



Sustainable Water Integrated Management - Support Mechanism (SWIM- SM)

Project funded by the European Union

**STUDY TOUR ON WASTEWATER MANAGEMENT  
USING NATURAL TREATMENT SYSTEMS (NTS) IN RURAL AREAS**

**National experience and capacity needs for the  
construction and operation of NTSs**

# Introduction

- Experiences on the natural wastewater systems for urban and productive settlements in Sicily
  - San michele di Ganzaria municipality
  - Marabino's winery
  - IKEA store of Catania
  - Valle dei Margi Agritourism
  - Citrus industry Ortogel
  - Grammichele and Caltagirone reuse systems

# San michele di Ganzaria municipality

National experience and capacity needs for the  
construction and operation of NTSs



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# Area location

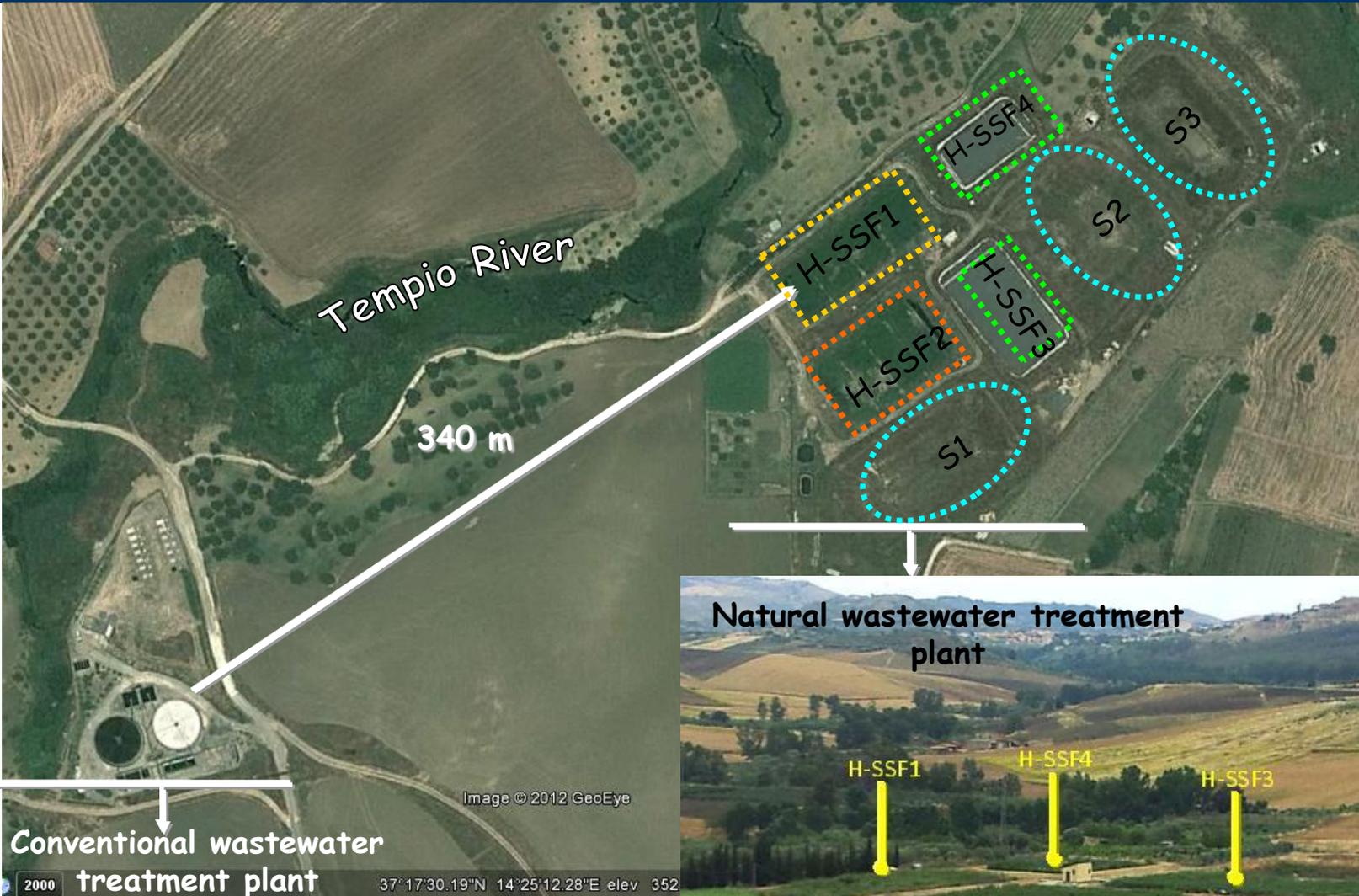


- 5.000 habitants
- Area 26 Km<sup>2</sup>

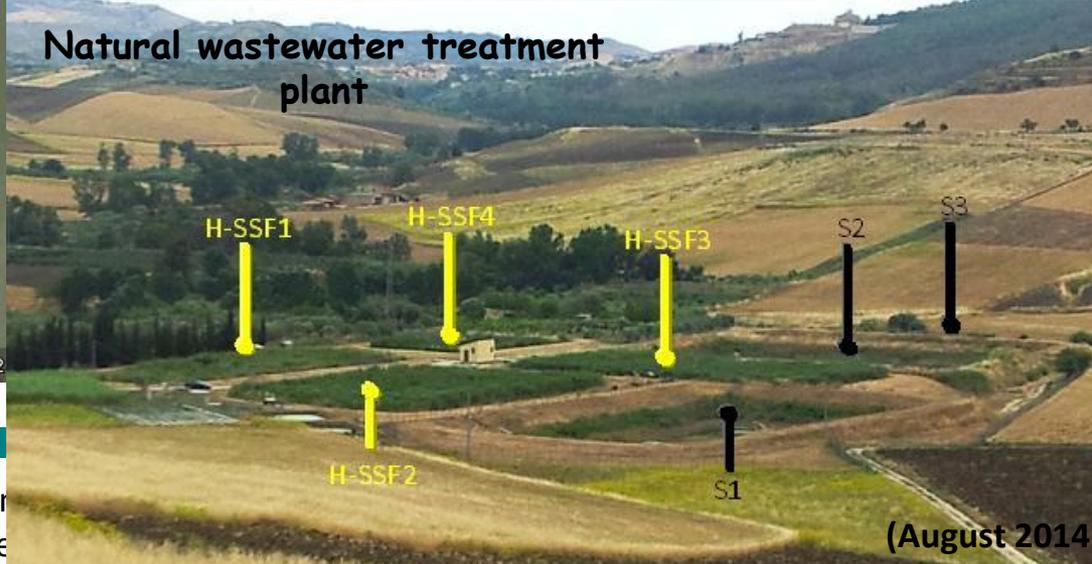
# Area location



# Plant description



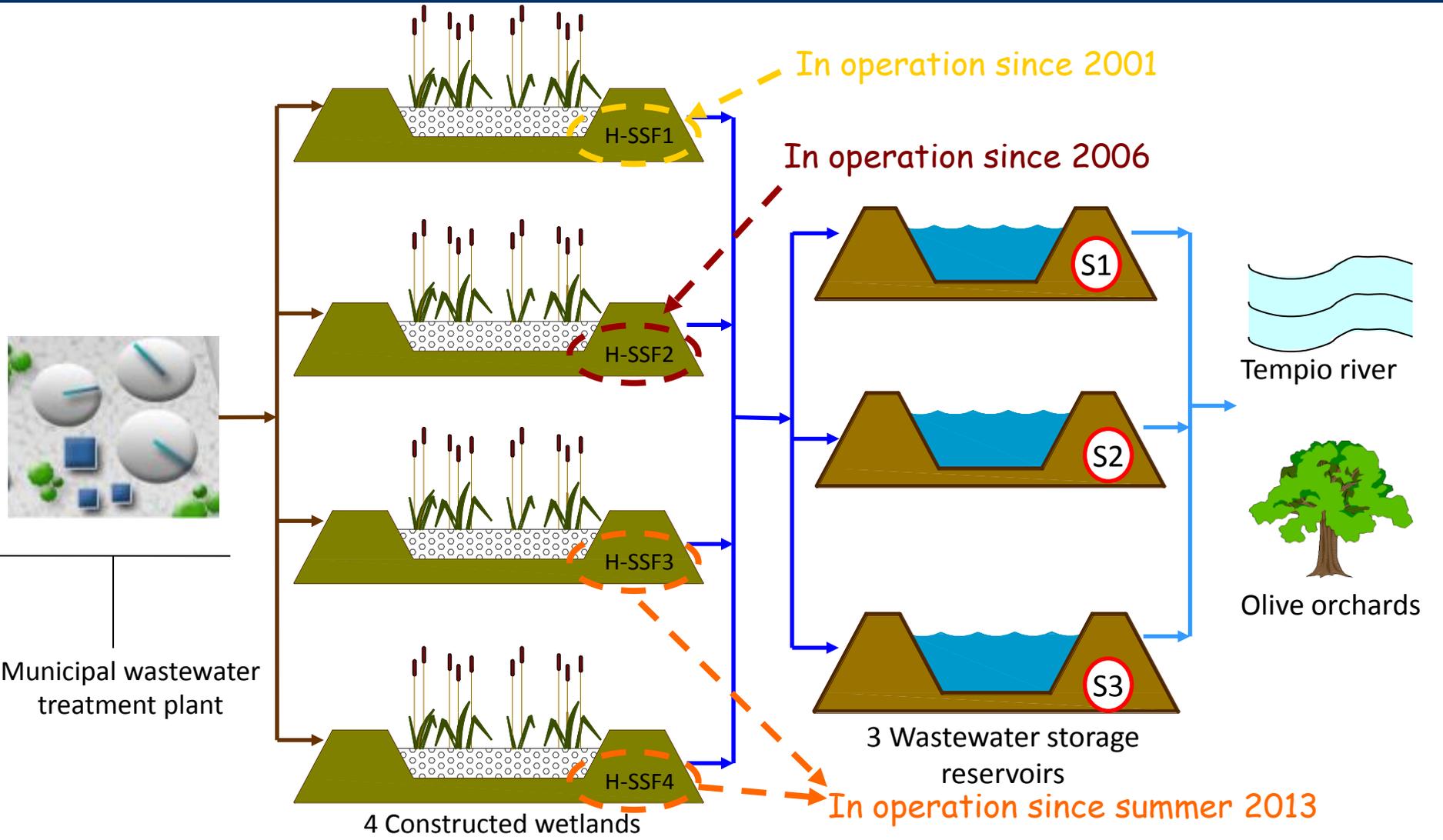
Conventional wastewater treatment plant



Natural wastewater treatment plant

(August 2014)

# Lay out of plant



# Characteristics of horizontal constructed wetlands



H-SSF1

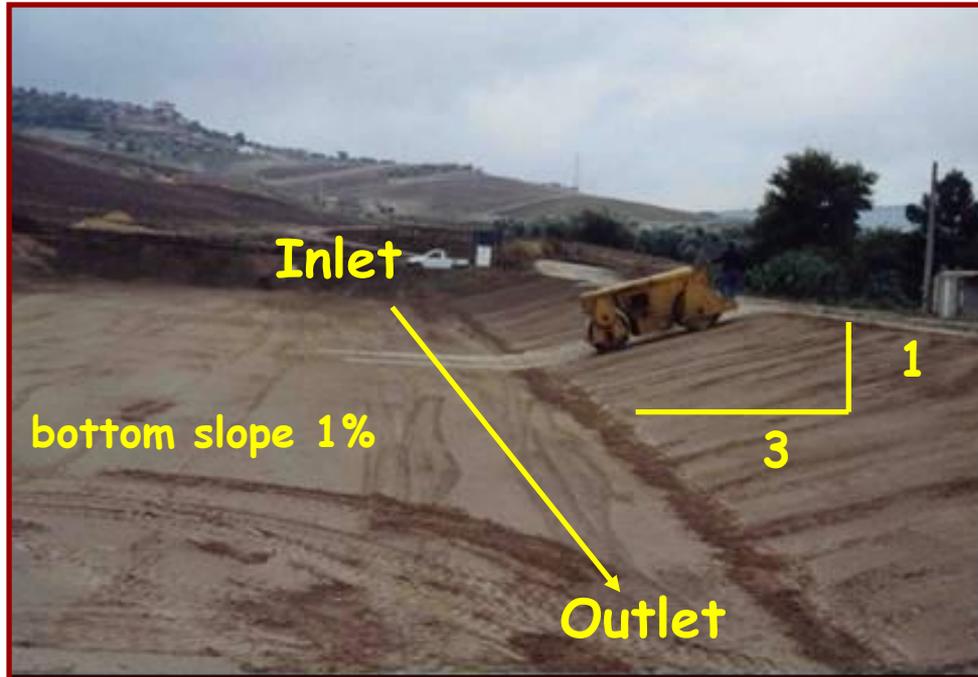
H-SSF2

H-SSF3

H-SSF4

Constructed wetlands	Operation time (year)	Flow rate (m <sup>3</sup> /day)	Area (m <sup>2</sup> )	Gravel			Filter bed depth (m)	Type of macrophytes
				type	size (mm)	nominal porosity		
H-SSF1	14	215	1950	<i>Calcareous</i>	8-15	0.38	0.6	<i>Phragmites sp</i>
H-SSF2	9	240	2000	<i>volcanic</i>	8-15	0.47		
H-SSF3	2	240	2000					
H-SSF4	2	125	1200					<i>Typha latifolia</i>

