MANAGED AQUIFER RECHARGE AS A TOOL TO INCREASE GROUNDWATER RESERVES FOR DRINKING WATER PRODUCTION AND AGRICULTURAL USE

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- WATERS CHEMICAL QUALITY: CECs LEVELS
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- RECHARGED WATER INTENDED FOR AGRICULTURAL IRRIGATION OF CROPS FOR HUMAN CONSUMPTION
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Introduction

Groundwater at risk

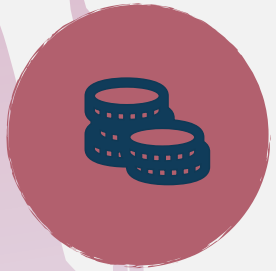
Groundwater resources are threatened globally

Increasing demand

Public water supply, industry, and agriculture expected to increase and, consequently, also water demand

Pollution

Depending on the source water used for aquifer recharge (*e.g.* river water, urban stormwater, or treated wastewater) a large variety of contaminants may be present



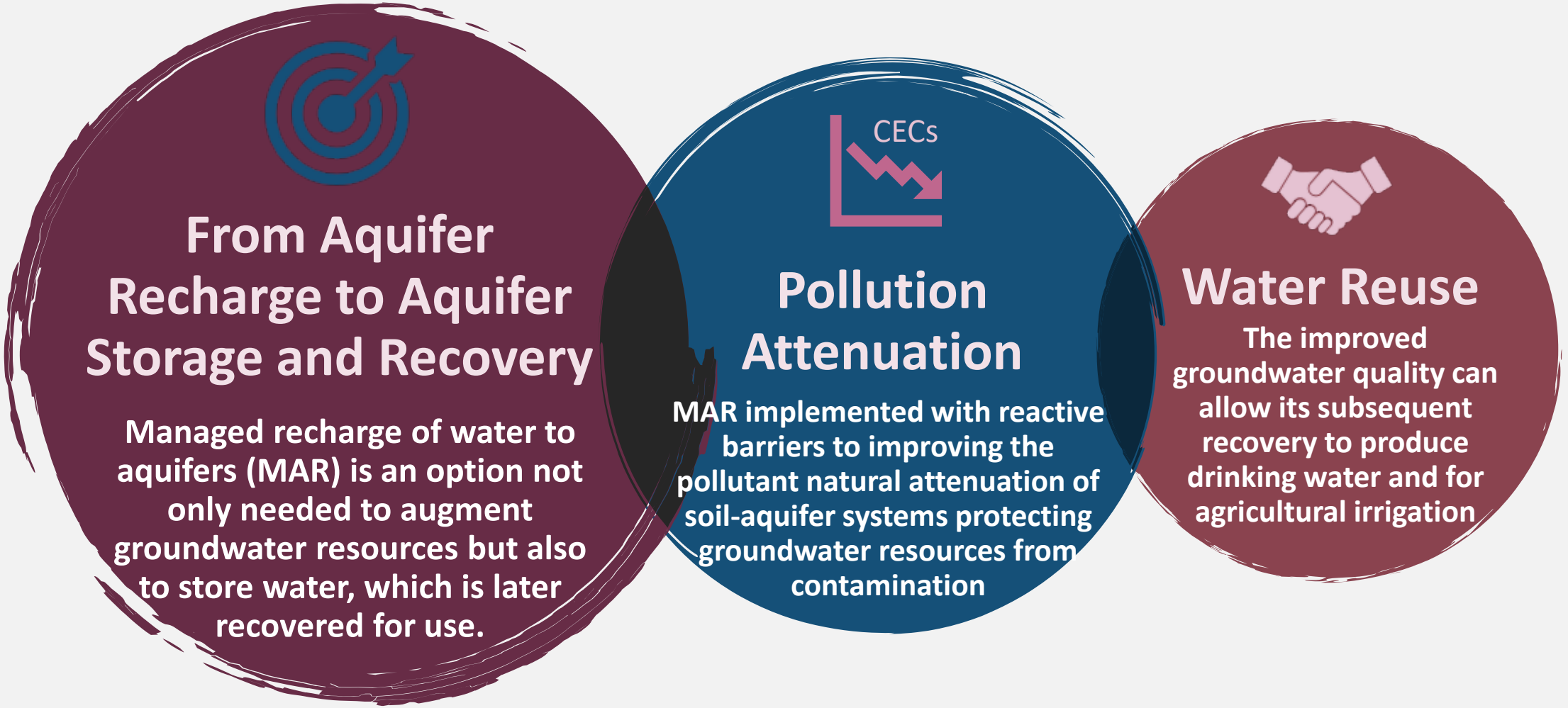
