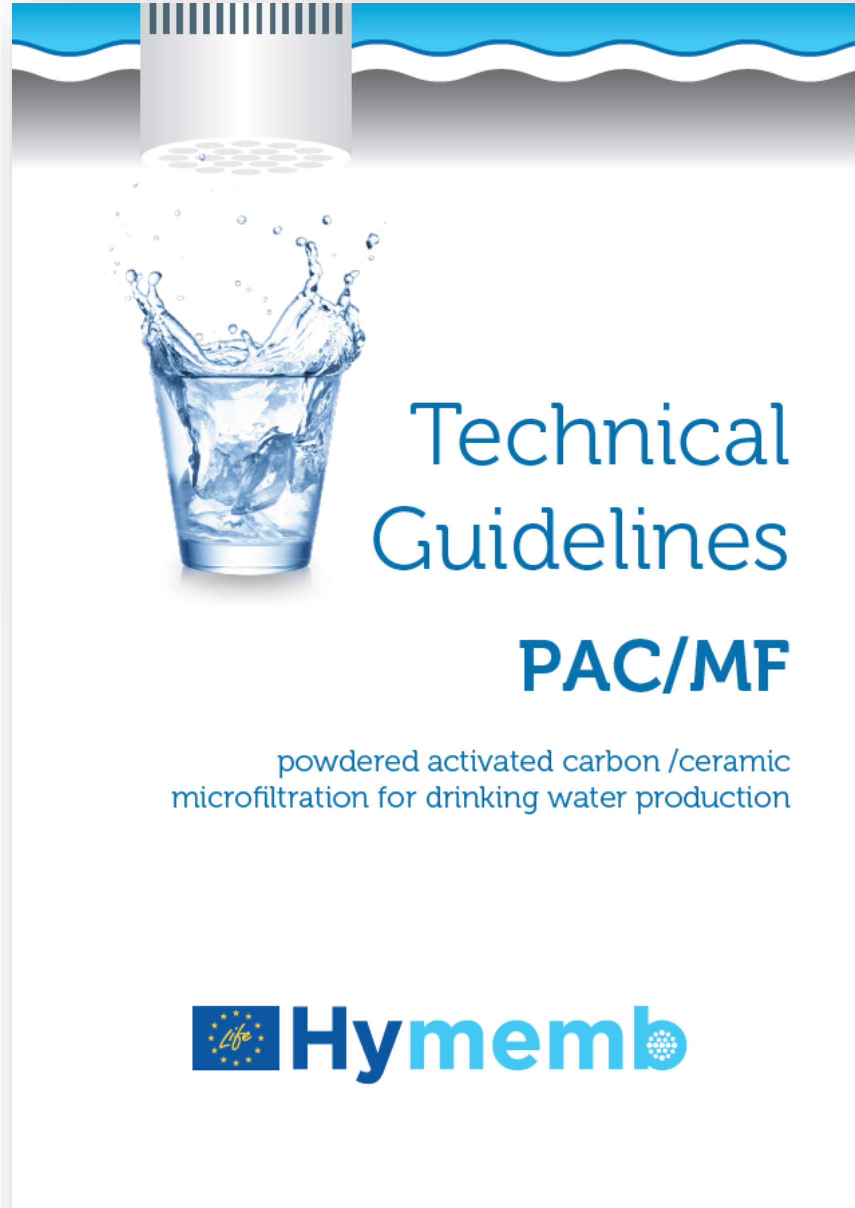
PAC is efficient for microcontaminants' removal, its use is very flexible and it can be selected according to the contaminant to be removed and applied only when necessary. It requires, nevertheless, efficient contact time and a retention method of the smaller PAC particles (fines).

PAC/MF combines PAC with MF, allowing a low pressure membrane technology to retain microcontaminants and fine PAC.

Why Ceramic MF Membranes?

One of the innovation pillars of LIFE Hymemb project is the use of ceramic microfiltration membranes, emerging in Europe and not yet used in Portugal. Compared to traditional polymeric membranes, ceramic membranes represent a higher initial cost but combine very low pressures (<0.5 bar) with high mechanical, chemical and thermal resistance, with significant advantages in terms of membrane cleaning (allowing high doses of oxidant, e.g. chlorine and ozone, to be applied), high solids loading capacity (including PAC dosing) and lifetime 2 to 5 times longer than the polymeric membranes. They also allow higher fluxes and water recovery and lower energy consumption.