# CWs Construction phase



beds depth = 1m

4 mm thick bentonite sheet



# CW Construction phase: Basin liner



# CWs Construction phase: Filling of substrate



# Wastewater distribution system



- The influent is distributed at the bed-head through a perforated 200 mm PVC pipe

- coarser rock with larger void spaces and a higher hydraulic conductivity was used at inlet zone to ensure rapid infiltration, and at outlet zone to favorite flow collection

# Wastewater drainage system

200 mm PVC pipe



adjustable outlet  
(spiral plastic pipe)



# Piezometers

- 9 piezometers in each bed



# macrophytes plating phase

- density: 4/5 rhizomes m<sup>2</sup>



# macrophytes

Beds were completely covered in a short time



# Characteristics of Wastewater reservoirs

Wastewater reservoirs	Volume (m <sup>3</sup> )	depth (m)	Nominal retention time (days)
S1	8,800	5	16
S2	8,800	5	16
S3	7,700	5	13

# Wastewater reservoirs Construction phase



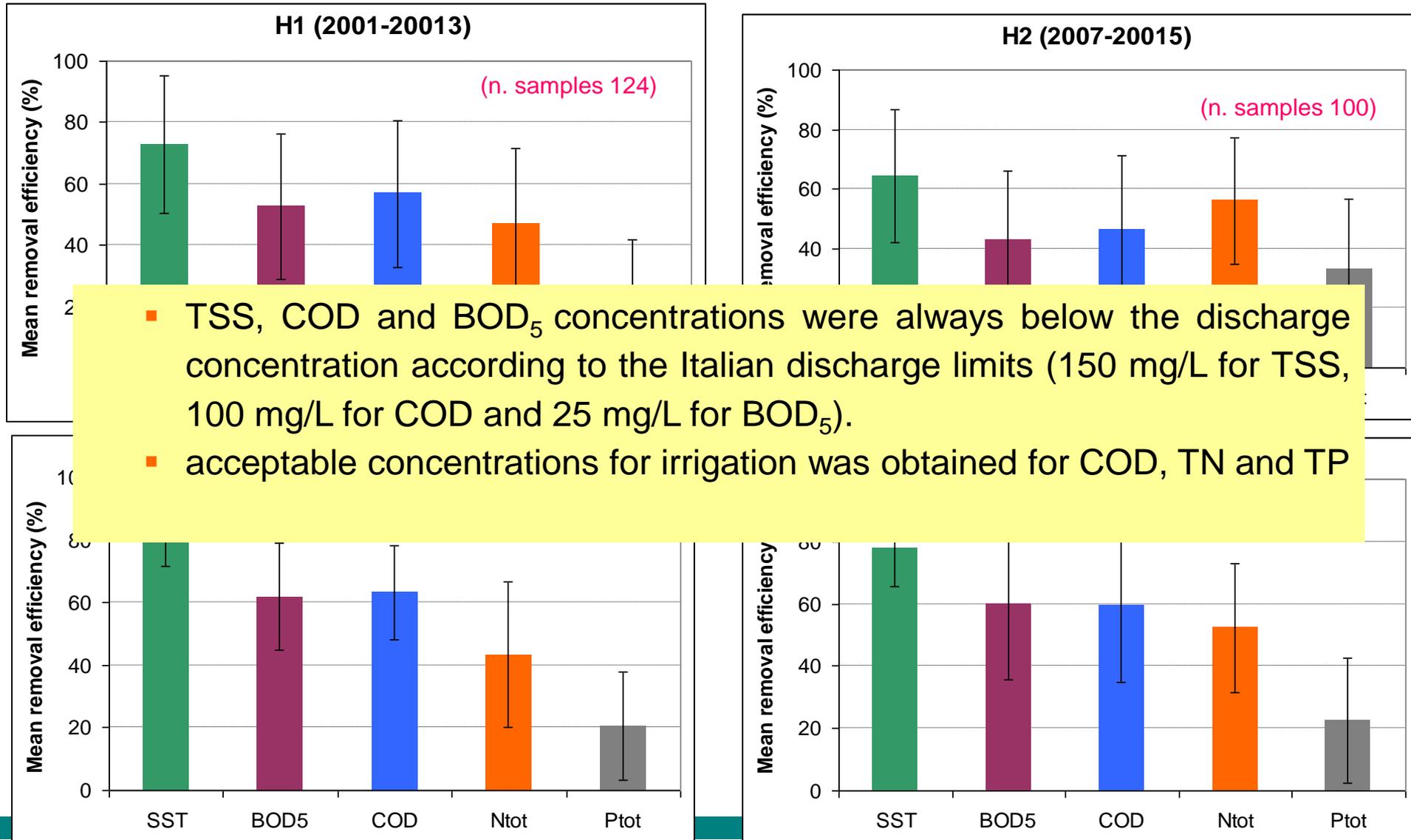
Drainage pipes



# Wastewater reservoirs: Hydraulic test

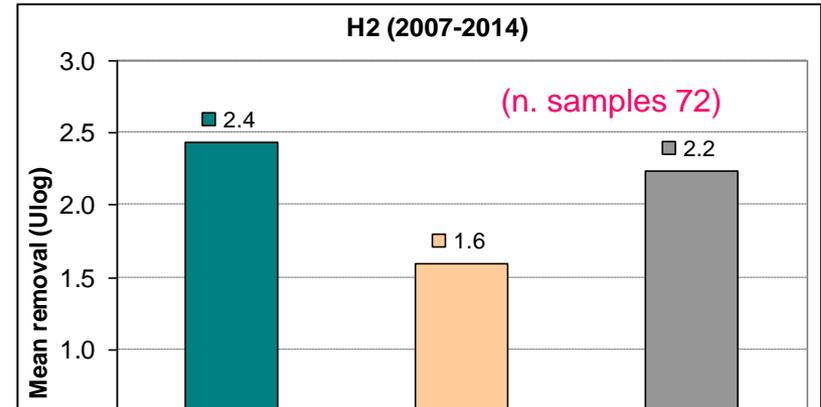
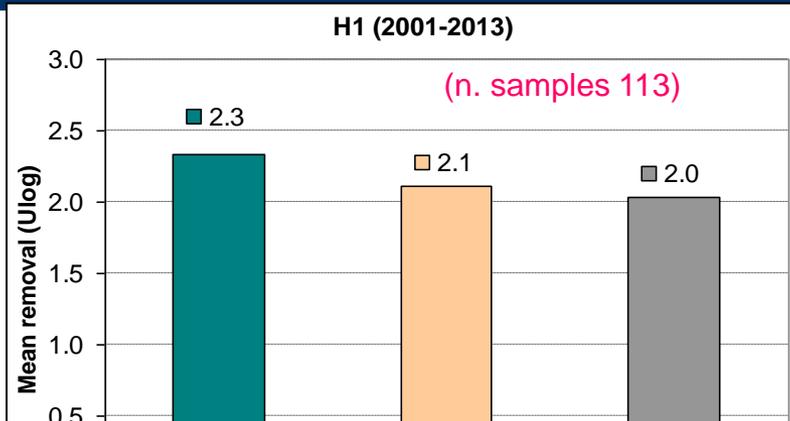


# Mean removal efficiency: Chemical-physical parameters

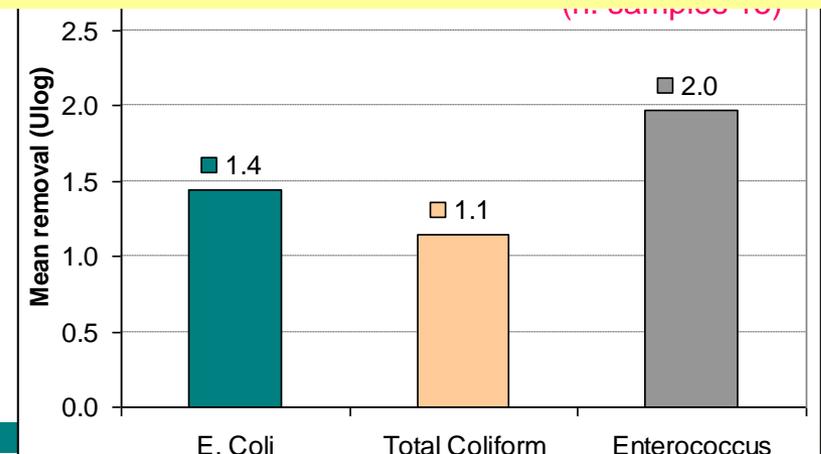
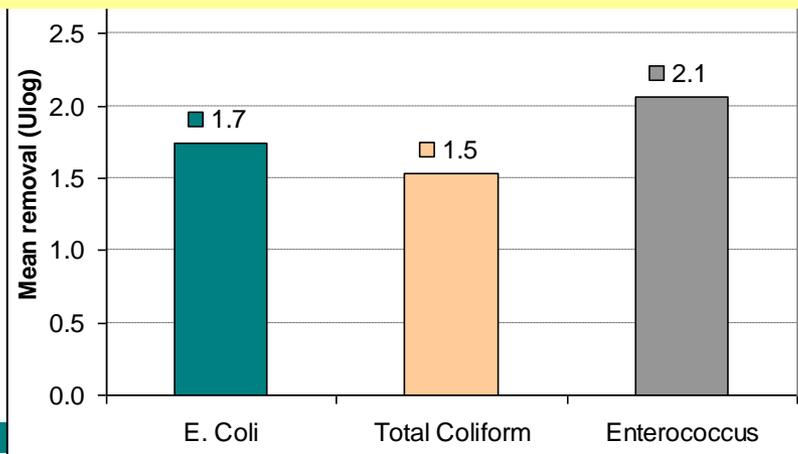


- TSS, COD and BOD<sub>5</sub> concentrations were always below the discharge concentration according to the Italian discharge limits (150 mg/L for TSS, 100 mg/L for COD and 25 mg/L for BOD<sub>5</sub>).
- acceptable concentrations for irrigation was obtained for COD, TN and TP

# Mean removal efficiency: Microbiological parameters



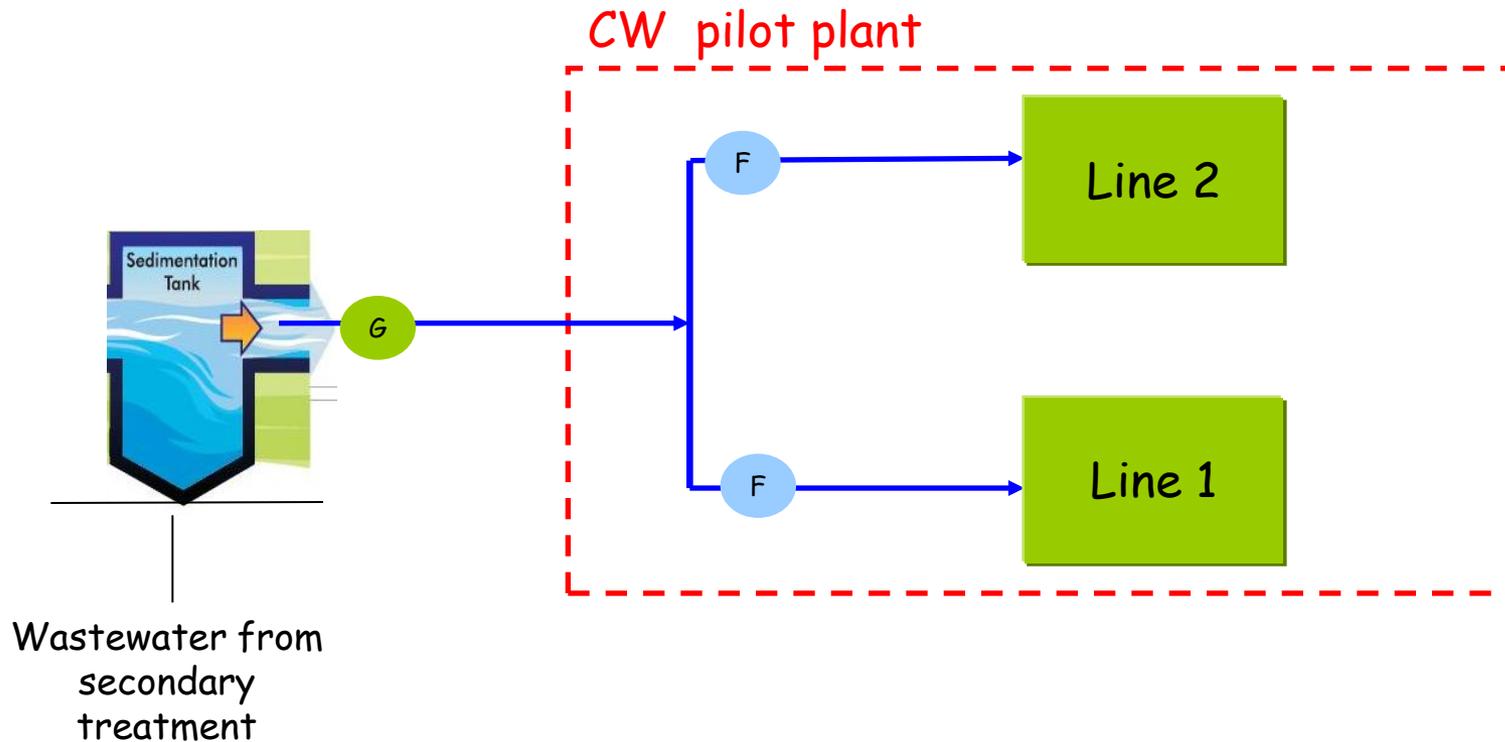
- Despite constructed wetlands having shown good removal of microbial indicators, the Italian reuse limit for *E. coli* was not always respected (50 UFC/100 ml). This result highlights the need for further treatment to achieve the threshold required for irrigation reuse



