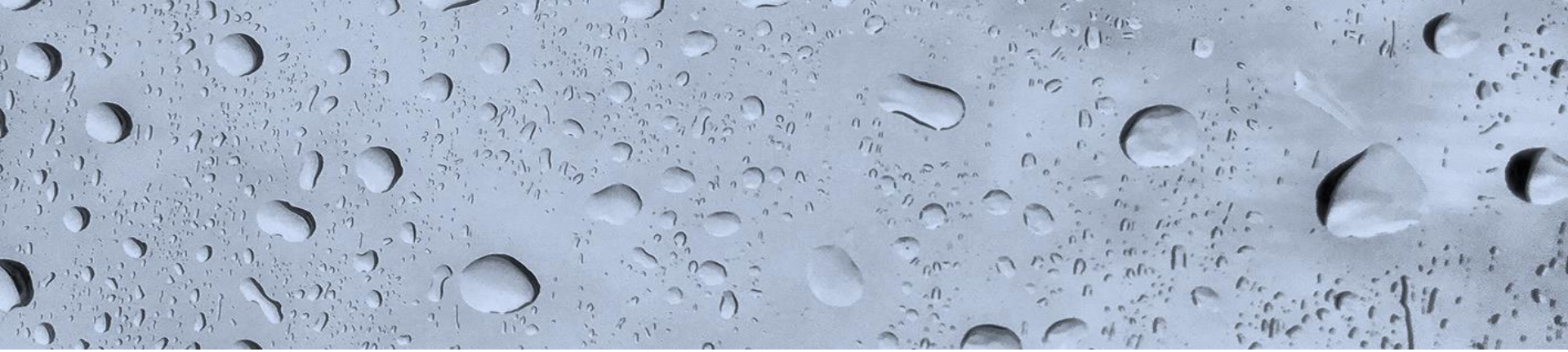


Monitoring strategies of wastewater reuse to increase water availability in the Catalan River Basin District.

Bringing solutions to manage drought periods

Antoni Munné (AnMunne@gencat.cat)
Catalan Water Agency. 21st November, 2019

Agència Catalana de l'Aigua

Generalitat de Catalunya
Departament de Territori i Sostenibilitat

WATERPROTECT

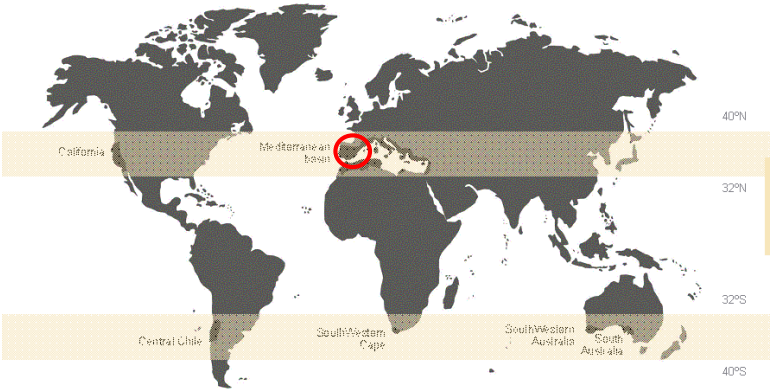
Index:

1. **What's the problem**: Several droughts have been affecting Catalonia for last decades, and it will probability increase in future due to climate change.

2. **Looking for solutions**: The Catalan Water Agency has initiate several trials in order to increase wastewater reuse to face droughts. Example: over 2 m^3/s from el Prat WWTP which currently flows into the sea can be reused to increase water availability in the lower Llobregat river, and water supply for urban uses.

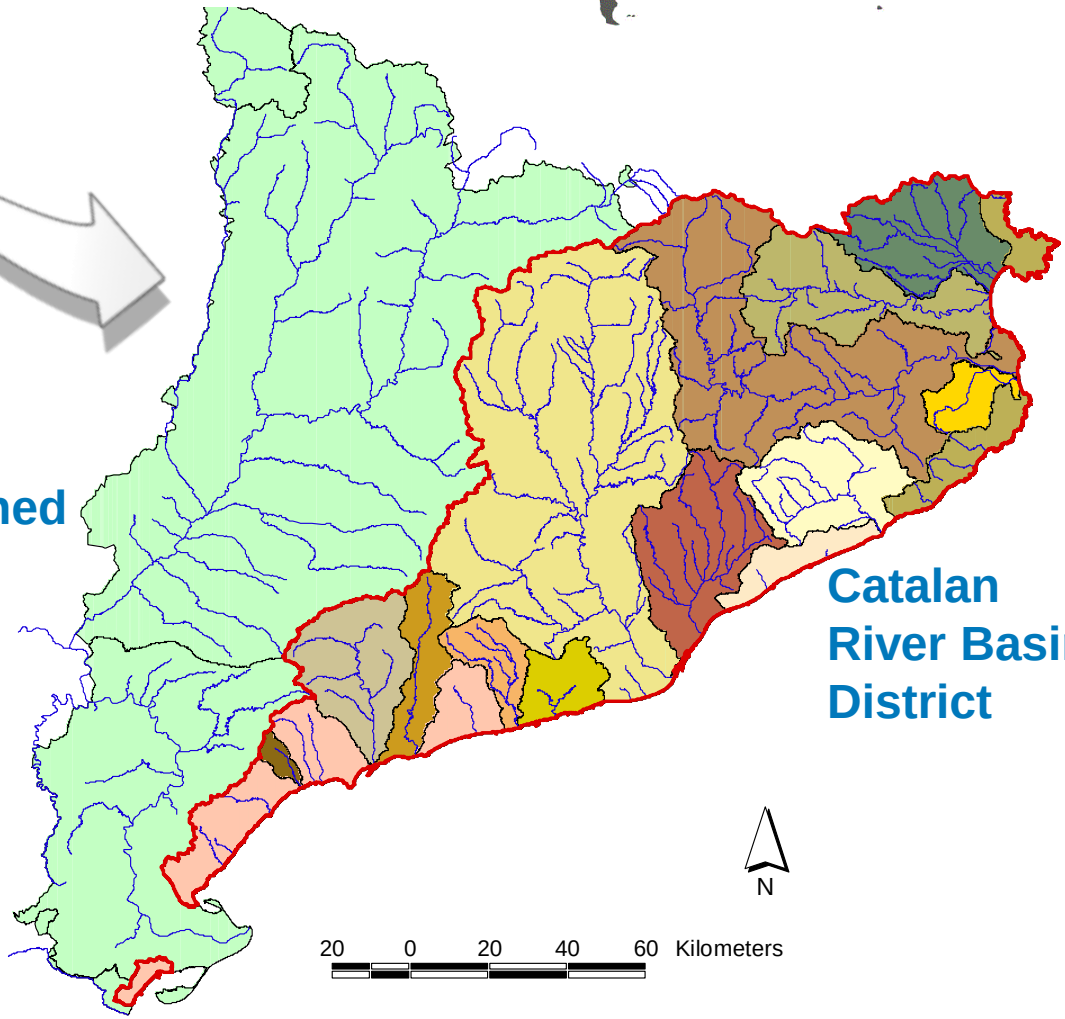
3. **Suitable and safety monitoring of wastewater reuse**:
   - Defining monitoring protocols
   - Selecting contaminants
   - Drafting a safety procedure roadmap (in terms of human health and ecosystem protection – "one health")