Cost

Wastewater treatment and reclamation technologies

Monitoring

There is an urgent need to strengthen data collection protocols to know the current real state of groundwater bodies

OBJECTIVES


From Aquifer Recharge to Aquifer Storage and Recovery
Managed recharge of water to aquifers (MAR) is an option not only needed to augment groundwater resources but also to store water, which is later recovered for use.
CECs
Pollution Attenuation
MAR implemented with reactive barriers to improving the pollutant natural attenuation of soil-aquifer systems protecting groundwater resources from contamination
Water Reuse
The improved groundwater quality can allow its subsequent recovery to produce drinking water and for agricultural irrigation

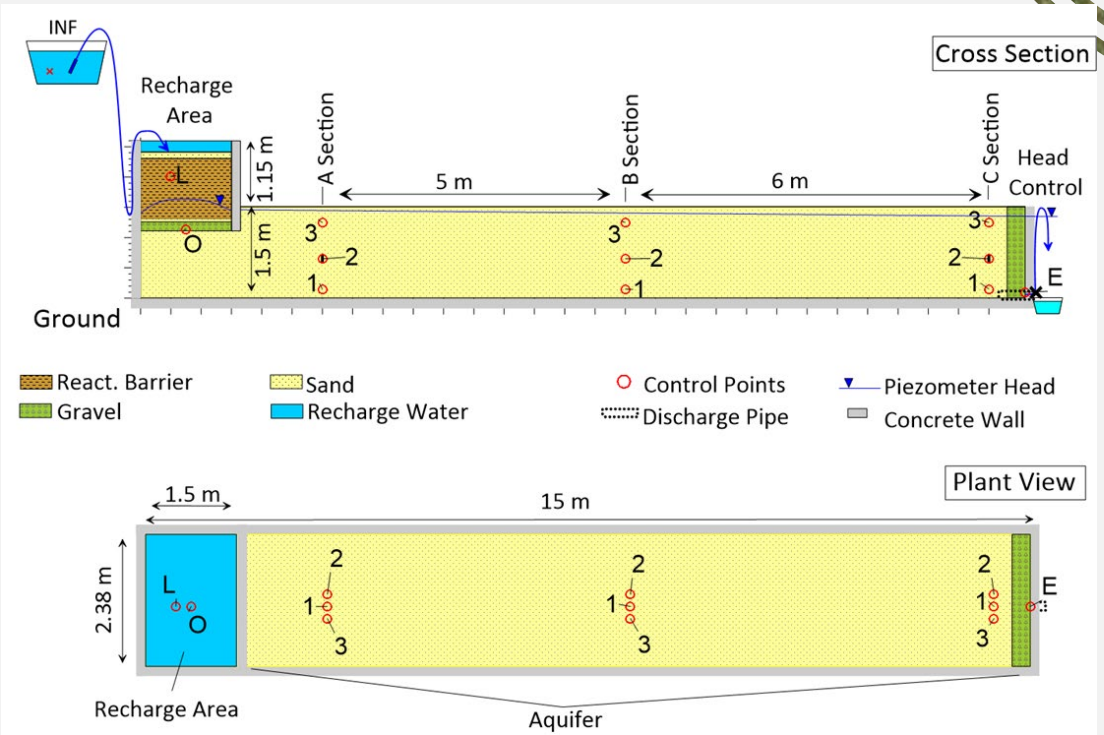
EXPERIMENTAL SITE

URBAN WASTEWATER TREATMENT PLANT

PALAMÓS, GIRONA (SPAIN)