# CW pilot plant: area location



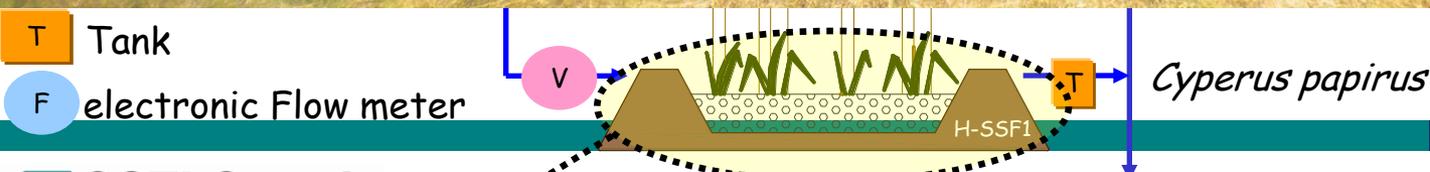
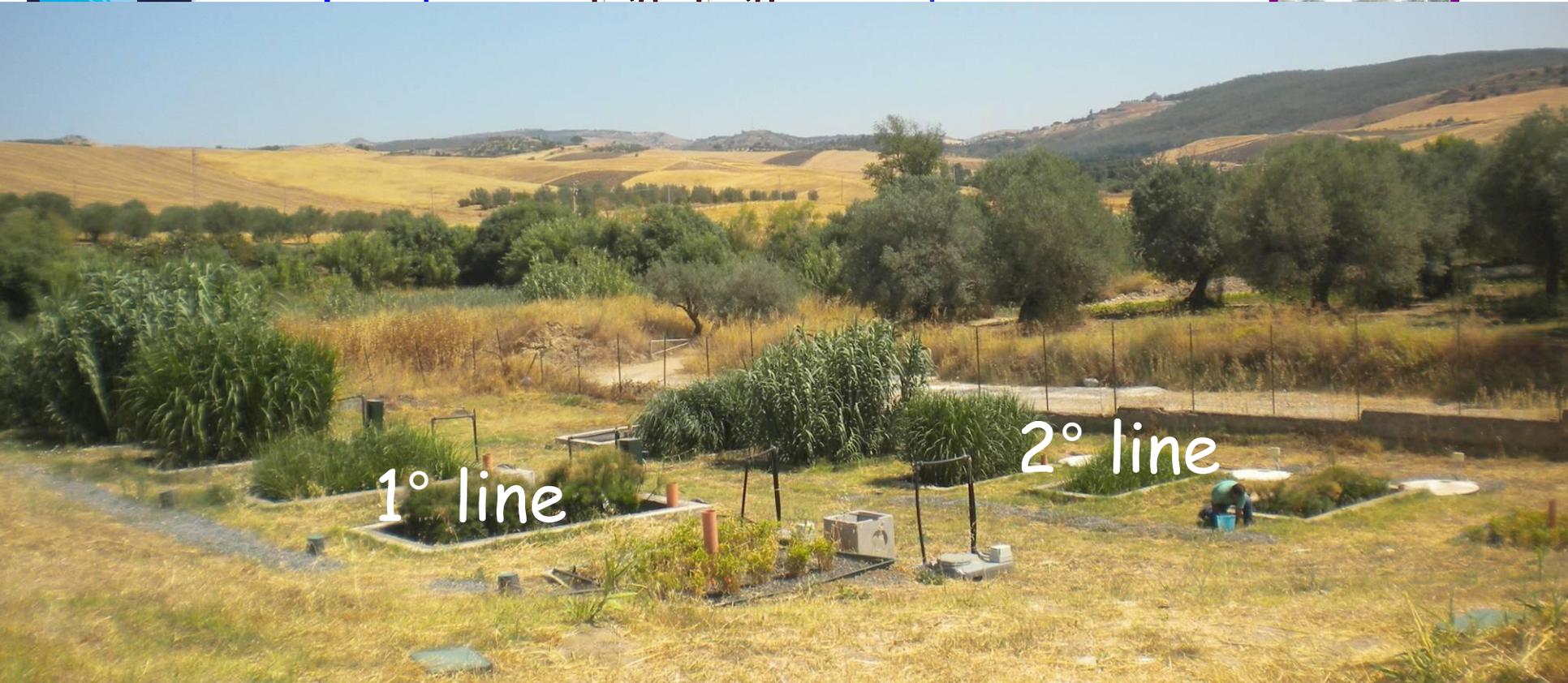
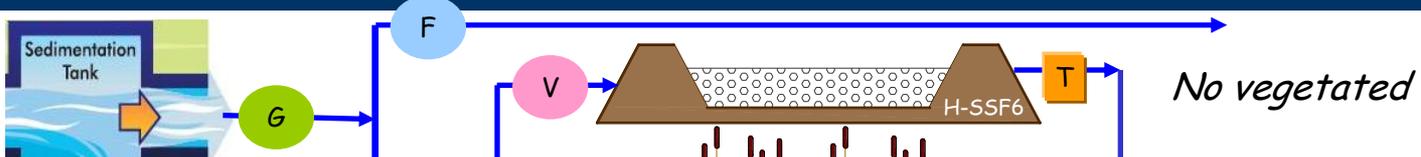
# Layout of CW pilot plant



## Legend

- G Filter
- F Electronic Flow meter

# Layout of CW pilot plant



CSFL Octon... tour on wastewater management rural treatment systems in rural areas

$3 \text{ (m)} \times 1.5 \text{ (m)} = 4.50 \text{ (m}^2\text{)}$

# CW pilot plant: results

Influente	(mg/L)	TSS		COD		NH <sub>4</sub>		N <sub>tot</sub>		PO <sub>4</sub>		E.Coli*	
		102	(71)	82	(36)	10	(4)	25	(8)	4	(1)	5.6	(0.4)
 <i>Cyperus papyrus</i>	out (mg/L)	9	(4)	26	(18)	4	(2)	9	(3)	3	(1)	2.8	(0.2)
	R (%)	82	(24)	60	(30)	48	(38)	53	(21)	24	(20)	2.8	(0.4)
 <i>Vetiveria zizanoides</i>	out (mg/L)	13	(19)	27	(13)	4	(2)	10	(4)	3	(1)	2.9	(0.5)
	R (%)	85	(16)	63	(19)	53	(18)	58	(13)	25	(19)	2.7	(0.5)
 <i>Myscanthus x giganteus</i>	out (mg/L)	13	(18)	27	(12)	4	(2)	10	(4)	3	(1)	2.9	(0.6)
	R (%)	84	(14)	62	(19)	52	(23)	57	(15)	24	(28)	2.8	(0.6)
 <i>Arundo donax</i>	out (mg/L)	13	(20)	28	(14)	4	(1)	10	(5)	3	(1)	2.8	(0.4)
	R (%)	87	(13)	61	(23)	58	(22)	61	(15)	29	(24)	2.8	(0.4)
 <i>Phragmites australis</i>	out (mg/L)	9	(14)	25	(13)	4	(2)	9	(5)	3	(1)	2.5	(0.6)
	R (%)	88	(15)	64	(21)	61	(21)	64	(12)	31	(25)	3.1	(0.6)
Non vegetato	out (mg/L)	16	(21)	36	(17)	6	(3)	14	(5)	3	(1)	3.4	(0.8)
	R (%)	78	(18)	49	(27)	40	(10)	46	(9)	22	(18)	2.2	(0.7)

\*Ulog

- The **vegetated beds** showed a better performance for all the investigated parameters than unvegetated beds, underlining the active role of macrophytes in the wastewater treatment.
- The best removal performances obtained in the beds planted with ***Phragmites australis***, confirm that this is the plant specie most suitable to be used in constructed wetlands for wastewater treatment.

# Marabino's winery

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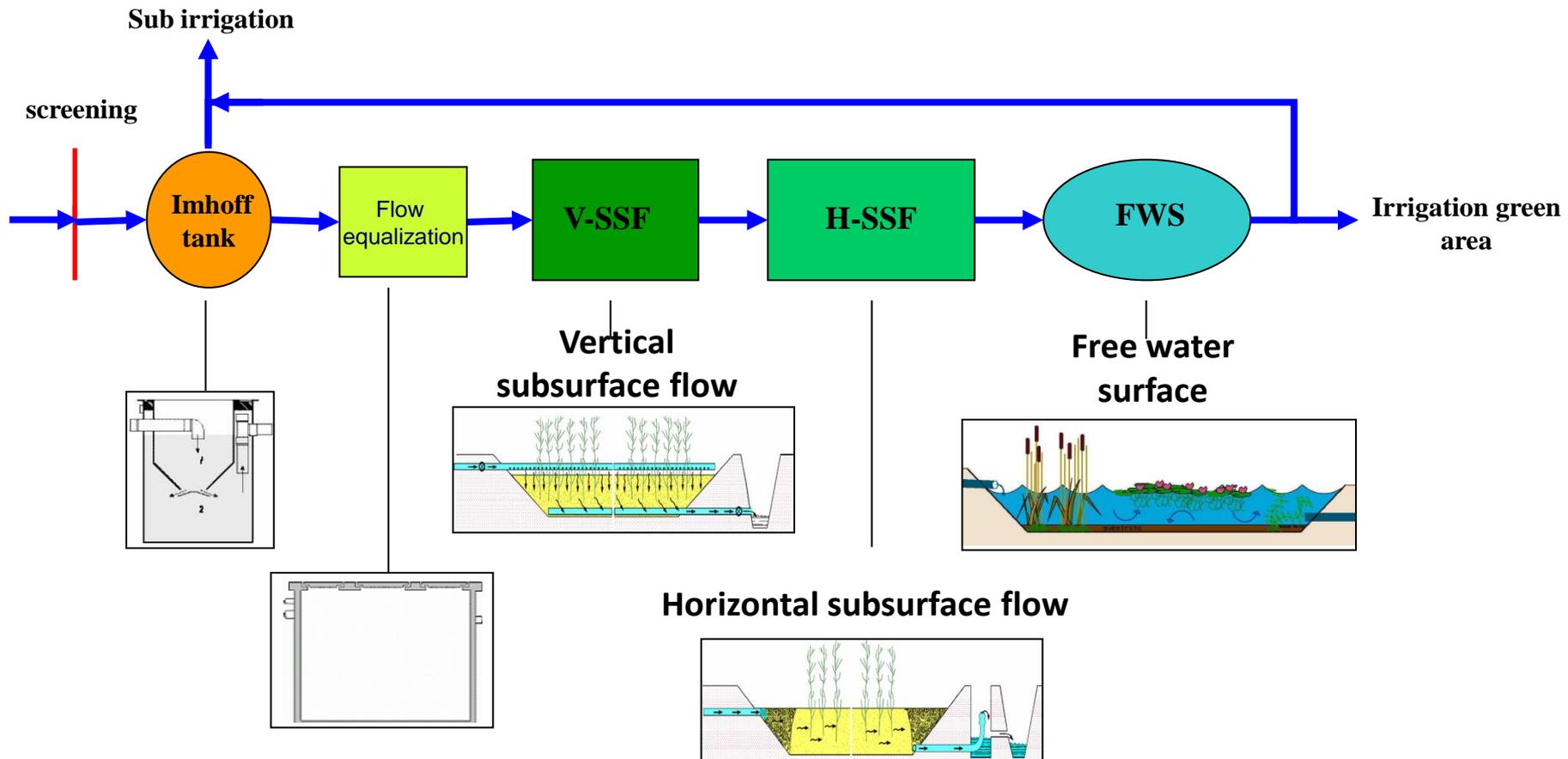
# Area location

- Marabino's winery is located into the Noto valley of Siracusa province
- 26 ha are cultivated (Nero d'Avola, Moscato Bianco and Chardonnay)
- 120.000 bottle of wine per year