3



Technical Guidelines

PAC/MF

powdered activated carbon /ceramic microfiltration for drinking water production

Hymemb

*Technical Guidelines of PAC/MF for Drinking Water Production*



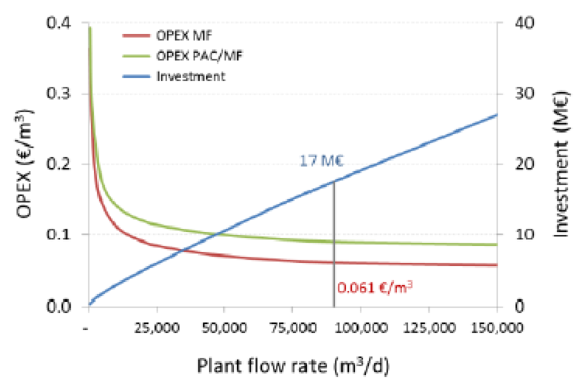
## Recommended ranges of operation of key parameters and variables

The recommended ranges of operation of the key parameters and variables presented below were derived during LIFE Hymemb demonstration for a low turbidity intake water (≤ 5 NTU, ≤ 3 mg/L TOC, ≤ 2 L /mg-m SUVA) and reflect a technical and economic analysis (the latter presented in *Economic Analysis*).

| Key parameter and variable | Recommended range of operation |
|---|---|
| **Flux (normalised) ($J_{20}$) (L/(m$^2$.h))** | 150 – 280 |
| **Inlet pressure (bar)** | 0.6 – 0.9 |
| **TMP (bar)** | 0.6 – 0.8 |
| **Filtration time (h)** | 2 – 3 |
| **Backwash** | |
| frequency (N./d) | 8 – 12 |
| flux (L/(m$^2$.h)) | 500 |
| pressure (bar) | ca. 1.5 (water backwash) |
| **CEB** | |
| water volume spent (L/m$^2$) | < 15 |
| cleaning agents | sodium hypochlorite (≤ 1000 mg/L $Cl_2$ in membrane)<br>sulphuric acid (pH 1-2 in membrane) |
| soaking time (min) | 15-30 |
| total frequency (N./d) | ⅔ – 1 |
| sodium hypochlorite freq. (N./d) | ⅙ – ½ |
| acid frequency (N./d) | ⅙ – ½ |
| **Specific flux (L/(m$^2$.h.bar))** | 200 – 500 |
| **Water recovery rate (%)** | 97 – 99 |
| **Treatment capacity (m$^3$/(m$^2$.d.bar))** | 5 – 10 |
| **Fouling rate** | |
| within cycles (FRw, mbar/h) | 0 – 15 |
| between cycles (FRb, mbar/h) | 0 – 5 |
| with CEB (FRc, mbar/d) | 0 – 5 |
| backwash efficiency (%) | 50 – 80 |
| CEB efficiency (%) | 95 – 100 |
| **PAC** | |
| size (µm) | 6 – 15 |
| $pH_{pzc}$ | depends on the contaminants targeted, usually alkaline PACs are more efficient for negatively charged contaminants |
| specific area ($S_{BET}$) (m$^2$/g) | the higher the better, often > 1000 m$^2$/g |
| porous structure | micropores host the preferential adsorption sites for low molar mass contaminants; mesopores are important for adsorbing intermediate molar mass contaminants and for compounds less amenable to adsorption under strong competition conditions, i.e. low PAC doses and/or high(er) competitors' concentration (other microcontaminants and water background NOM); good results were obtained with 50/50 of microporous/mesoporous volume and total per volume > 0.7 cm$^3$/g |

| Key parameter and variable | Recommended range of operation |
|---|---|
| PAC suspension concentration (slurry) | ≤ 2 g/L (recommended), agglomerates formation should be avoided |
| contact time (min) | ≥ 30 |
| mixing velocity gradient (G) (s$^{-1}$) | 120 |
| PAC dose (mg/L) | depends on the target contaminants |
| chemically resistant biological forms protozoan (oo)cysts | total removal by MF, no need for PAC addition |
| NOM and oxidation by-products | |
| good and reliable removal (DOC < 1.6 mg/L) | 10 |
| Low molar mass microcontaminants | depends on the target contaminants, indicative ranges below should be validated case-by-case |
| for 75% average removal | 2 |
| for 85% average removal | 5 |
| for 90% average removal | 10 |
| **PAC/MF coagulant ($Al_2O_3$) dose (mg/L)** (for non coagulated waters) | 3 |
| **PAC/MF unit energy consumption (kWh/m$^3$)** | 0.05 |
| **PAC/MF chemicals consumption (kg/m$^3$)** | |
| non-coagulated intake waters | 0.07 |
| coagulated intake waters | 0.02 |
| **PAC/MF sludge production (kg/m$^3$)** | |
| non-filtered intake waters | 36 – 41 |
| filtered intake waters | 16 –21 |