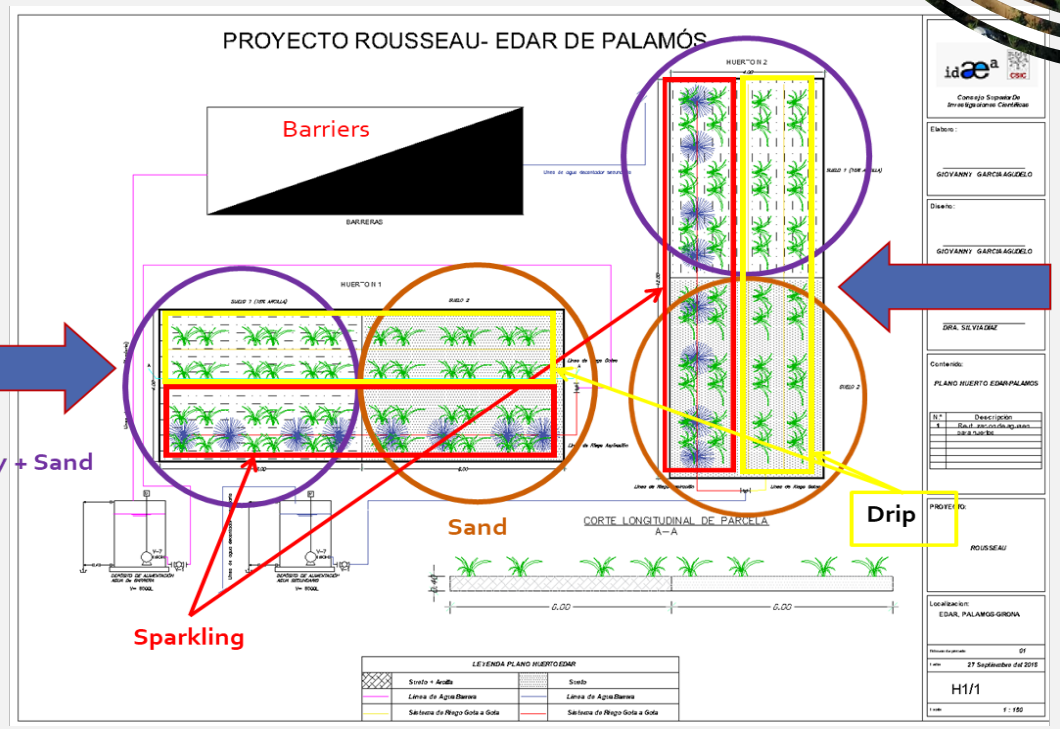
STRUCTURE OF A SYSTEM WITH A REACTIVE BARRIER

The pilot MAR system



AGRICULTURAL PLOTS DESIGN

The Agricultural plots



CROPS

Sampling Dates

Water, Soil and Carrots

Water and Soil

SEP OCT NOV DIC ENE FEB MAR ABR MAYO JUN JUL AGO

2018 2019

Water, Soil and Lettuces

Water, Soil and Tomatoes

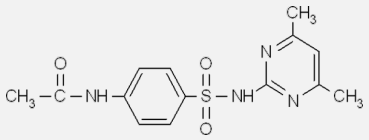
Target CECs : PPCPs

Urban origin

57 compounds - 4 groups of substances

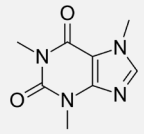
Pharmaceuticals

- **35 Antibiotics, anti-inflammatories,…**



Sulfamethazine (SMZ)

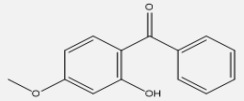
- **1 Stimulant: Caffeine**



Caffeine (CFF)

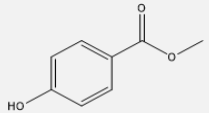
Personal care products

- **UV filters /UV stabilizers: 15 compounds**



Oxybenzone, benzophenone-3 (BP3)

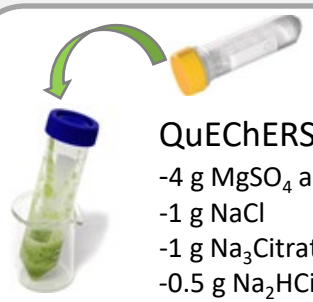
- **Paraben preservatives: 4 compounds**