Location: Mediterranean area



River Basin Districts (25):

Ebro watershed

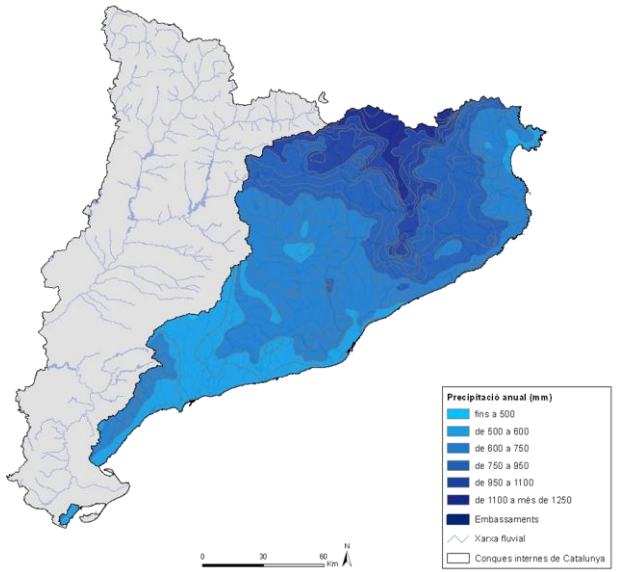


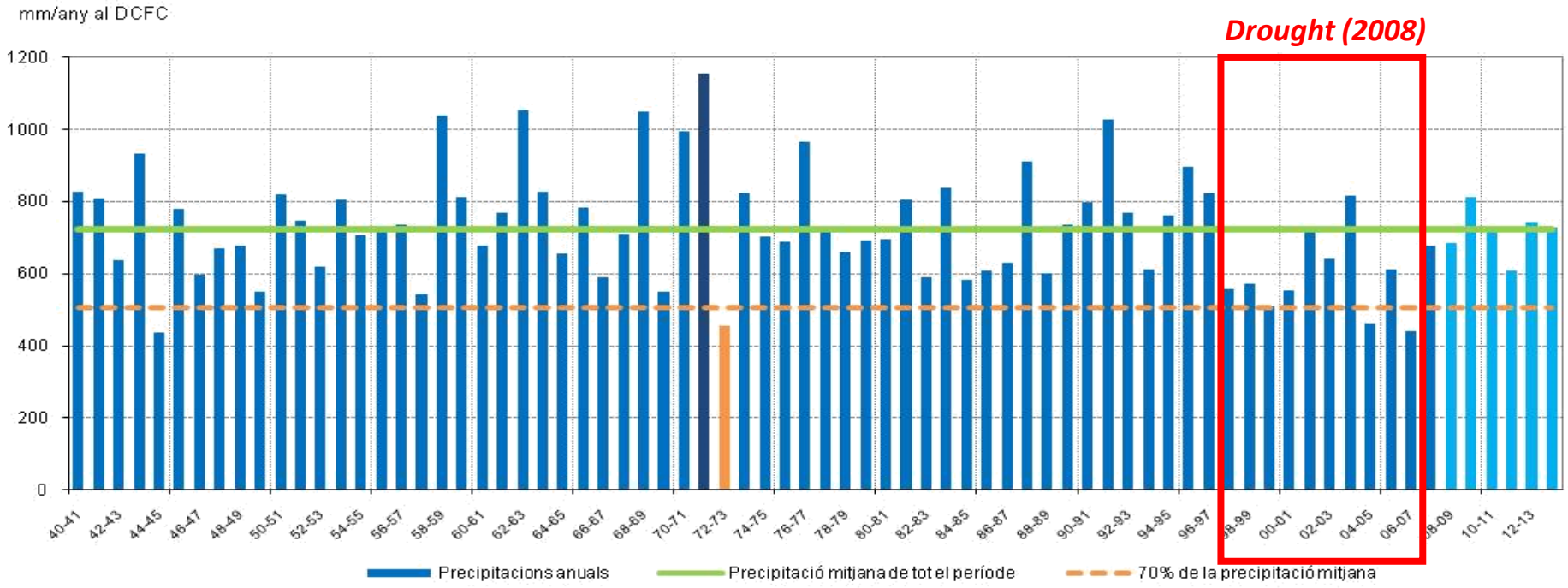
Catalan River Basin District

What's the problem

High variability in precipitation:

Precipitation decreases from north to south. In the northern area, the average annual values exceed 1,000 mm, and even 1,200 mm. In southern Catalonia, the annual rain values are 460 mm. Moreover this can highly vary from year to year.