PAC/ceramic MF intake = raw water
(1.6 – 3 NTU, 1.5-2.5 mg/L DOC, < 2 L/m/mgC)



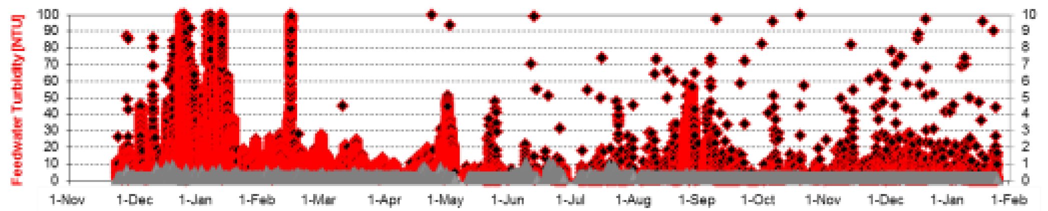
# Advanced treatments for water reuse

www.trust-i.net

## FP7 EU project, WP44.2.1

- **PAC/MF** and PAC/UF (ceramic MF and UF) for **unrestricted urban water reuse**

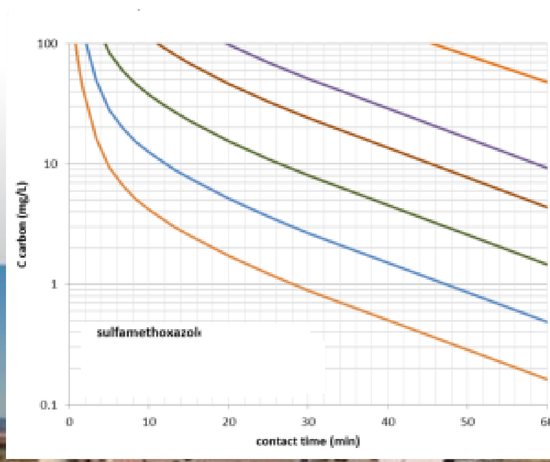
- LNEC, IWW (Germany)
  SimTejo, Metawater (Japan)




# Advanced treatments for water reuse

- **Activated carbon** selection and optimization for PAC/NF or GAC for micropollutants (EDCs, pharmaceuticals, …) control for **water reuse**
- Lab testing of a **new low-pressure NF membrane** (hollow-fiber)
- Design of **PAC/NF configuration** and operating conditions


- **Innovative hybrid MBR-(PAC-NF) systems to promote WAter Reuse**
- **CETaqua (SP)**
  **Aigües de Barcelona**
  **LNEC**