Methylparaben (MePB)

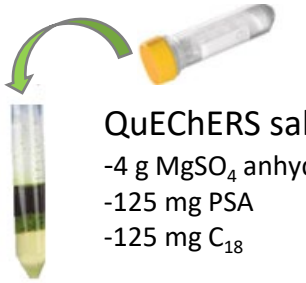
ANALYTICAL METODOLOGY

SOILS AND VEGETABLES
QuEChERS⸸ & HPLC-QqLIT-MS/MS[1]



QuEChERS salts 1:
- -4 g $MgSO_4$ anhidrous
- -1 g NaCl
- -1 g $Na_3Citrate \cdot 2\ H_2O$
- -0.5 g $Na_2HCitrate \cdot 1.5\ H_2O$

Centrifugation



QuEChERS salts 2:
- -4 g $MgSO_4$ anhydrous
- -125 mg PSA
- -125 mg C_{18}

Centrifugation
pH adjustment

HPLC-MS/MS analysis

⸸ *Quick, Easy, Cheap, Effective, Rugged & Safe*

WATERS
On-line SPE-HPLC-QqLIT-MS/MS[2]

On-line SPE Cartridges
Oasis HLB (Waters)

Symbiosis™ Pico (Spark Holland) - 4000 Q TRAP
(Applied Biosystems-Sciex).

Samples	MLOD range*	MLOQ range*
Irrigation waters	0.04-2.21 ng/L	0.15-7.36 ng/L
Soils	0.01-0.29 ng/g	0.0-0.97 ng/g
Lettuces	0.01-0.40 ng/g	0.05-1.34 ng/g
Tomatoes	0.01-1.46 ng/g	0.03-4.87 ng/g
Carrots	0.02-1.61 ng/g	0.08-5.35 ng/g

*** all units in ng/g are expressed in dw**

1. Sunyer-Caldú, A and Diaz-Cruz M.S. ., "Development of a QuEChERS-based method for the analysis of pharmaceuticals and personal care products in lettuces grown in field-scale agricultural plots irrigated with reclaimed water", Talanta, 2021, vol. 230, 1–12.
2. L. Vassalle, Sunyer-Caldu, Diaz-Cruz, MS. et al., "Bioremediation of emerging micropollutants in irrigation water. The alternative of microalgae-based treatments," J. Environ. Manage., vol. 274,

RECHARGED WATER INTENDED FOR DRINKING WATER PRODUCTION

Human Health Risk Assessment

RQ (Risk Quotient)

$$RQ = {C_{max}}/{DWEL}$$

C_{max}: maximum CECs concentration

DWEL (Drinking Water Equivalent Level)