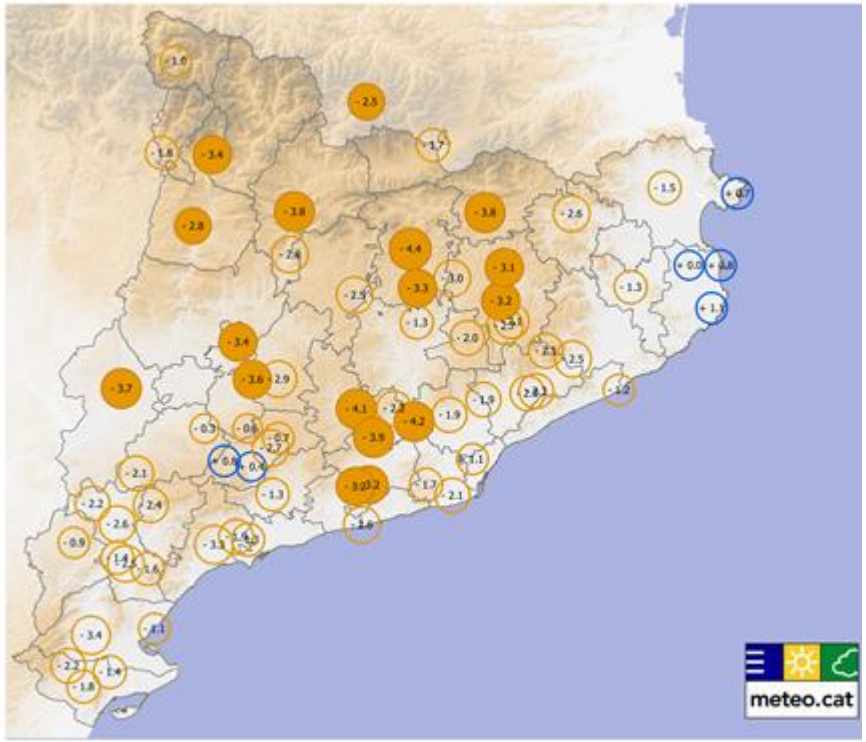


What's the problem

Temperature increases, and precipitation decreases:

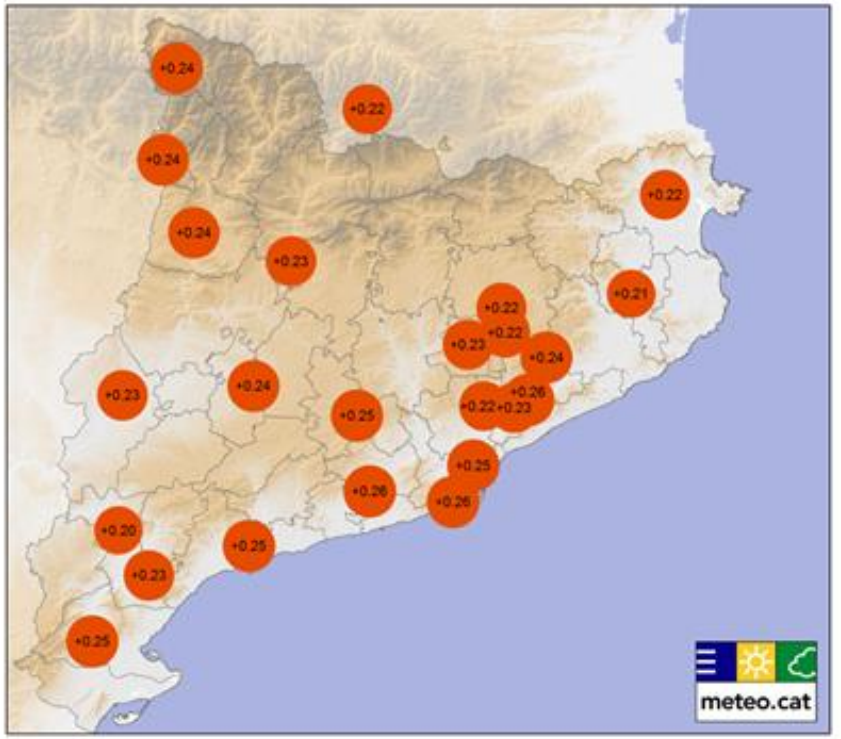
Temperature has been increasing significantly **over the last 67 years** (1950 – 2017) around **0.25 °C** per decade, whilst rainfall has been decreasing significantly around **1.4%** per decade (up to 5% per decade in summer).

Trend in rain (1950-2017) %



L'àrea dels cercles representa el percentatge de canvi per dècada.
Precipitació: blau = positiu, taronja = negatiu
Cercle sòlid indica tendència estadísticament significativa: p < 0.05

Trend in temperature (1950-2017) °C



L'àrea dels cercles representa el canvi en °C per dècada

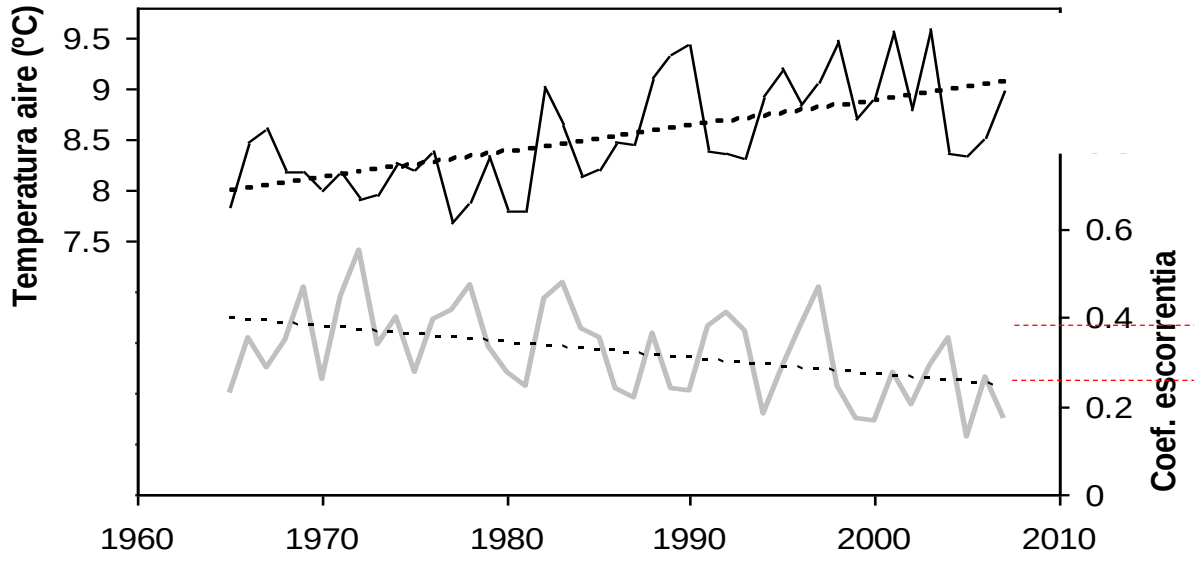
Cercle sòlid indica tendència estadísticament significativa: p < 0.05

What's the problem

Water runoff progressively decreases:

Water runoff currently decreases due to evapotranspiration and changes in rain patterns (concentrated rains in time).