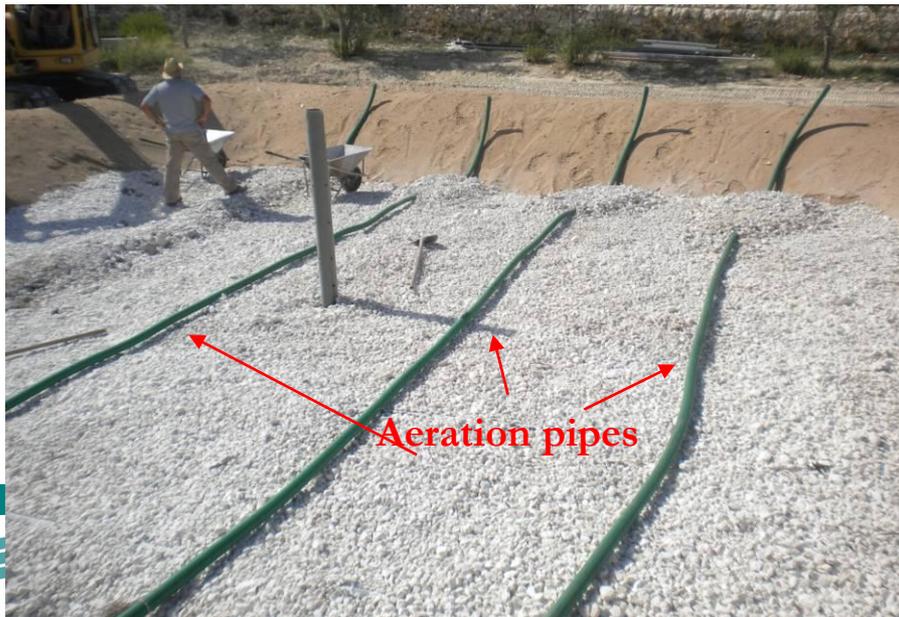
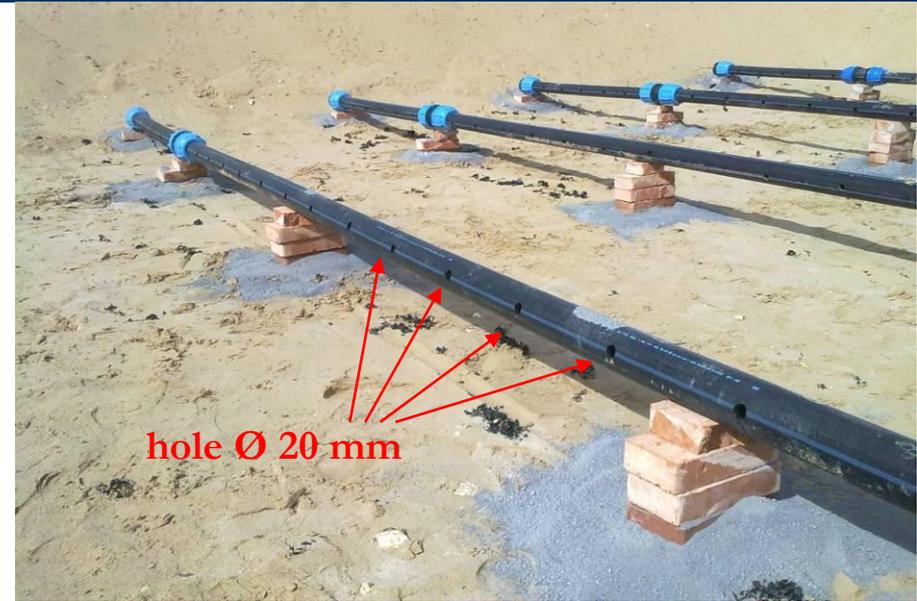


# Wastewater treatment plant

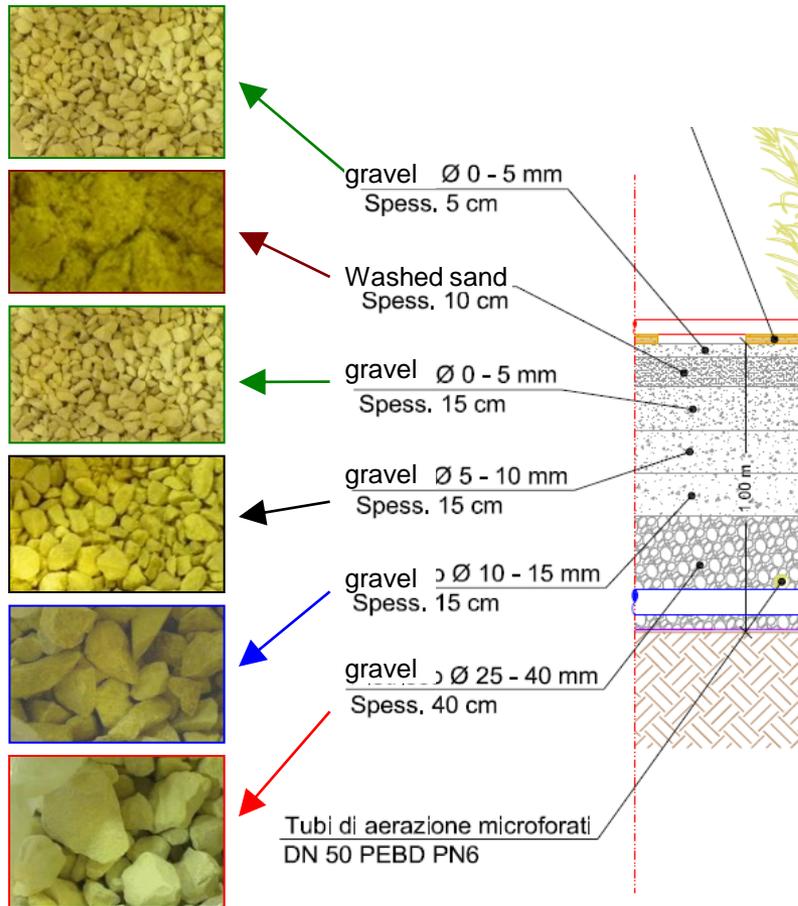
- 4,5 L of wastewater per 1 L of wine
- Wastewater volume: 3 m<sup>3</sup>/day



# Construction phase V-SSF



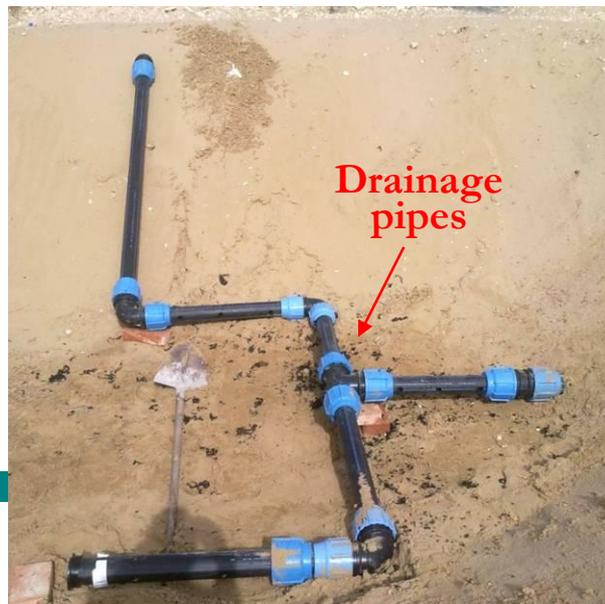
# Construction phase V-SSF



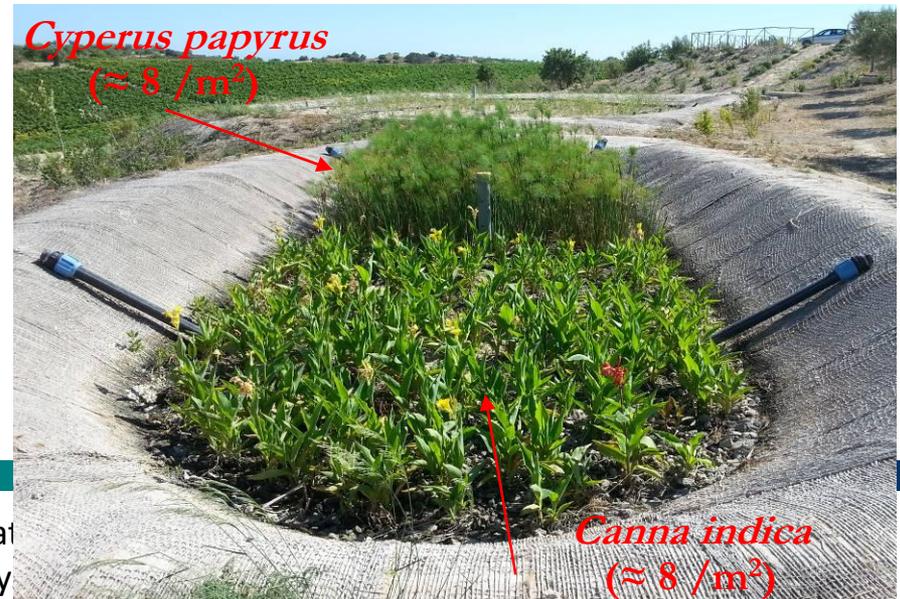
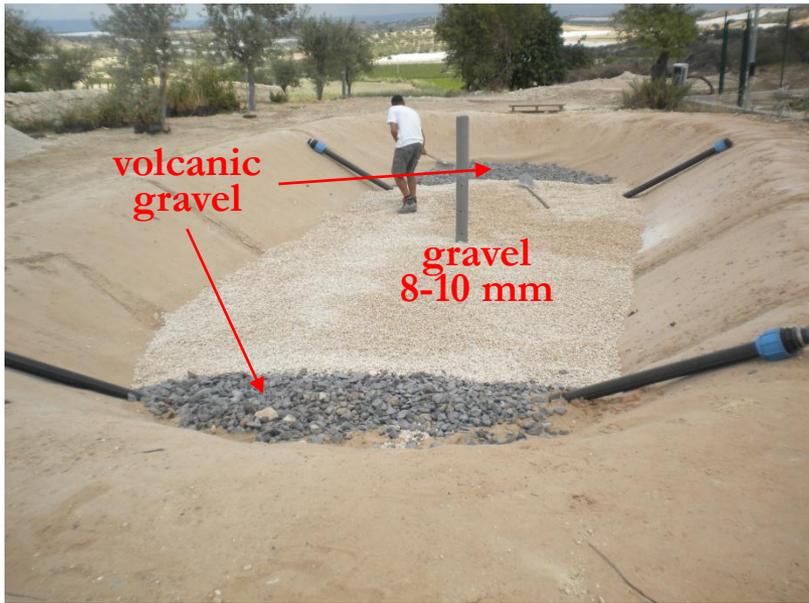
***Phragmites australis***  
(4 rhizomes/m<sup>2</sup>)



# Construction phase H-SSF



# Construction phase H-SSF



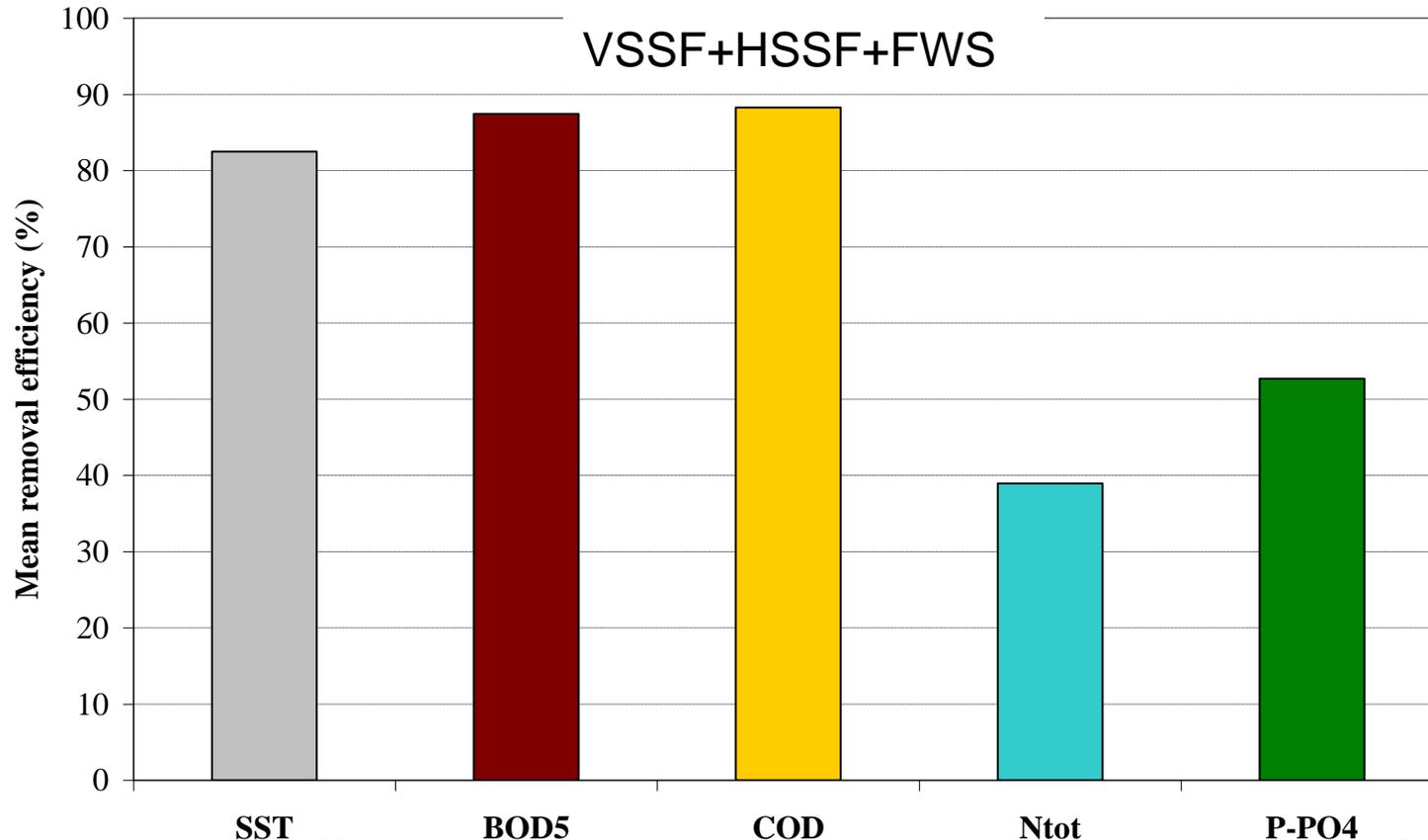
# Construction phase FWS



..to day



# Mean removal efficiency: Chemical-physical parameters



- The mean removal efficiency for TSS was high, about 80%, and quite stable for the entire period of record.
- About 90% was the mean removal efficiency of organic matter.
- the mean removal of nutrient was lower, about 30% for TN and 55 % for PO4, due to low influent concentrations