$$DWEL = {ADI \times BW \times 1000}/{DWI}$$

DWI: daily water ingestion rate
BW: body weight

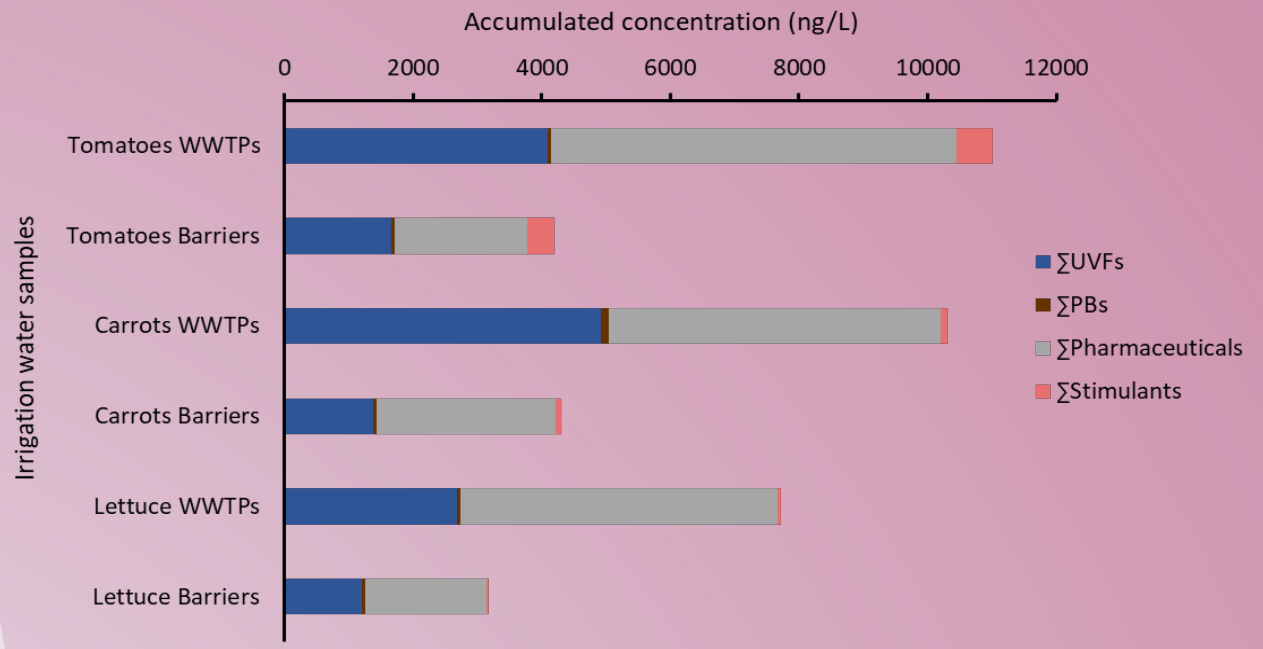
ADI (Acceptable Daily Intake)