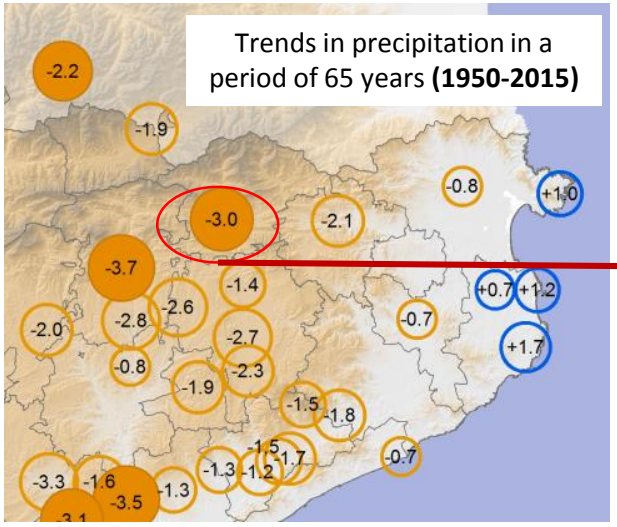
MEDACC LIFE Project (http://medacc-life.eu) provides good and recent information on this topic in three Catalan basins:



Air temperature has been increasing for the last 40 years, whereas runoff coefficient decreases (- 0.18).

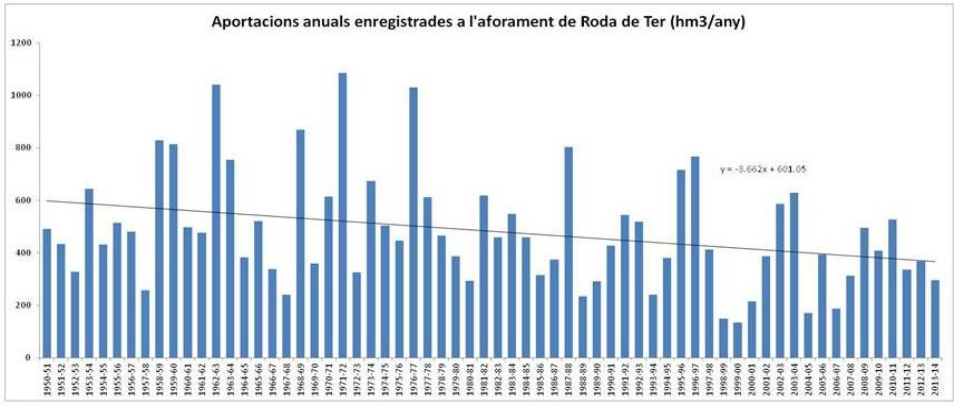
What's the problem

Rain trend over the last 65 years:

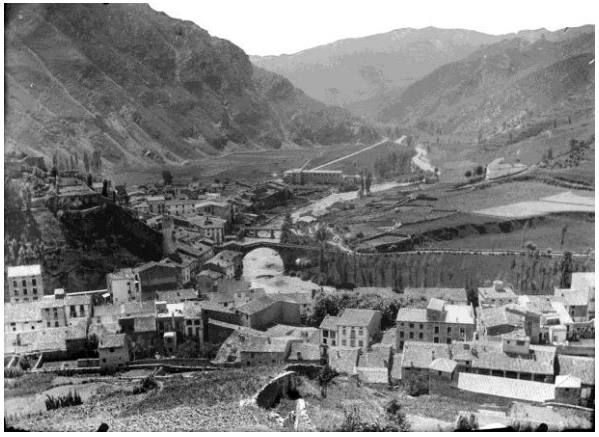


Rainfall is decreasing **3% per decade** (significantly) in the upper Ter river.

Trend water discharge measured in Ter river over the last 10 years:



1950-2014: 64 years
Average annual discharge: 482 hm^3
Slope regression: -3.662 hm^3/any
Flow reduction in the whole period: **7 % per decade**



From 1907 to 2015

Camprodon

What's the problem

Water reduction due to Climate Change. Several studies and information sources have been used to predict scenarios:

2009 - Water Management Plan (1st cycle). Water and Climate Change Book (ACA-FNCA).

2010 – Spanish Ministry studies (CEDEX).

2011 - SMC (first regional projections)

2016 - CADS Report: 3rd Climate Change Report (TICC), estimated for the period 2031-2050 (relative to the 1971-2000 averages).

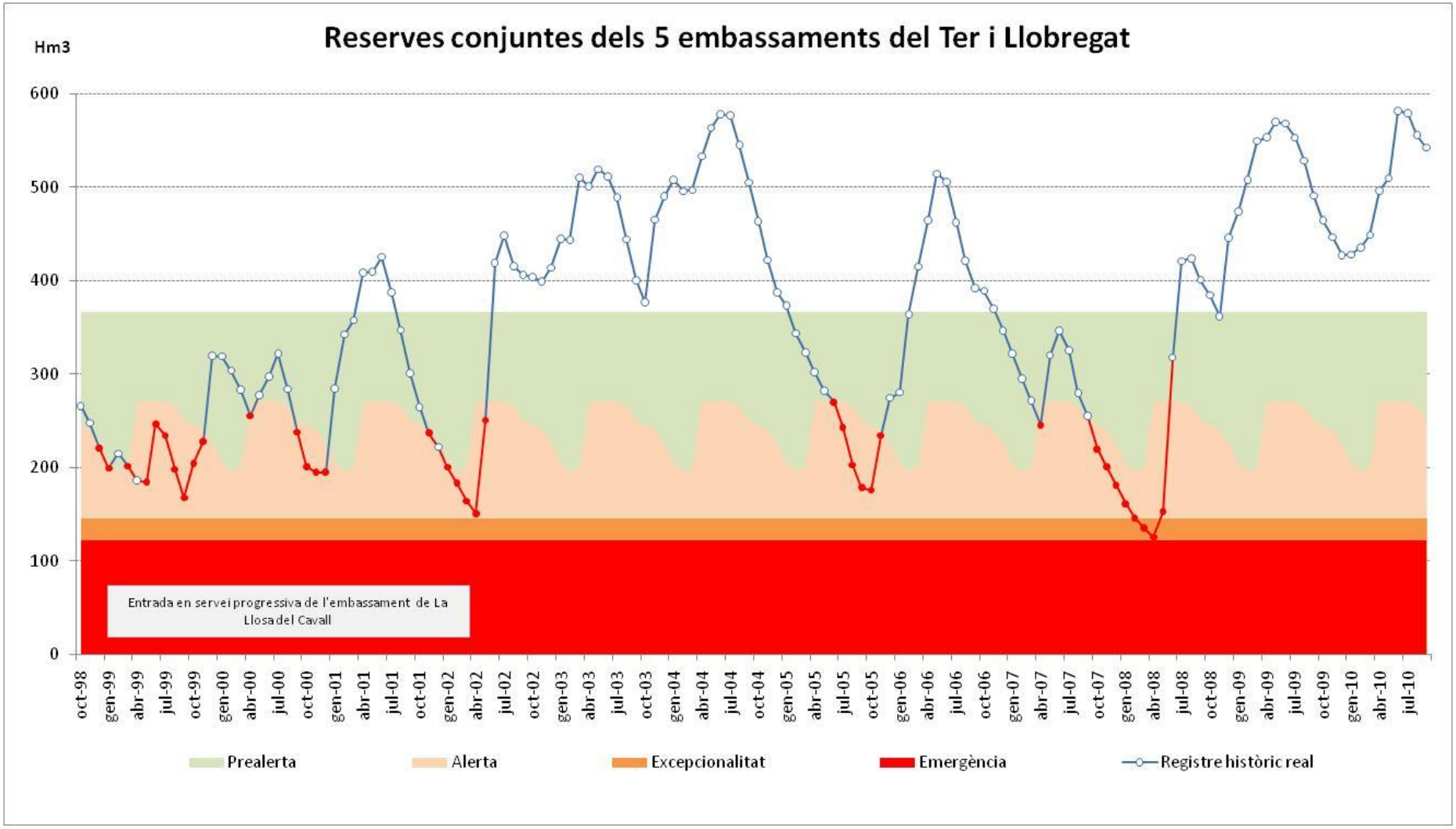
2018 - LIFE MEDACC results (it analyses evapotranspiration changes).