# IKEA store of Catania

National experience and capacity needs for the  
construction and operation of NTSs



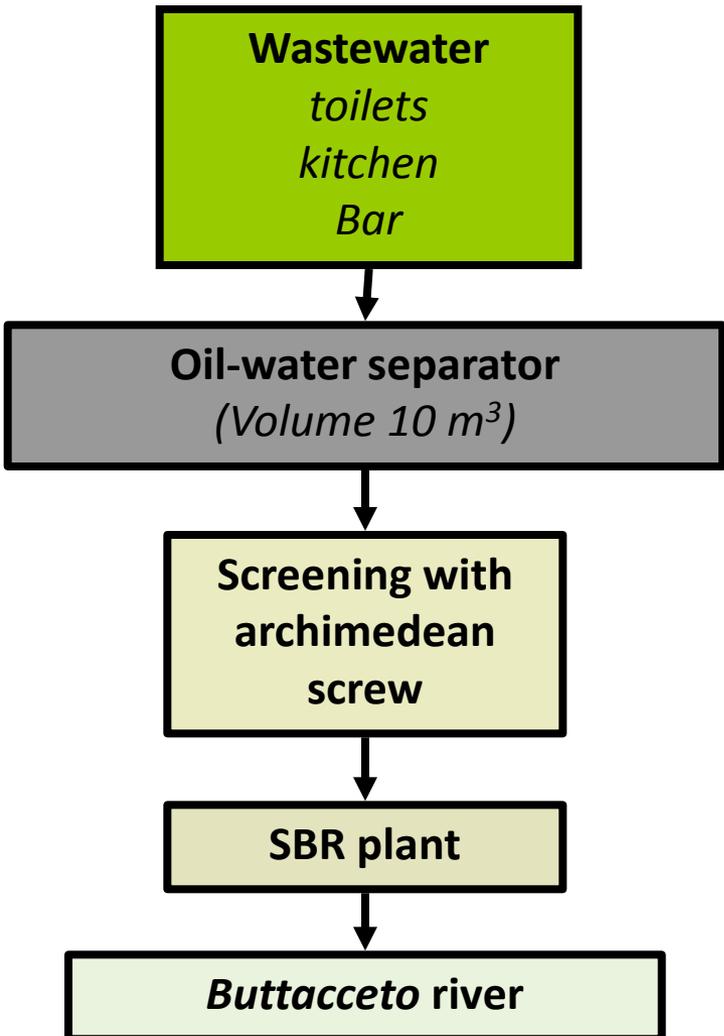
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# Area location



# Conventional wastewater treatment



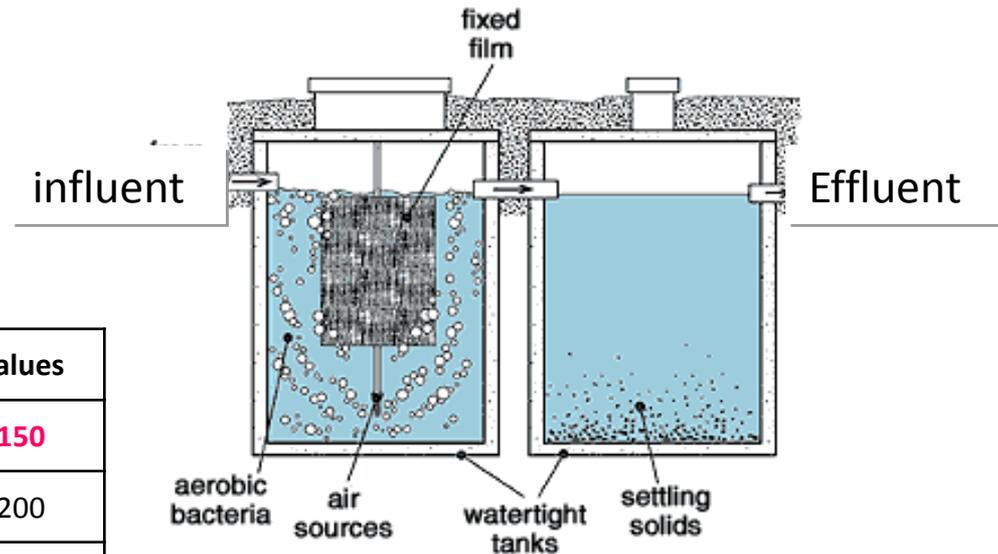
Italian legislative decree 152/06 imposes wastewater effluent limits to discharge in surface water bodies for **51 chemical parameters** some of these are:

- BOD 40 mg/L;
- COD 160 mg/L;
- TSS 80 mg/L;



# SBR (Sequential Batch Reactor)

**SBR (Sequential Batch Reactor)** is a biological wastewater treatment, based on activated sludge process, where oxidation and sedimentation occur in two chambers



Design Parameter	Unit	Values
<b>P.E. (people equivalent)</b>	<b>N°</b>	<b>150</b>
water consumption per person	L/day	200
<b>Maximum daily flow (Qi)</b>	<b>m<sup>3</sup>/day</b>	<b>30</b>
Mean flow (24 hours)	m <sup>3</sup> /day	1,3
SS	mg/L	350
COD	mg/L	500
BOD	mg/L	300
<b>Total Nitrogen (TKN)</b>	<b>mg/L</b>	<b>135</b>
Total Phosphorus (P)	mg/L	15

# Catania IKEA Store data



- Opened in 2011
- in only six months:
  - 1.700.000 visitors
  - 200.000 meals served

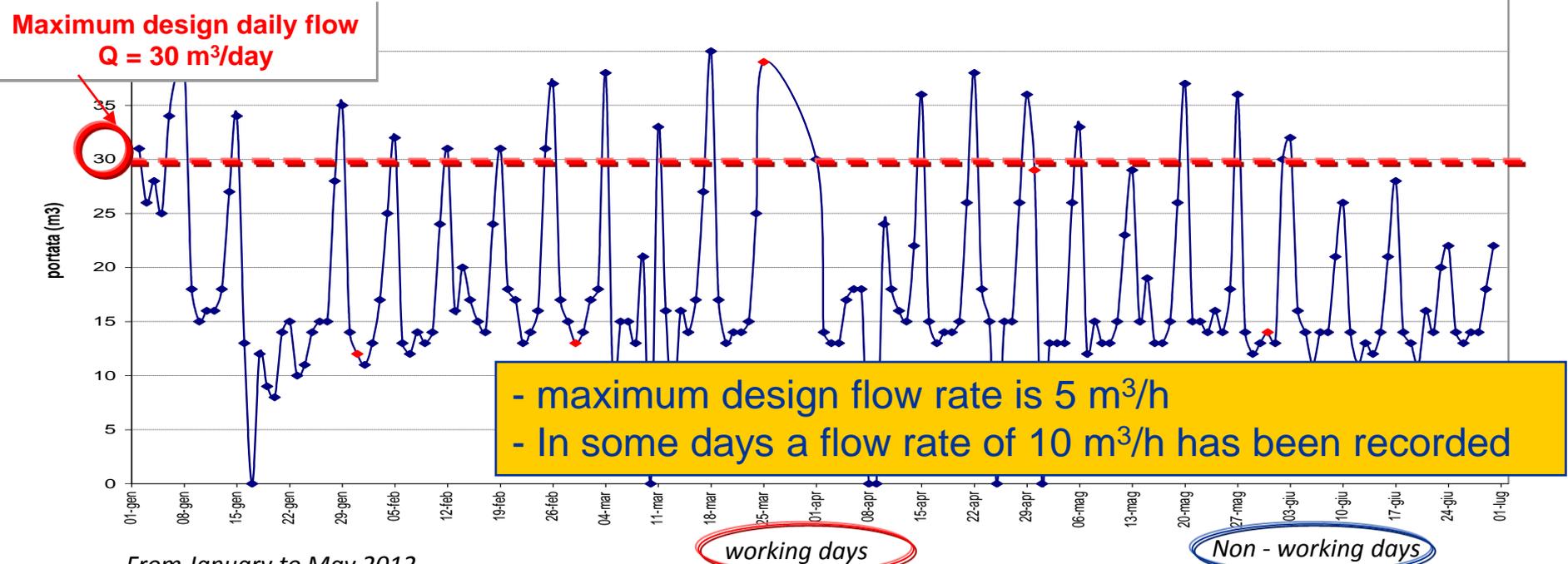
## To day

- ~300 employees (full time and part time)
- ~ 6.000 visitors per day
- ~ 14.000 visitors on Saturdays
- ~ over 16.000 visitors on Sunday/ holidays
- ~ 800 meals served per day



# Wastewater volume

From January to May 2012, the daily wastewater volume from toilets, showers, kitchen sinks, ecc. has been measured by two flow meters.



From January to May 2012

<b>Min value</b>	m <sup>3</sup> /day	7
<b>Max value</b>	m <sup>3</sup> /day	40
<b>Range</b>	m <sup>3</sup> /day	33
<b>Mean value</b>	m <sup>3</sup> /day	18,24

<b>Min value</b>	m <sup>3</sup> /day	7
<b>Max value</b>	m <sup>3</sup> /day	27
<b>Range</b>	m <sup>3</sup> /day	20
<b>Mean value</b>	m <sup>3</sup> /day	14,73

<b>Min value</b>	m <sup>3</sup> /day	15
<b>Max value</b>	m <sup>3</sup> /day	40
<b>Range</b>	m <sup>3</sup> /day	25
<b>Mean value</b>	m <sup>3</sup> /day	27,85

Parameters	Units	Sampling date			
		25/01/2012	06/03/2012	26/05/2012	27/05/2012
		ln	ln	ln	ln
pH		7,69	7,83	7,44	7,93
SST	mg/L	160	120	160	230
BOD <sub>5</sub>	mg/L	333	207	286	303
COD	mg/L	620	660	600	740
sulfates (SO <sub>4</sub> )	mg/L	124	82,4	21,6	54,6
chloride	mg/L	211	241	245	237
Total phosphorus	mg/L	18,04	16,1	16,84	17,92
ammonium (NH <sub>4</sub> )	mg/L	229	217	213	201
nitrite	mg/L	<0,01	0,07	<0,01	<0,01
nitrate	mg/L	<0,22	<0,22	<0,22	<0,22

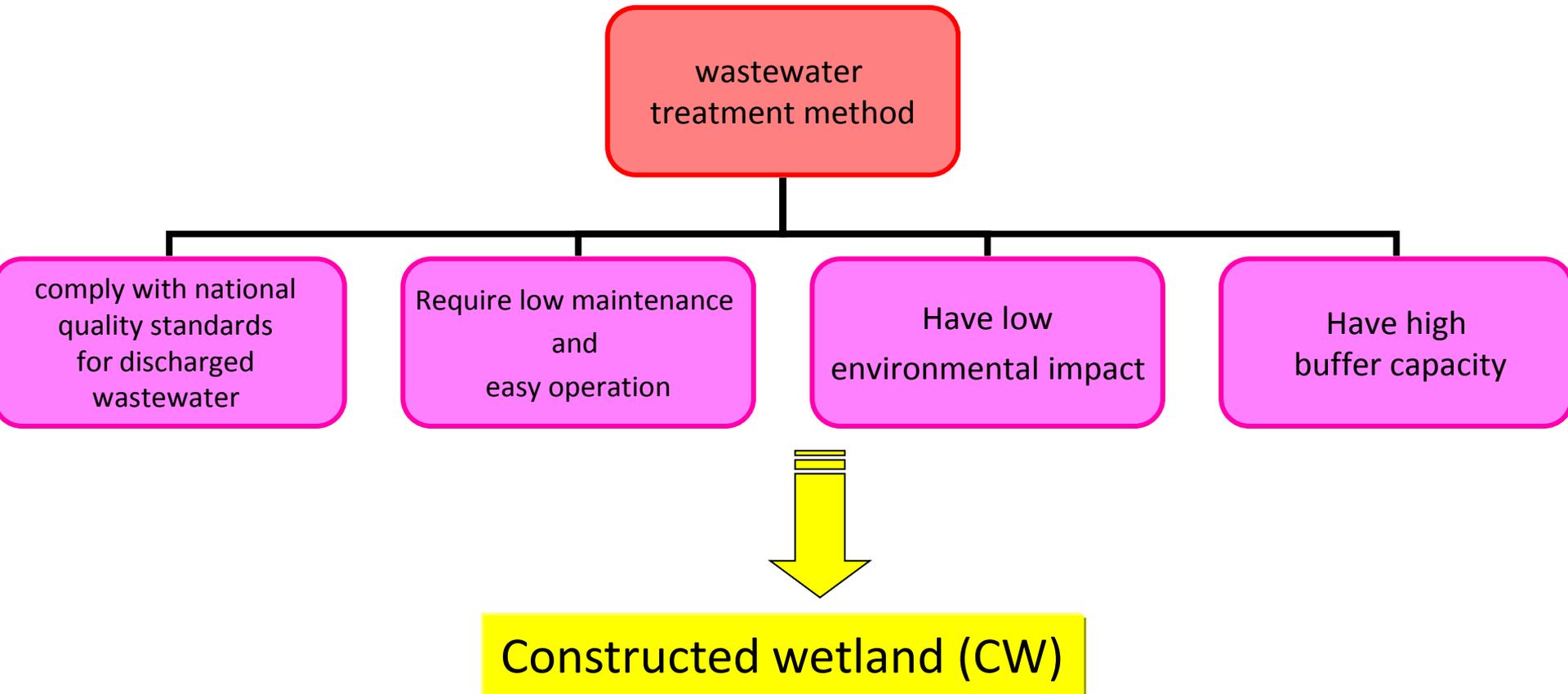
Mean value

Total suspended solids (SST)	mg/L	167,5
BOD <sub>5</sub>	mg/L	282,3
COD	mg/L	655
Total phosphorus	mg/L	17,2
Ammonium (NH <sub>4</sub> )	mg/L	215