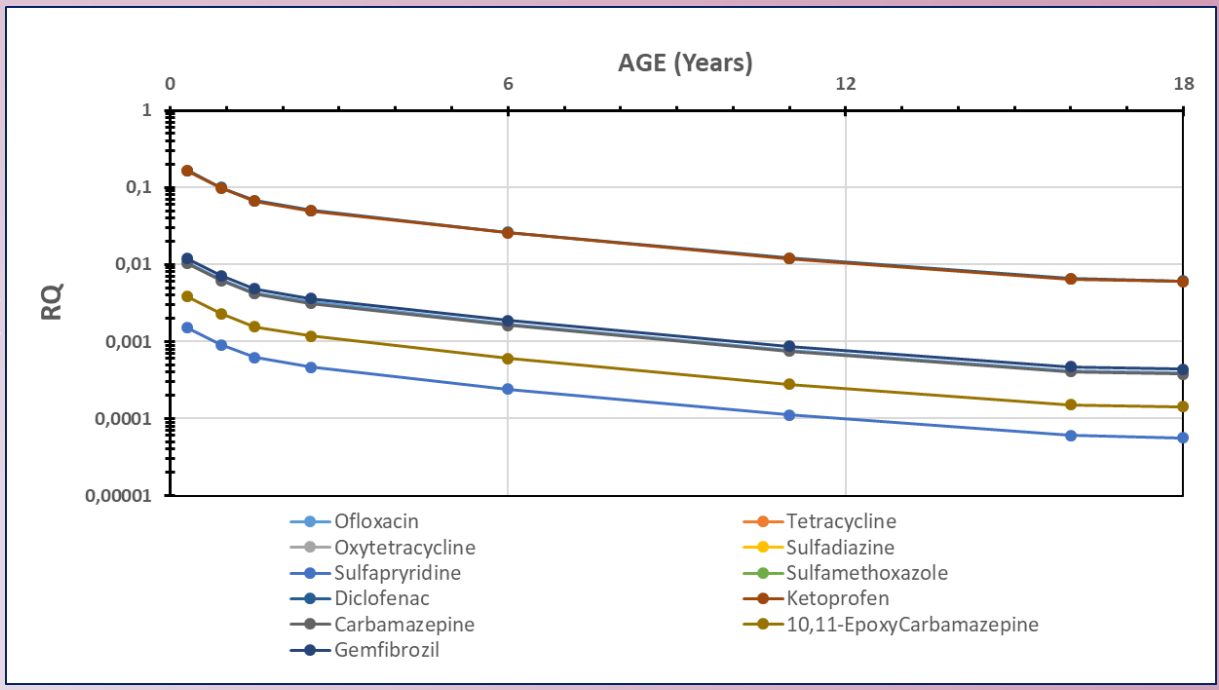
$$ADI = \frac{NOAEL}{100}$$

NOAEL: no observed adverse effect level

Age Groups	BW (kg)*	DWI (L/day)*
0-6 months	7.6	0.68
6-12 months	8.6	1
1-2 years	10.6	1.2
2-3 years	13	1.3
4-8 years	20.4	1.6
9-13 years	35.4	2
14-18 years	58	2.25
Adults	62	2.25

* Data on body weight was extracted from the WHO website and the DWI doses were those published by European Food Safety Authority (EFSA).





RECHARGED WATER INTENDED FOR AGRICULTURAL IRRIGATION OF CROPS FOR HUMAN CONSUMPTION

Human Health Risk Assessment

HQ (Hazard Quotient)

$$HQ = \frac{ADI}{EDI}$$

HI (Hazard Index)

$$HI = \Sigma HQ$$

- *DI, ENALIA and ENALIA2 Surveys from AECOSAN.*
- *BW, 70 Kg average Spanish male adult of 18-74 years, and 24 Kg average child of 3-9 y.*
- **ADI, from datasets compiled by Prosser et al. (2015) and Wang et al. (2017).*

EDI (Estimate Daily Intake)