Predicted water reduction:

- Up to **5-10%** short-term (2033)
- Up to **20-35%** long-term (2050-2100)

Effects on water uses

Current water demands in Catalonia are very close to annual water availability. Water storage drops and increase rapidly according to raining events.



Effects on aquatic ecosystems

IOP PUBLISHING ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. 7 (2012) 014037 (11pp) doi:10.1088/1748-9326/7/1/014037

How is the impact of climate change on river flow regimes related to the impact on mean annual runoff? A global-scale analysis

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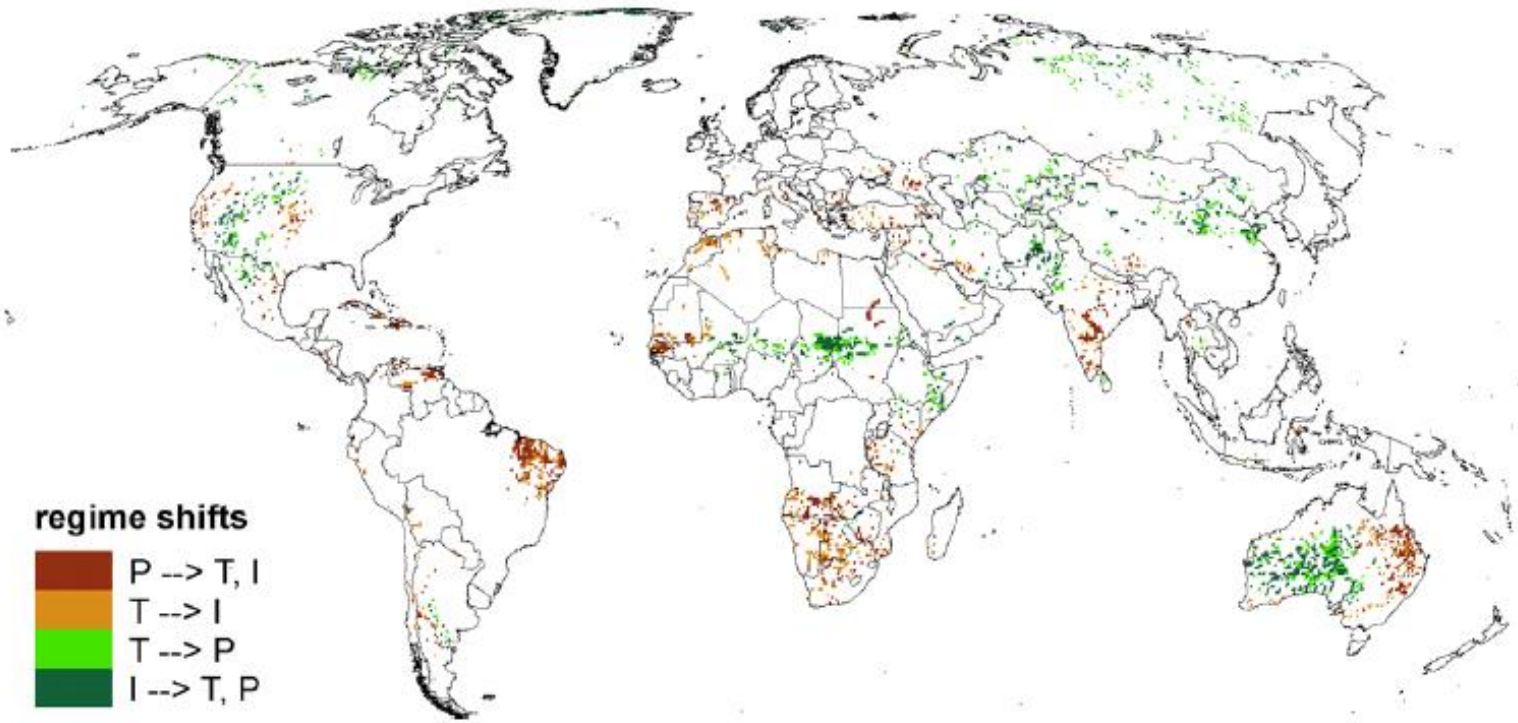
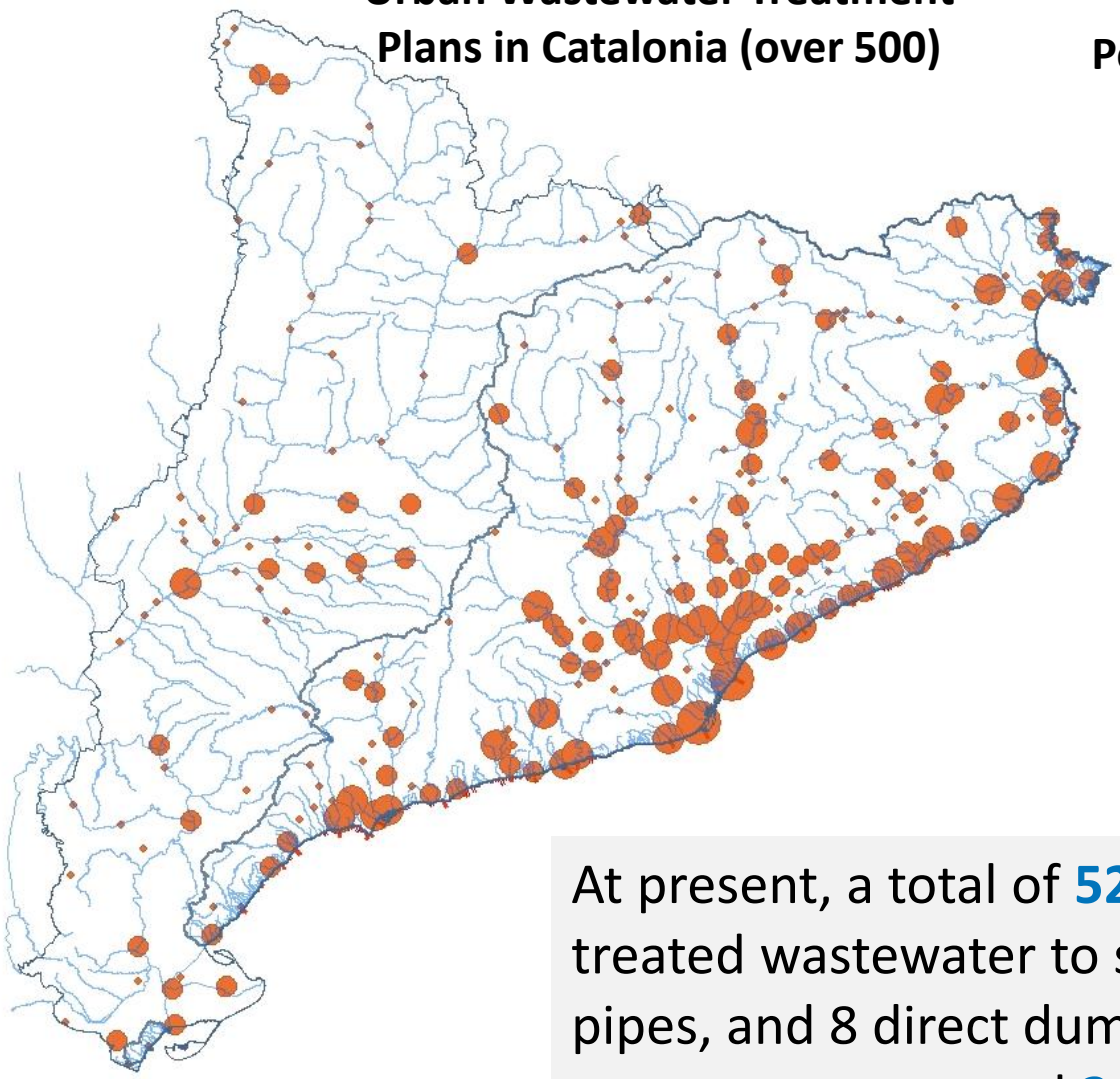