Design concentration of Total Nitrogen was 135 mg/L

# Improvement SBR treatment



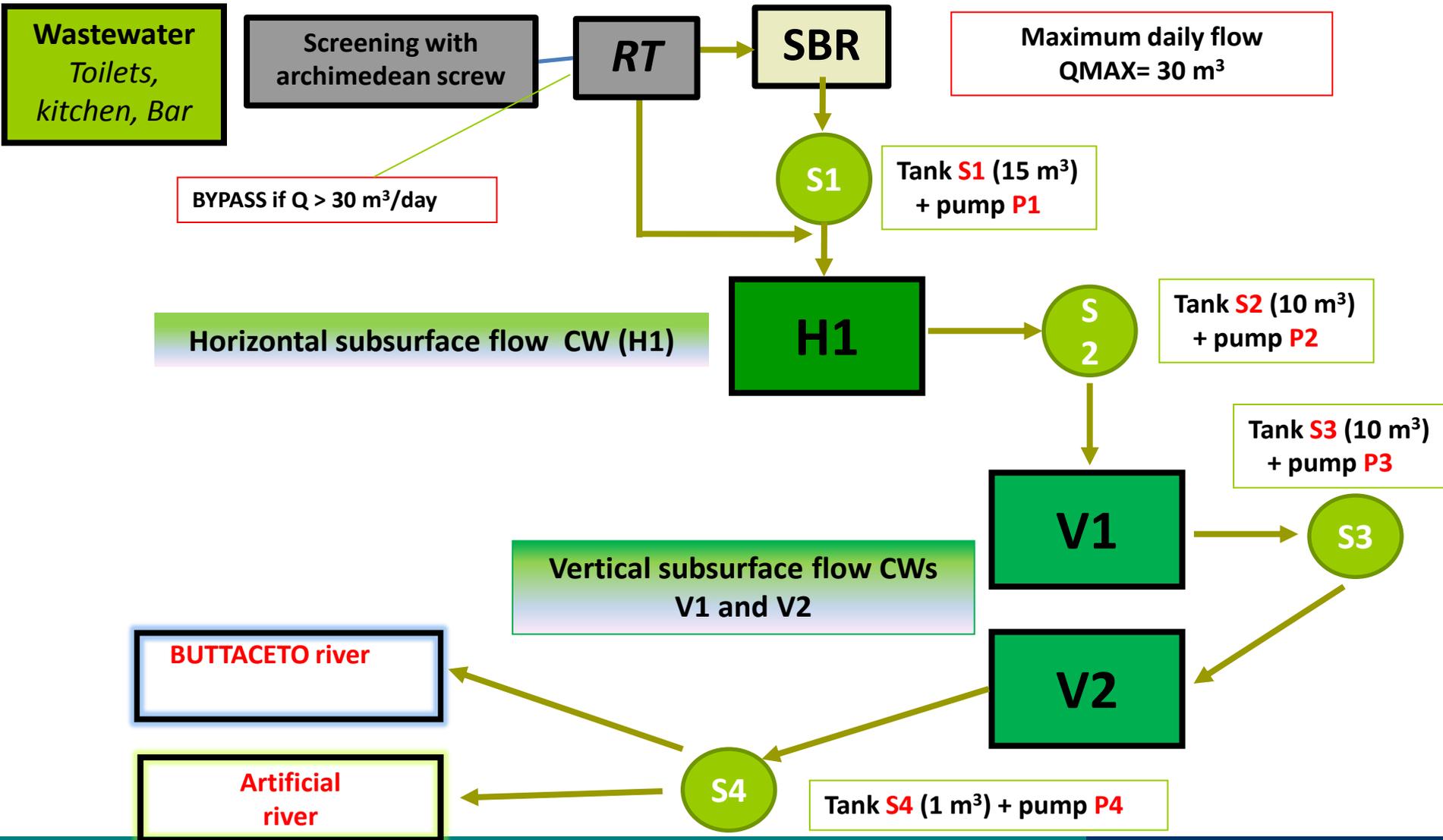
CW combined with conventional treatment plants, seem to be an attractive solution for wastewater purification, able to improve water quality through efficient pollutant removal

# Characteristics of constructed wetlands

➤ **Q: 45-50 m<sup>3</sup>/day**

Constructed wetlands	Area m <sup>2</sup>	Gravel			macrophytes	
		Type	size (mm)	depth (m)	name	Density (rhizomes m <sup>2</sup> )
H1 	400	<i>Volcanic gravel</i>	8-15	0.6	<i>Phragmites australis</i>	4
V1 	530	<i>Volcanic sand</i>	~ 0.05-10	0.40	<i>Cyperus papyrus</i>	2.5
		<i>volcanic gravel</i>	8-15	0.40	<i>Canna Indica L.</i>	
V2 	530	<i>Volcanic sand</i>	~ 0.05-10	0.40	<i>Ibiscus palustris</i>	
		<i>volcanic gravel</i>	8-15	0.40	<i>Iris pseudacorus</i>	

# wastewater system flow chart



# macrophyte species planted

## Horizontal subsurface flow CW (H1)

- *Phragmites australis*
  - density: 4 rhizomes m<sup>2</sup>



## Vertical subsurface flow CWs (V1)

- *Cyperus papyrus and Canna Indica L.*
  - density: 2.5 rhizomes m<sup>2</sup>



## Vertical subsurface flow CWs (V2)

- *Ibiscus palustris and Iris pseudacorus*
  - density: 2.5 rhizomes m<sup>2</sup>



# Construction phases H1



excavation



Filling of substrate



Filling of substrate



Hydraulic test

# Construction phases: V1 and V2



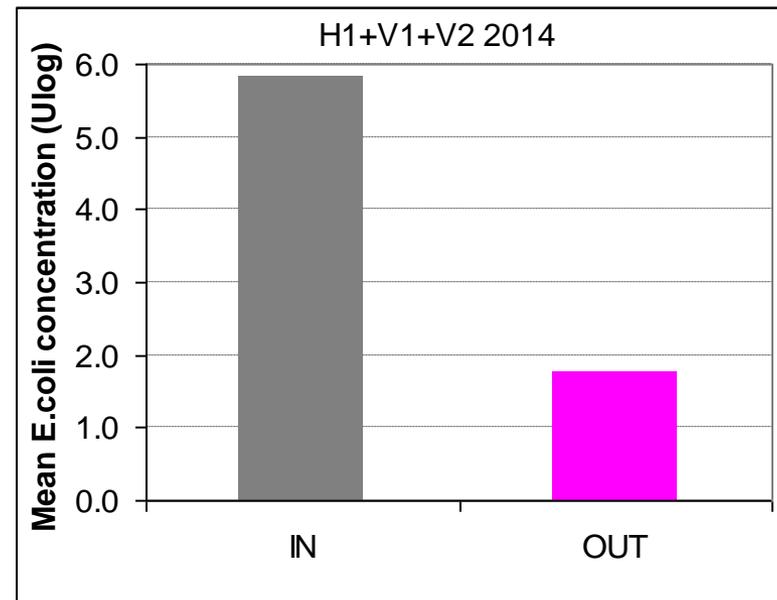
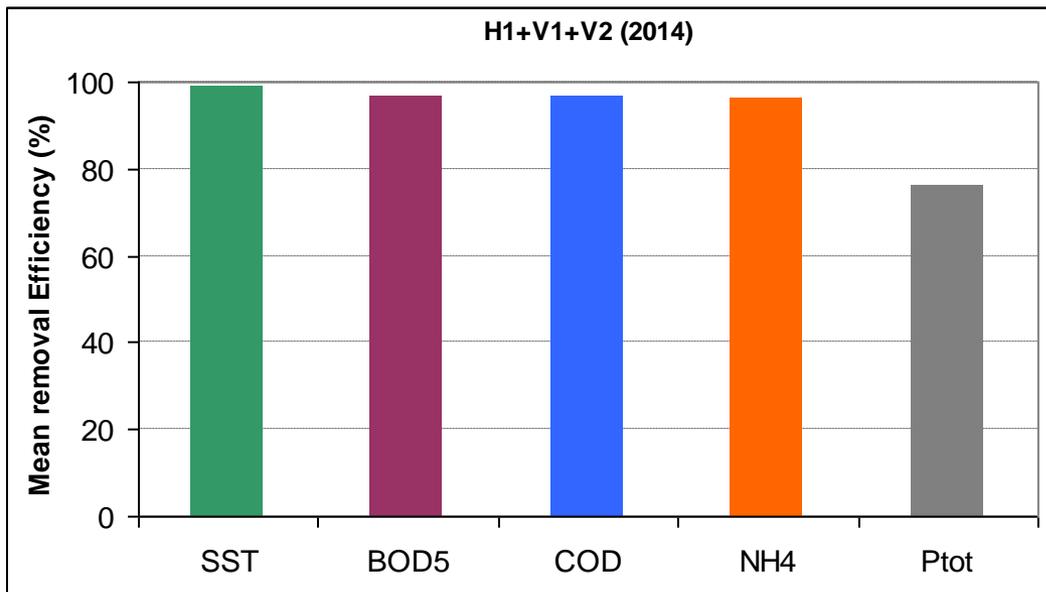
# macrophytes plating phase



..to day



# Removal efficiency



- Good removal of chemical-physical parameters and microbial indicators
- The Italian discharge (D.Lgs 152/06) and reuse limits (D.M. 185/03) were **always** respected

# Valle dei Margi Agritourism

National experience and capacity needs for the  
construction and operation of NTSs



# Area location



- 13.000 habitants
- Area 30 km<sup>2</sup>

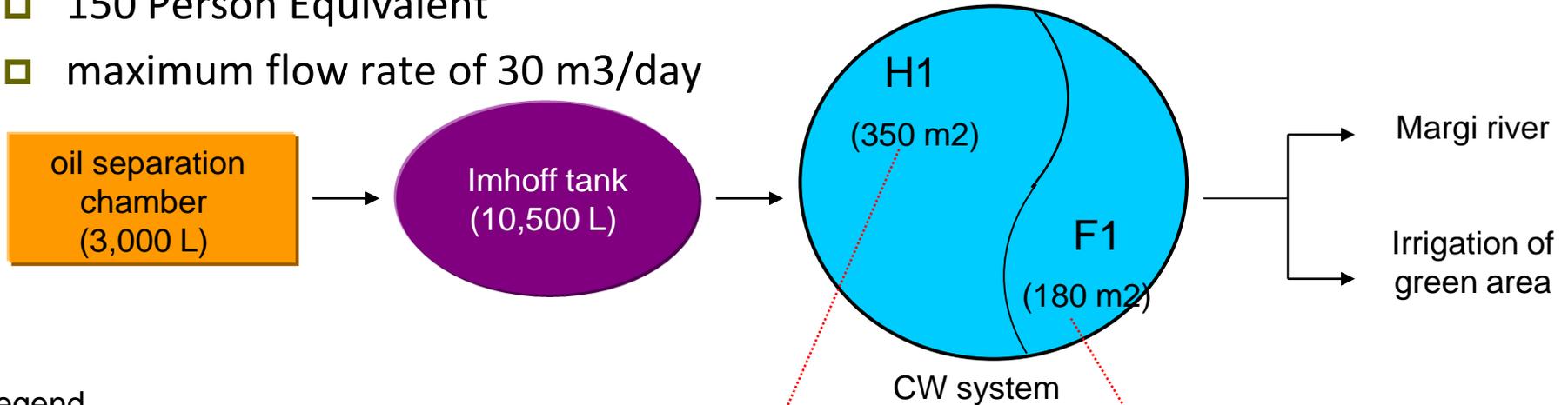
# Site description

- Agritourism *Valle dei Margi* has an area of 18 ha and offers many types of activities/services
  - educational activities (e.g., school tours, culinary lessons)
  - agri-food service (e.g. restaurant, bar, typical food products on sale)
  - relaxing actives (e.g., wellness center, swimming poll with solarium, picnic area, orchard tours)
  - accommodation rooms and farm.