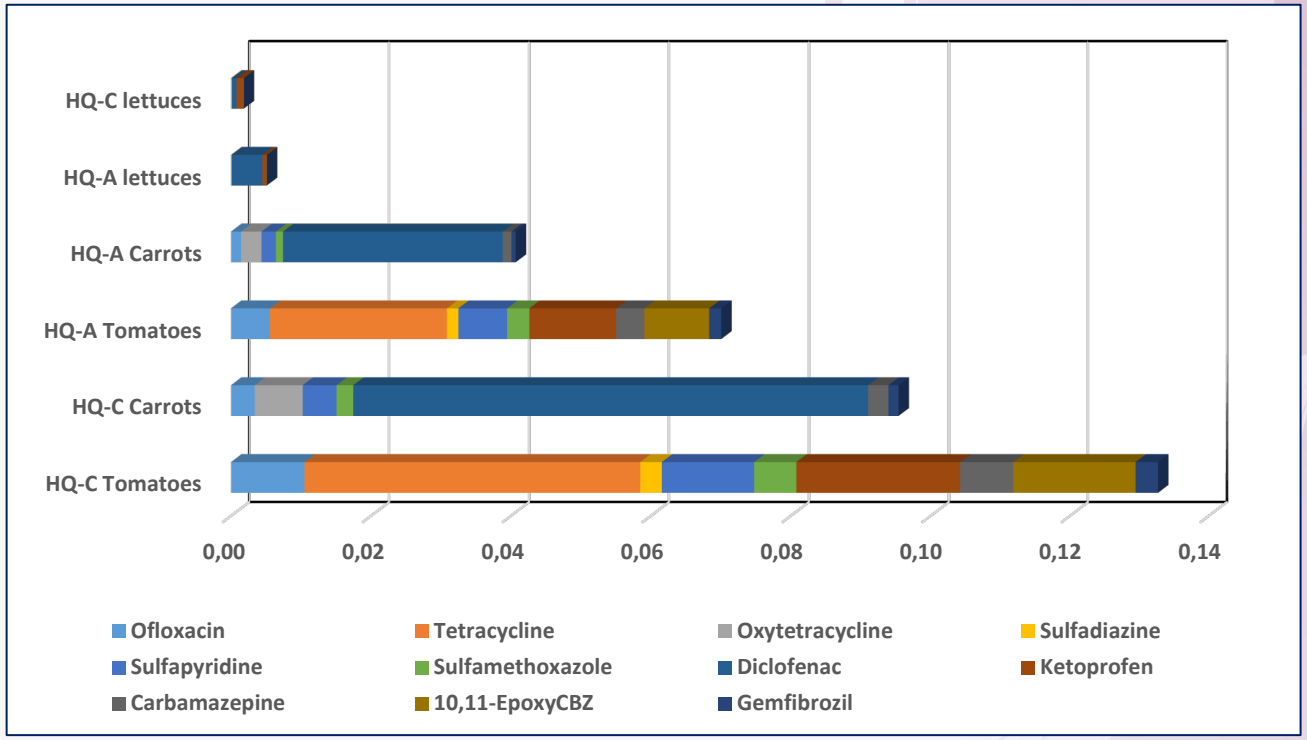
$$EDI = \frac{DI \cdot C_e}{BW}$$

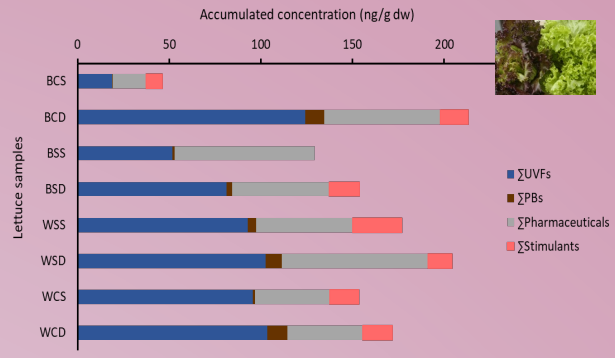
DI: Daily Intake
C_e: Average CECs concentration
BW: Body Weight

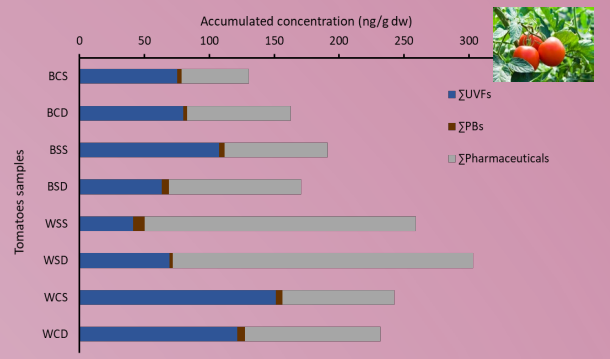
ADI (Acceptable Daily Intake)