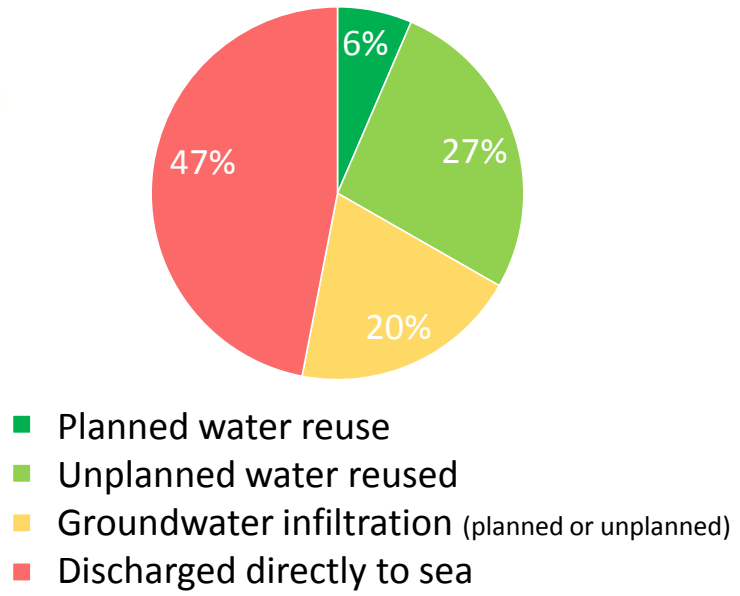
Figure 4. Regime shifts among perennial (P), transitional (T) and intermittent (I) river flow regimes occurring between 1961–90 and 2041–70 due to climate change (as computed with WaterGAP, climate scenario HadCM3 A2).

Wastewater treated in Catalonia

Urban Wastewater Treatment Plans in Catalonia (over 500)



Percentage of waste water allocation (724 Hm^3/y) (97% of people)



At present, a total of **52 WWTPs** are discharging treated wastewater to sea through 36 long sewer pipes, and 8 direct dumps. The total water discharge to sea comes around **340 Hm^3/y.**

Security: Environmental quality and health *(one health)*

- European Action Plan "One health" (**COM/2017/0339 final**).
- The Directive on priority substances (**2008/105/EC**, amended by Directive **2013/39/EU**) establishes a list of **45 priority and hazardous substances** that must be monitored (with quality standards in water and biota).
- **Emerging Contaminants** (Article 8b. Directive 2013/39/EU): **Watch List**. Implementation decision of the Commission C (2018)3362 final:
  - Diclofenac, EE2, E2, E1, macrolide antibiotics (erythromycin, clarithromycin, azithromizin), amoxicillin and ciprofloxacin.
  - Antioxidant (2,6-Di-tert-butyl-4-methylphenol), sunscreen compound (2-Ethylhexyl 4-methoxycinnamate)
  - Triallate, oxadiazon, methiocarb, neonicotinoids (pesticides).
  - Metaflumizone (veterinary treatment)
- JRC proposes to consider in future: pyrethroids, pyridaben and body creams (parabens).