# Wastewater treatment plant

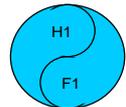
- 150 Person Equivalent
- maximum flow rate of 30 m<sup>3</sup>/day



## Legend

 oil separation chamber

 Imhoff tank

 CW system



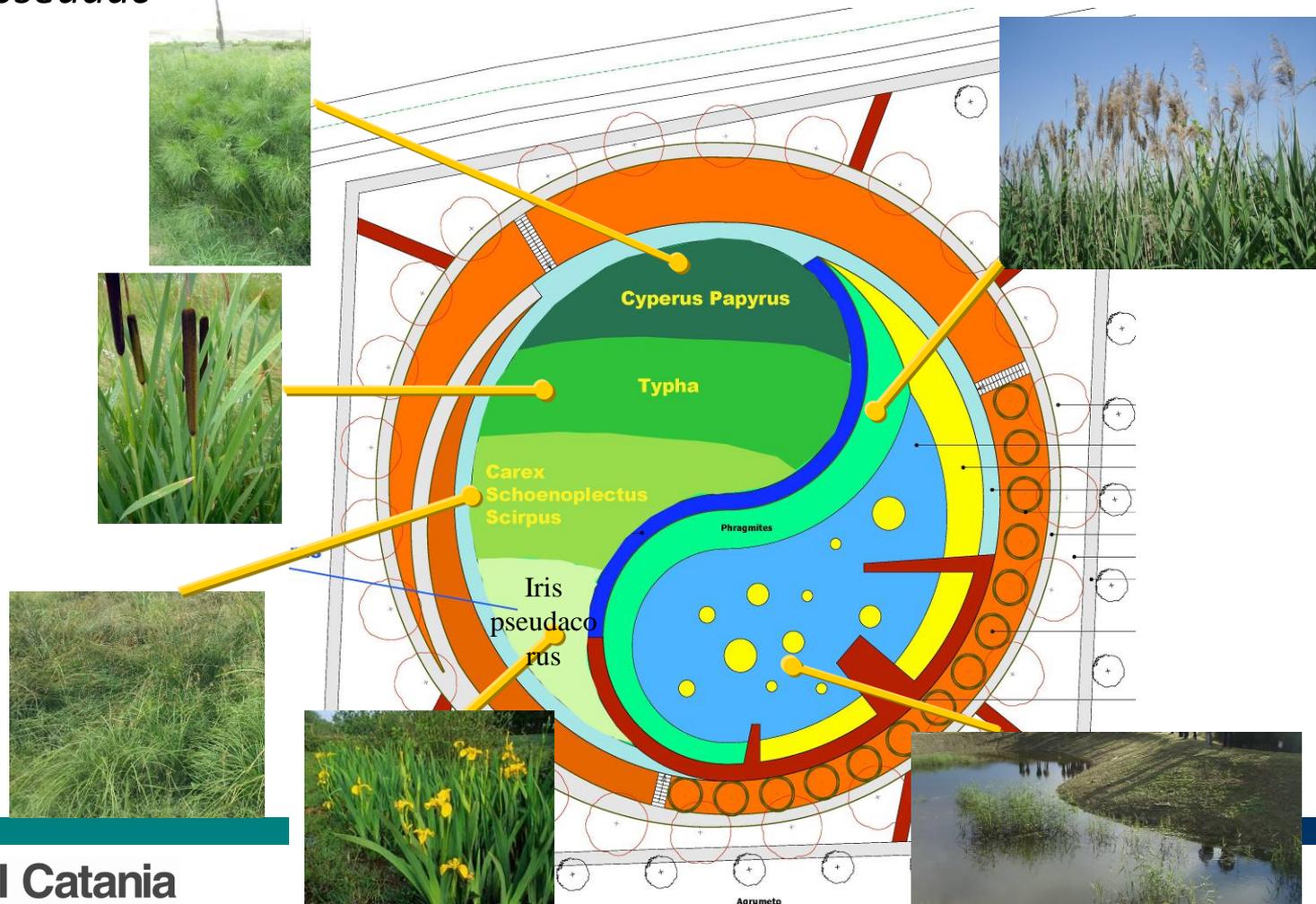
horizontal subsurface flow (H1)



free water flow (F1)

# macrophyte species planted

- The H1 beds vegetated with different macrophyte species..*Cyperus Papyrus*, *Typha*, *Carex Schoenoplectus S.*, *Juncus Effusus* and *Iris pseudacorus*

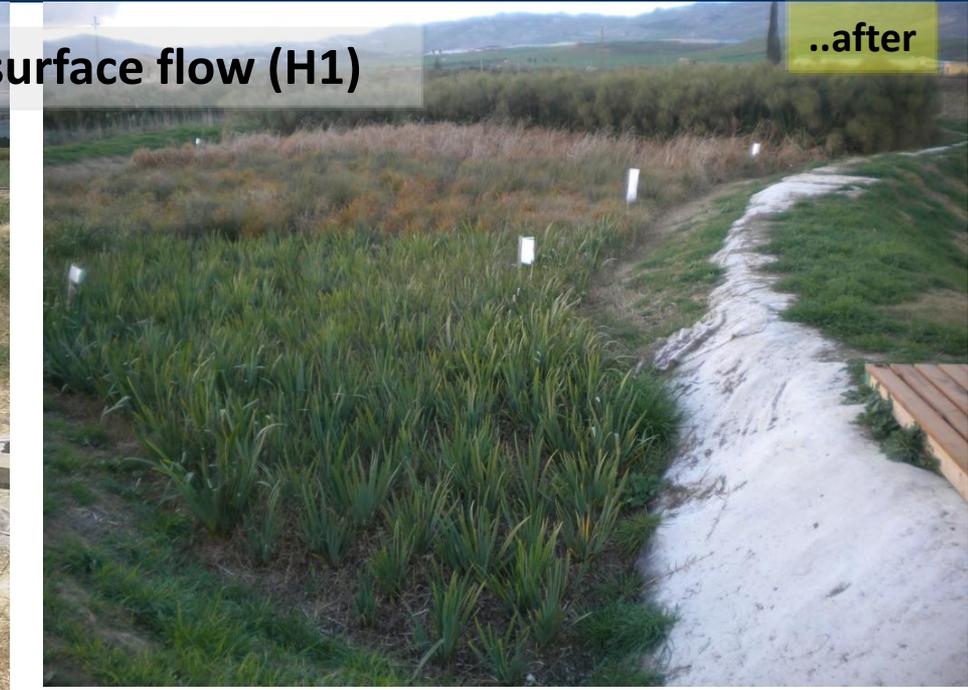


# constructed wetland system

Before..



horizontal subsurface flow (H1)

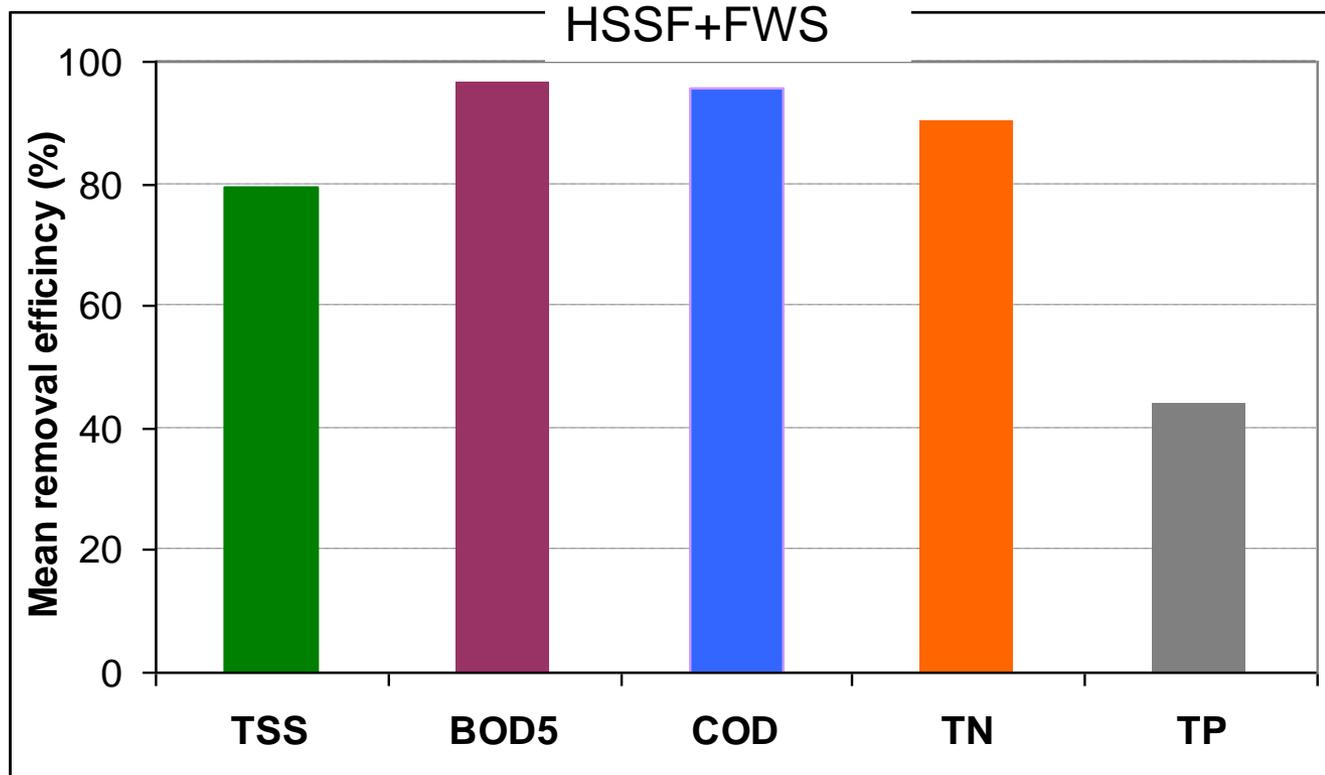


..after

free water flow (F1)



# Mean removal efficiency



- Good removal of chemical-physical parameters
- The Italian discharge (D.Lgs 152/06) and reuse limits (D.M. 185/03) were almost respected

# Citrus industry Ortogel

National experience and capacity needs for the  
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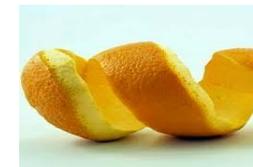


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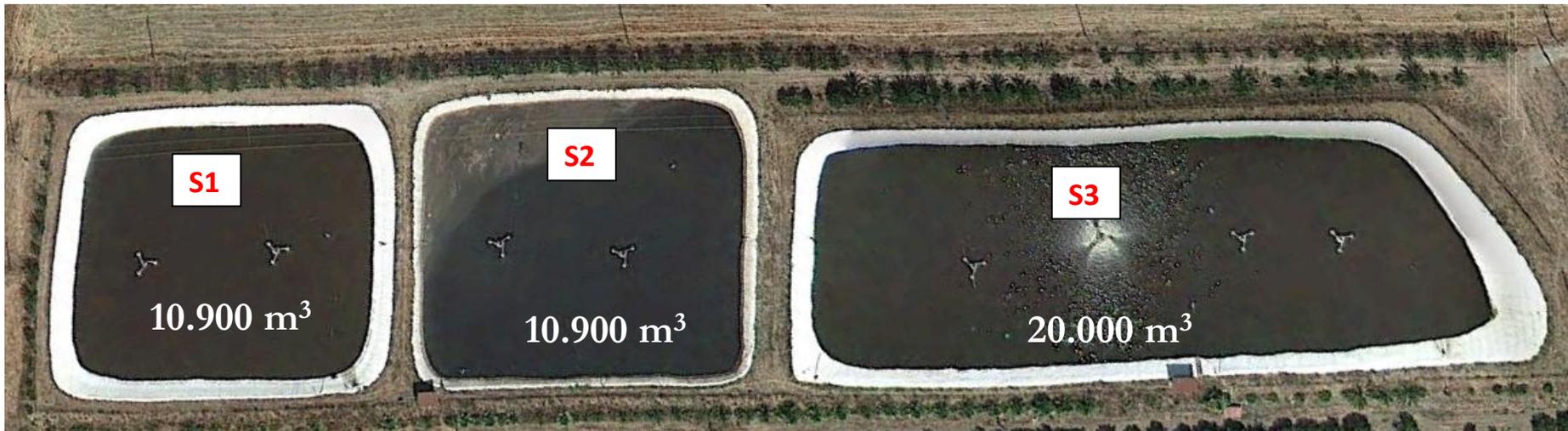
# Area location

- Ortogel is a citrus industry located in Caltagirone city, in the Province of Catania (Sicily).



# Natural wastewater system

- Wastewater is treated in 3 aerated lagoons working in series. Two lagoons have a volume of 11.000 m<sup>3</sup> while the third one of 20.000 m<sup>3</sup>
- The aerated lagoon depurated the citrus processing wastewater with the highest organic load (up to 20-30 g L<sup>-1</sup> of COD)
- Aeration was ensured by 1-3 floating aerators



# Natural wastewater system

- The investigation showed a good depuration capacity of the organic load with a COD removal efficiency up to 97%
- No bad smell were detected in proximity of the lagoon thanks to the aeration of the surface layer.