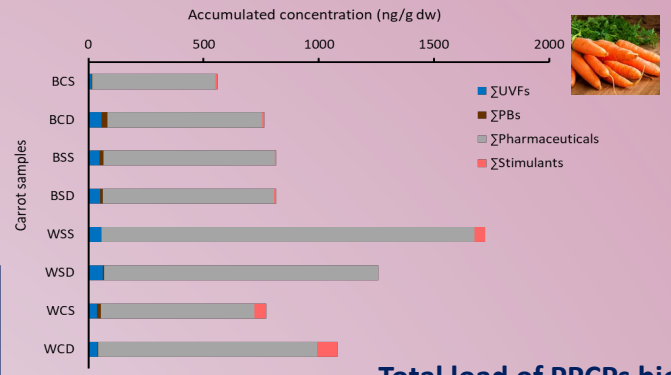
$$ADI = \frac{NOAEL}{100}$$

NOAEL: no observed adverse effect level



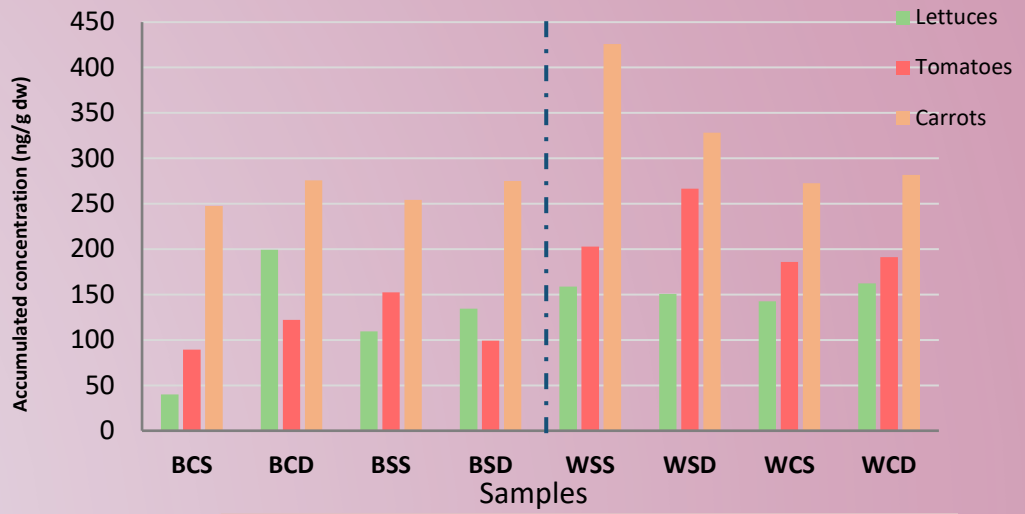






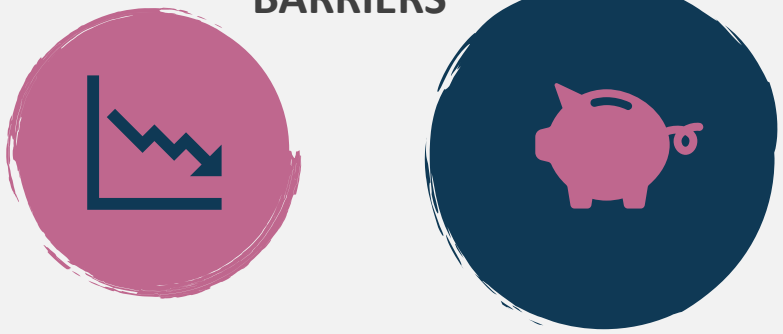
B: Barriers water, **W:** WWTP effluent water, **S:** sand (less clay) soil, **C:** clay soil, **S:** sprinkler irrigation system, **D:** drip irrigation system.

Total load of PPCPs bioaccumulated (ng/g dw)



*Wang, H. Et al. 2017. Environmental Science and Technology, 51, 3518–3525.
Prosser, R. et al., 2015. Environment International, 75, 223–233.*

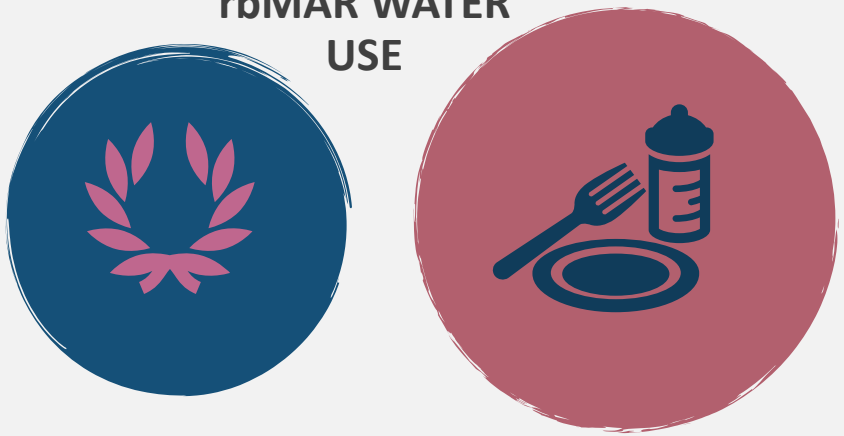
MAR + REACTIVE BARRIERS



Significative attenuation of pollutants

Cost effective nature-based approach

rbMAR WATER USE



Improves GW quality

Safe for human health, No risk state

CONCLUSIONS

Emerging risks of chemical and microbiological contamination in the reuse of wastewater for agricultural irrigation: integrated study. ROUSSEAU

http://rousseauproject.es

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Agència Catalana de l'Aigua

RESTORA

Managed aquifer recharge and use of organic subsurface treatment to accelerate water renaturation

https://restora.h2ogeo.upc.edu

CONSORCI D'AIGÜES COSTA BRAVA GIRONA

Water JPI

Water Works 2017

2018 JOINT CALL

MARadentro: Managed Aquifer Recharge: Addressing the Risks of Recharging Regenerated Water

http://www.maradentro-jpi.eu

THANK YOU

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