Security: Environmental quality and health *(one health)*

- **SCARCE Project** found a total of **24 endocrine disruptors** (bisphenol A, caffeine, estradiol, nonylphenol, triclosan, etc.) in the mid and lower Llobregat river, **79 pharmaceuticals** (carbamacepine, codeine, diazepam, diclofenac, ibuprofen, naproxen, etc.), **12 drugs of abuse** (amphetamine, cocaine, methadone, morphine, etc.), **11 personal care products** and **sunscreen compounds** (octocrylene, bentophenone), **19 perfluorinated compounds** (PFOS, PFOA, etc.), and **31 pesticides** (carbendazim, diacinone, pyriproxifen, etc.).

- **WHO** indicates that the problem of **pharmaceutical waste and its possible effects on long-term exposure in vulnerable populations can not be ignored**, which justifies the need to adopt a precautionary approach.

- New compounds in the new **Drinking Water Directive** are suggested: **PFOS/PFOA, β-estradiol, nonylphenol,** and **bisphenol A**. Chlorination by-products: **NDMA, haloacetic acids**.

Security: Environmental quality and health *(one health)*

- Regulation of the European Parliament and of the Council on the **minimum requirements for water reuse** (for agricultural uses). **COM (2018) 337 final**.
- Microbiological controls (**indicators**): E. coli, total coliforms, clostridium perfringens, bacteriophages.
- Depending on the outcome of the **risk assessment**, the requirements of additional controls may be:
  - heavy metals
  - pesticides
  - disinfection by-products
  - pharmaceutical products
  - other substances of emerging concern
  - antimicrobial resistance
- We already have the **RD 1620/2007** (Spanish law) for reuse of treated water.

Suitable and safety monitoring of wastewater reuse

The Catalan Water Agency has initiate a procedure in order to select contaminants to be monitored in terms of human health and ecosystem protection.

Selecting sampling sites:

Suitable and safety monitoring of wastewater reuse

Selecting contaminants (step 1):

A first list (candidates to be considered):

- **Pharmaceuticals**: a total of **778** prescribed pharmaceuticals and its metabolites were obtained as possible (antibiotics, antivirals, antidiabetics, antidepressants, etc.).
- **Pharmaceuticals used additionally in hospitals**: **17** cytostatic products (used in chemotherapy), drugs, hormones, radiological contrast agents.
- **Personal care products and food additives** : **11** compounds (food preservatives, additives for domestic products "e.g. toothpaste", sunscreen, skin creams, etc.)
- **Contaminants from industrial activities**: **51** compounds (heavy metals, VOCs, dioxins, phenols, organic solvents, PAHs, flame retardants, phthalates, etc.).
- **Other contaminants from domestic and urban uses (pesticides, organochlorides, etc.)**: **208** compounds (pesticides, PFOS, PBDEs, etc.).
- **Chlorination byproducts**: **5** compounds (NDMA, chloroform, bromoform, etc.).
- **Regulated compounds**: **2** additional compounds (from 39/2013/UE Directive - Watch List): 2,6-ditert-butyl-4-methylphenol and metaflumizone.

Total: **1,072** compounds (initial list)

Suitable and safety monitoring of wastewater reuse

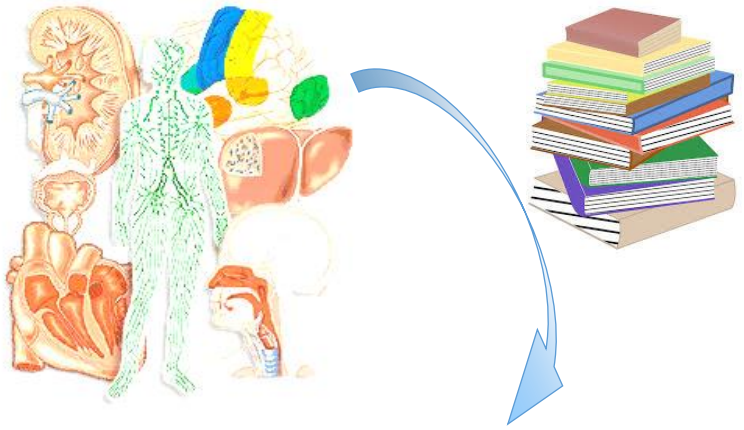
Selecting contaminants (step 2):

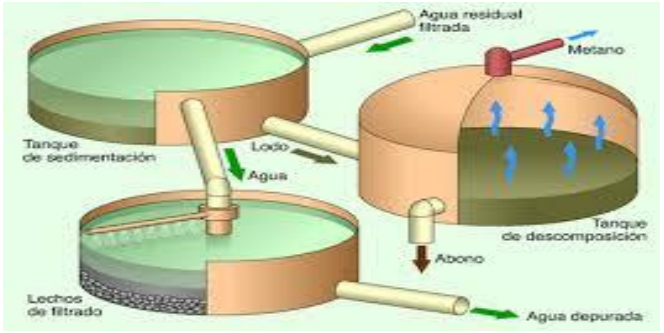
Pharmaceuticals were selected regarding its possible effects and fate in environment.

Metabolites were also considered according to literature and pharmaceuticals removal from WWTP.

From total annual Daily Dose (**DDD**), we calculated the maximum concentration of each drug that could be found in the wastewater influent. It is assumed an average maintenance dose per day for a drug used for its main indication in adults (from WHO). **Estimated concentration in Waste Water** was assessed.

We used the **EPI Suite program** (US EPA), a predictive method to assess exposure and fate of chemicals, to assess concentrations at effluent.





$$\textbf{\textit{Estimated concentration in Waste water}} = \frac{\text{DDDt} \times \frac{\text{mg}}{\text{DDD}}(\text{WHO})}{\text{waste water inflow}\left(\frac{\text{m}^3}{\text{day}}\right)} \times \frac{\frac{1000\mu g}{1mg}}{\frac{1000L}{1\text{m}^3}}$$

Suitable and safety monitoring of wastewater reuse

Selecting contaminants (step 2):

On the other hand, we calculated a Guide Value (**GV**) for each pharmaceutical compound. The compounds for which it was established an acceptable daily intake (**TDI**: Tolerable Daily Intake, or **ADI**: Acceptable Daily Intake).

$$\boldsymbol{GV}(\mu g\ L^{-1}) = \frac{\boldsymbol{ADI}\ or\ \boldsymbol{TDI}\left(\frac{mg}{kg}\ bw\right) \times\ bw\ (kg) \times\ P\ \ \times\ 10^{3}}{V\ (L/d\ ay)}$$

Where: V= 2 L/day; TDI: Tolerable daily intake; P: Proportion from water

For those compounds for which has not been established yet a TDI, we use the Minimum Therapeutic Dose (**MTD**) values to calculate the GV:

$$\boldsymbol{GV}\ (\mu g\ L^{-1}) = \frac{\mathbf{MTD}\left(\frac{\mathbf{mg}}{\mathbf{day}}\right) \times\ \boldsymbol{P} \times\ 10^{3}}{\mathbf{SF}\ \times\ \mathbf{V}\ (\mathbf{L/d\ ay})}$$

Where: V=2 L/day; MTD: Minimum Therapeutic Dose; P: Proportion of MTD from water; SF: Safety factor (1,000 for most compounds, and 10,000 for cytotoxic compounds and hormones).