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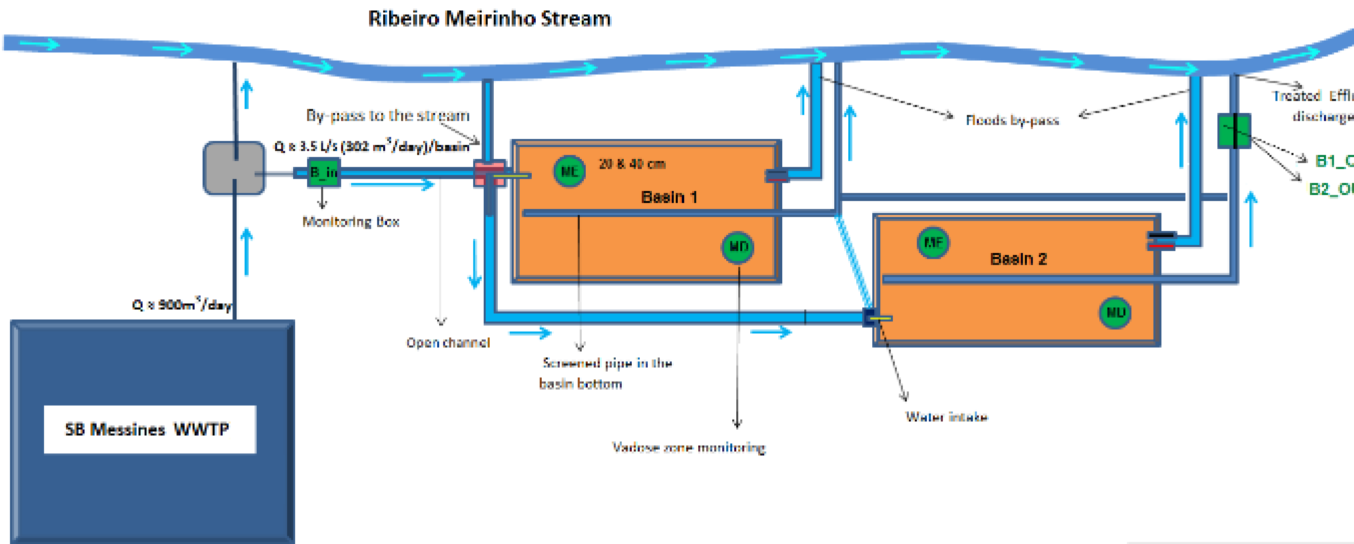
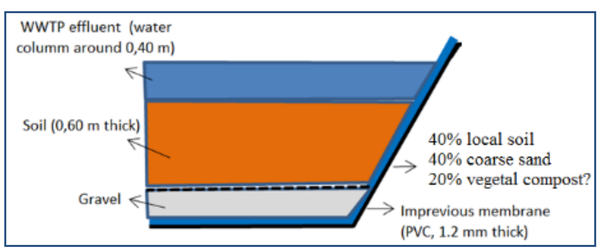
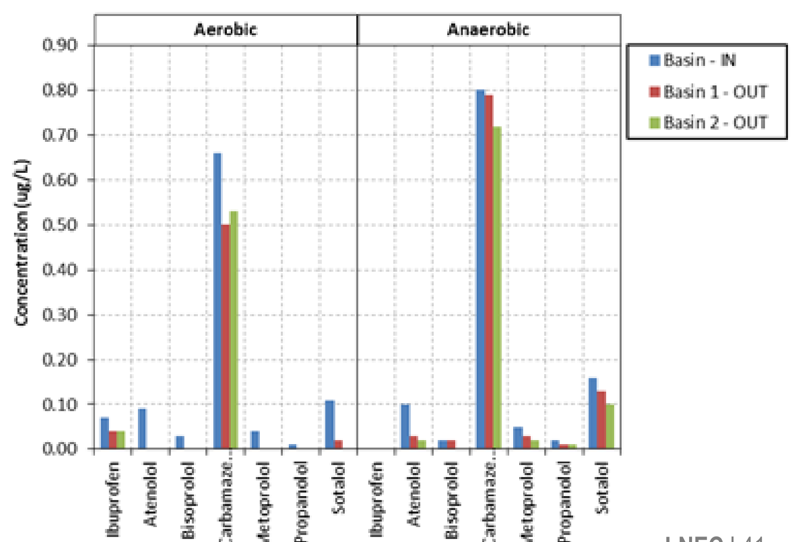
# Soil-Aquifer Treatment as a passive solution to enhance treated wastewater quality.

**Teresa E. Leitão** et al. (E. Mesquita, M.J.Rosa) (2018) *In* Sanitation Approaches and Solutions and the Sustainable Development Goals. Eds. J.S. Matos, M.J. Rosa. ERSAR, EWA, APESB, 69-82








2 basins in parallel
(or in series, if needed)

2 sequential periods:
1) higher ORP values
2) negative ORP values

# Exploring the use of Azorean native plants and rock material for sustainable wastewater treatment through constructed wetland systems

**Sílvia Quadros**, Rio P., Mesquita E., Rosa M.J. (2018) *In* Sanitation Approaches and Solutions and the Sustainable Development Goals. Eds. J.S. Matos, M.J. Rosa. ERSAR, EWA, APESB, 49-67

*Juncus acutus L.*

*Bolboschoenus maritimus L. Palla*

Native species

*Arundo Donax L.*

Conventional species

Angra do Heroísmo WWTP, Azores

After 4 cycles

***B. maritimus*** better adapted than *J. acutus*

6 log reduction of fecal coliforms

# Final messages

- **Be water smart is…**
  - Work with people
  - Work with nature
  - Plan on the long run
  - Act on the short run
  - Keep the legacy for future generations
  - Knowing (measuring) – innovating – replicating
  - Circular schemes
  - Product design and process design
    longer lifetimes, higher efficiency
  - Fit for purpose in water use, water-energy-P balances in the city
    (H2020 proposal with LNEC, CML, AdTA, ADENE, Baseform)

# Thank you!

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