Suitable and safety monitoring of wastewater reuse

Selecting contaminants (step 2):

Once **GV** is obtained, we finally assess a Risk Coefficient (**RC**): Ratio between the calculated or estimated guides values for a compound and the calculated initial theoretical concentrations in the wastewater influent (as exposed before). A margin (RQ) below 1, indicates that the concentration is above the value guide for the compound. This margin is taken as a first approach in order to prioritize which compounds we would consider to assess regarding its possible presence in the reclaimed water.

$$RQ\ (Risk\ Coefficient) = \frac{Estimated\ concentration\ in\ water}{Guide\ Value\ (GV)}$$

We selected pharmaceuticals with **RQ > 0.1**

Total selected pharmaceuticals: **77** out of 795 total pharmaceuticals previously listed.

Final total compounds to be analysed: **315** out of 1,072 compounds

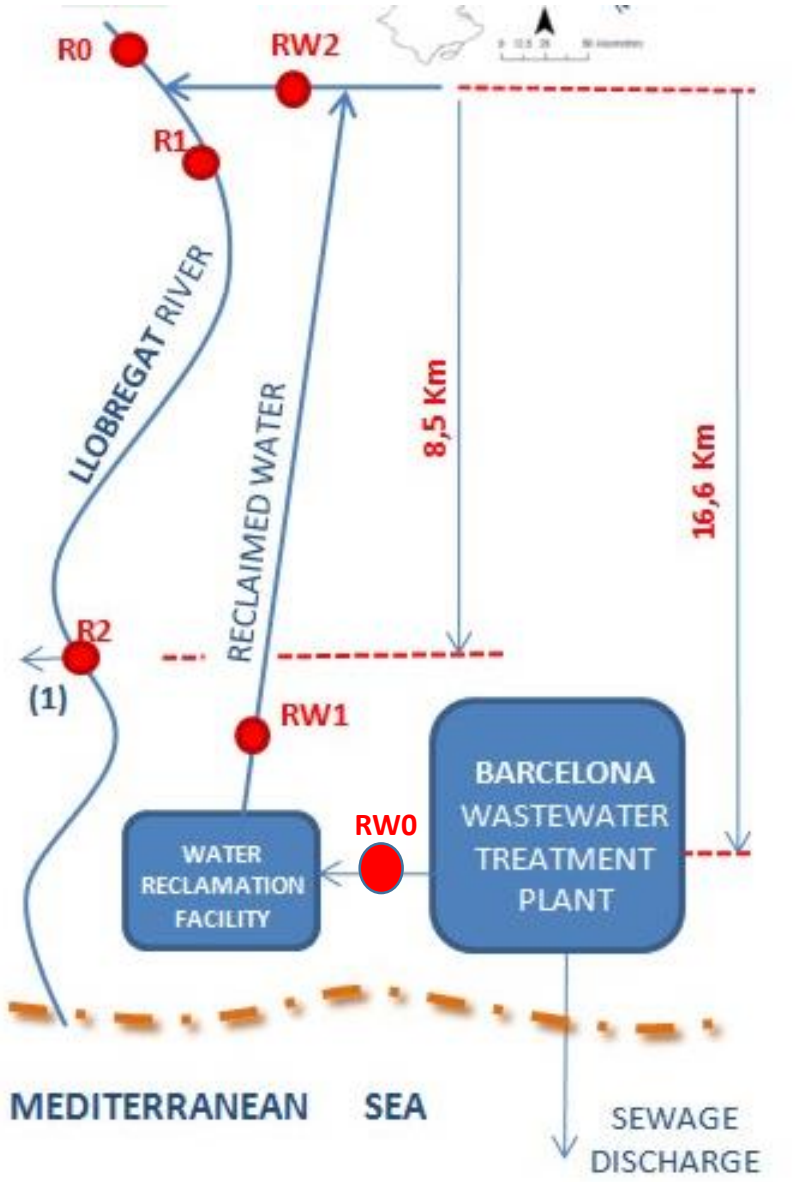
Suitable and safety monitoring of wastewater reuse

Monitoring procedure:

A total of **315 compounds** have been analysed in a monitoring exercise for selected sampling sites (6).

Samples were taken during a period of **2 months (non chlorinated and chlorinated)**:

- **RW1**: monthly (2 samples)
- **RW2**: biweekly (4 samples: 2 chlorinated + 2 without chlorine)
- **R0** and **R2**: weekly (8 samples: 4 chlorinated + 4 without chlorine)



Preliminary results and conclusions

- ✓ Analysis are still on going. So, only partial results are available so far.
- ✓ Few compounds, from the selected list, are detected over the limit of quantification (LOQ) (around 30%).
- ✓ The discharge of reclaimed water from “ERA - El Prat” seems to increase the concentration of just a few compounds of concern.
- ✓ Most of detected contaminants already come from upstream.
- ✓ Enhancing additional treatment in “ERA - El Prat” will be carefully analysed after the trial (e.g. advanced oxidation, etc.). Also considering some WWTPs located upstream.
- ✓ The need of chlorine addition in the effluent will be analysed.

Final remarks

This work has been undertaken through a **technical working group** composed by members of:

- Public Health Agency of Catalonia (public human health authority)
- Barcelona Metropolitan Area (WWTP regulator)
- *Aigües de Barcelona* (Drinking Water Plant and WWTP operator)
- Catalan Water Agency (public water authority)

In addition, an Expert Panel was settled to provide expert advice on this issue:

- Members of research centres focused on chemical contamination, river ecology and toxicology, waterborne pathogens, water treatment, etc.
- Human health and environmental risk assessment centers.
- Experts on social media, communication and public participation.

Agència Catalana de l'Aigua

Thank you very much for your attention

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