# Grammichele and Caltagirone reuse systems

National experience and capacity needs for the  
construction and operation of NTSs

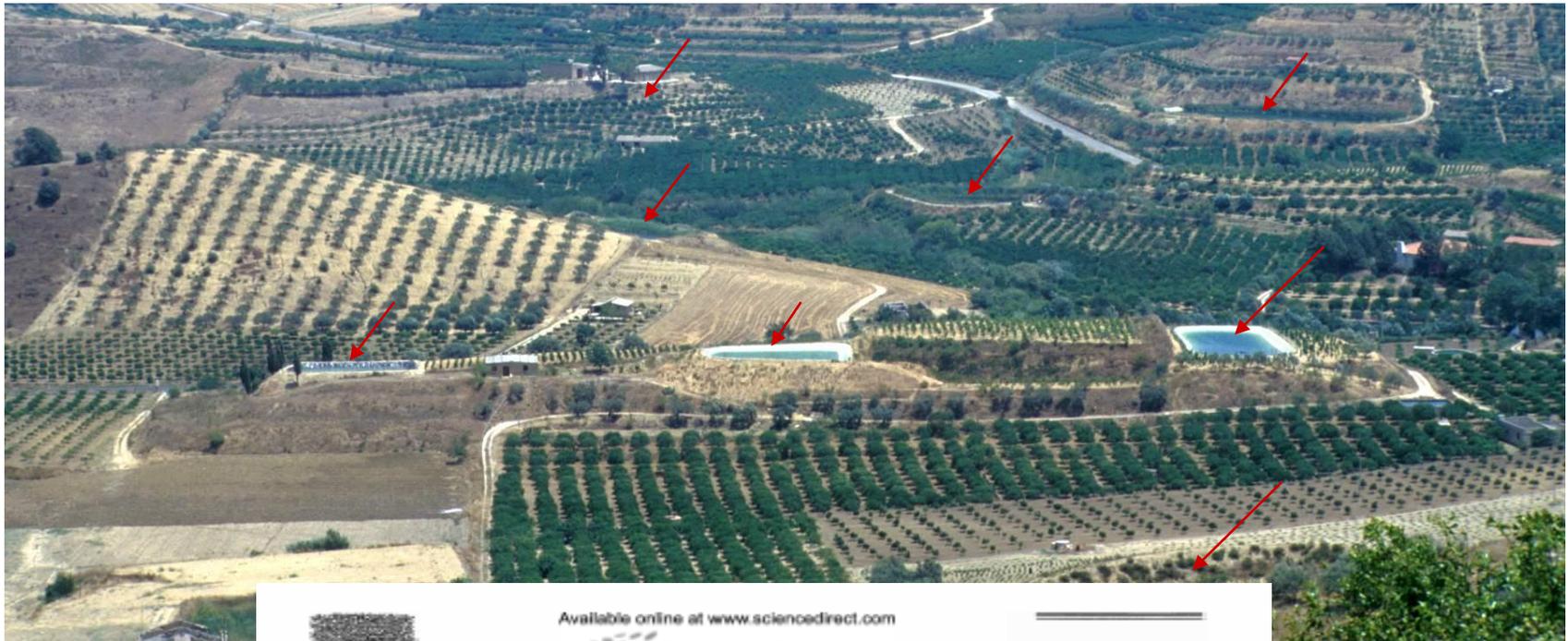


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# Our experiences on wastewater reservoirs

Since '90 in Sicily several wastewater reuse systems have been put in operation including storage in small reservoirs



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

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DESALINATION

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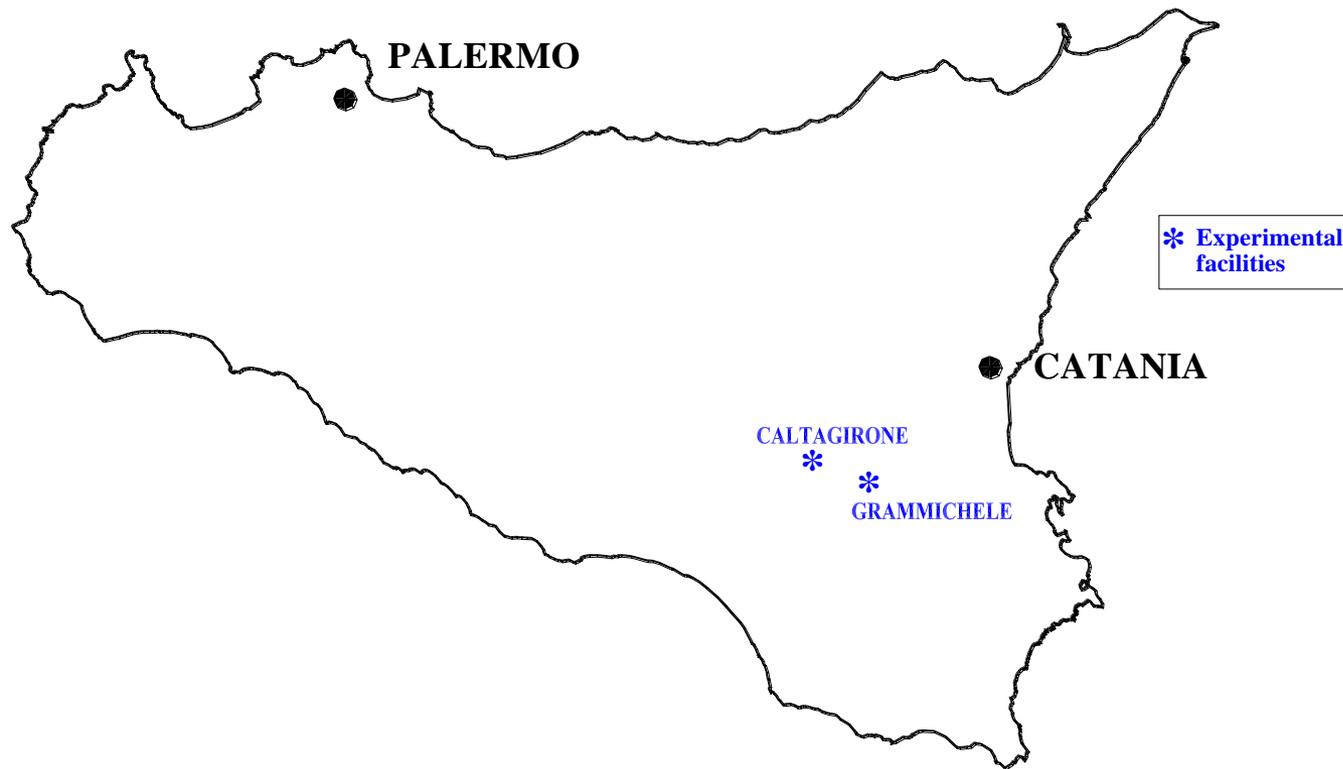
## Long-term storage of reclaimed water: the case studies in Sicily (Italy)

Giuseppe Luigi Cirelli\*, Simona Consoli, Vanessa Di Grande

Department of Agricultural Engineering, University of Catania, Via S. Sofia 100, 95123 Catania, Italy  
Tel. +39 (095) 7147545; Fax +39 (095) 7147600; email: [giuseppe.cirelli@unict.it](mailto:giuseppe.cirelli@unict.it)

Received 1 February 2006; accepted 4 September 2006

# Area location

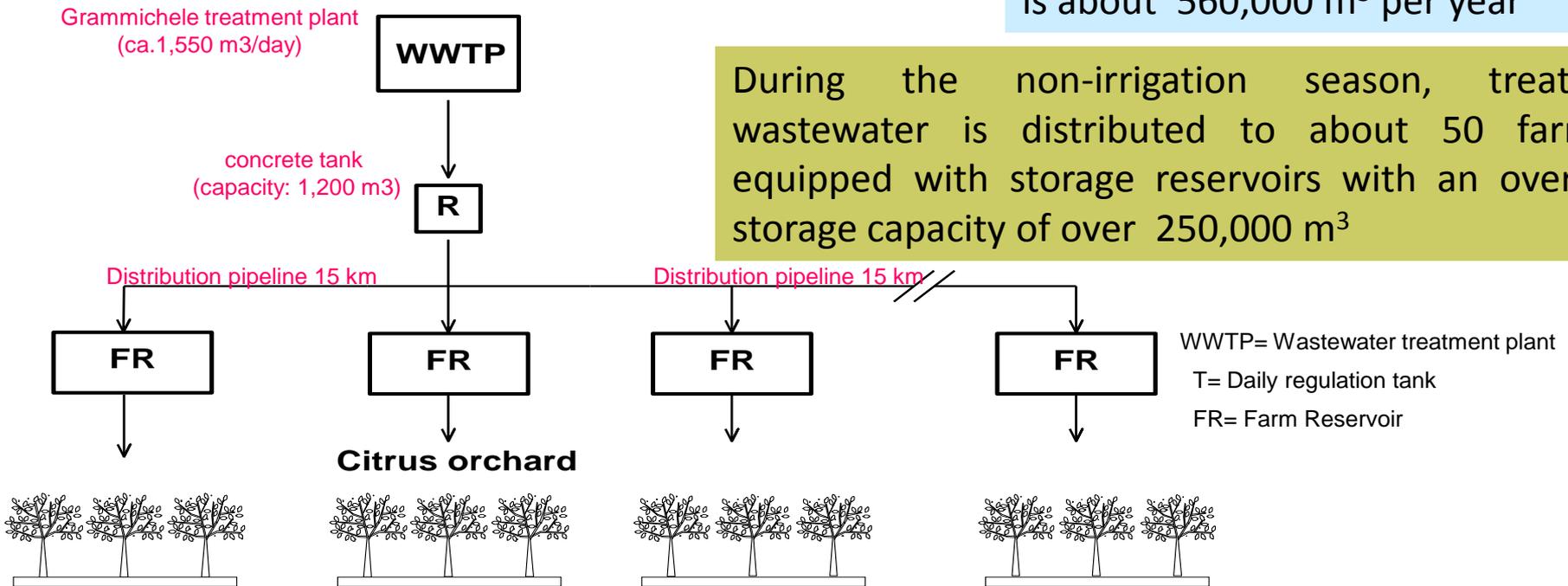


# Grammichele reuse systems

- farmers in the Grammichele area have increasingly used treated wastewater to irrigate citrus orchards, organizing a reuse system where effluent from the Grammichele treatment plant (ca.1,550 m<sup>3</sup>/day) is stored for daily regulation in a concrete tank (capacity: 1,200 m<sup>3</sup>), and then distributed to numerous farmers at the foot of the town, through a distribution pipeline network about 15 km long.

volume of wastewater distributed is about 560,000 m<sup>3</sup> per year

During the non-irrigation season, treated wastewater is distributed to about 50 farms equipped with storage reservoirs with an overall storage capacity of over 250,000 m<sup>3</sup>



# Grammichele reuse systems

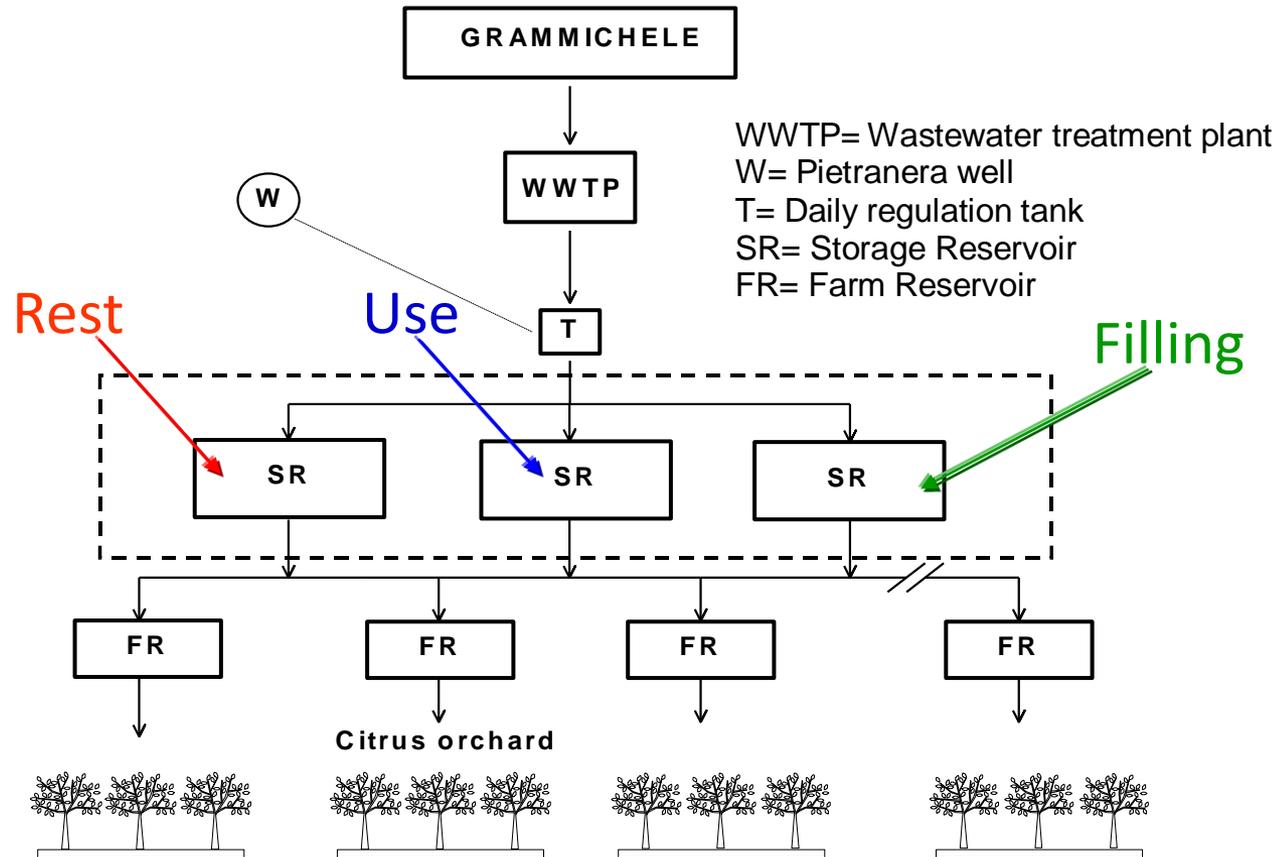
- Farm Reservoir in earth:
  - depth 4-7 m
  - capacity 25,000-40,000 m<sup>3</sup>
  - treated or untreated wastewater
  - different operational regime: batch or continuous



BATCH RESERVOIR

- Results
  - A negligible algal development
  - Up to 70% removal of organic matter and TSS
  - Significant reduction of microbiological indicators (up to 5 log units) and parasites (up to 100%)
  - Quality of stored water influenced by reservoir operational regime
  - No unpleasant odours
  - Landscape improvement

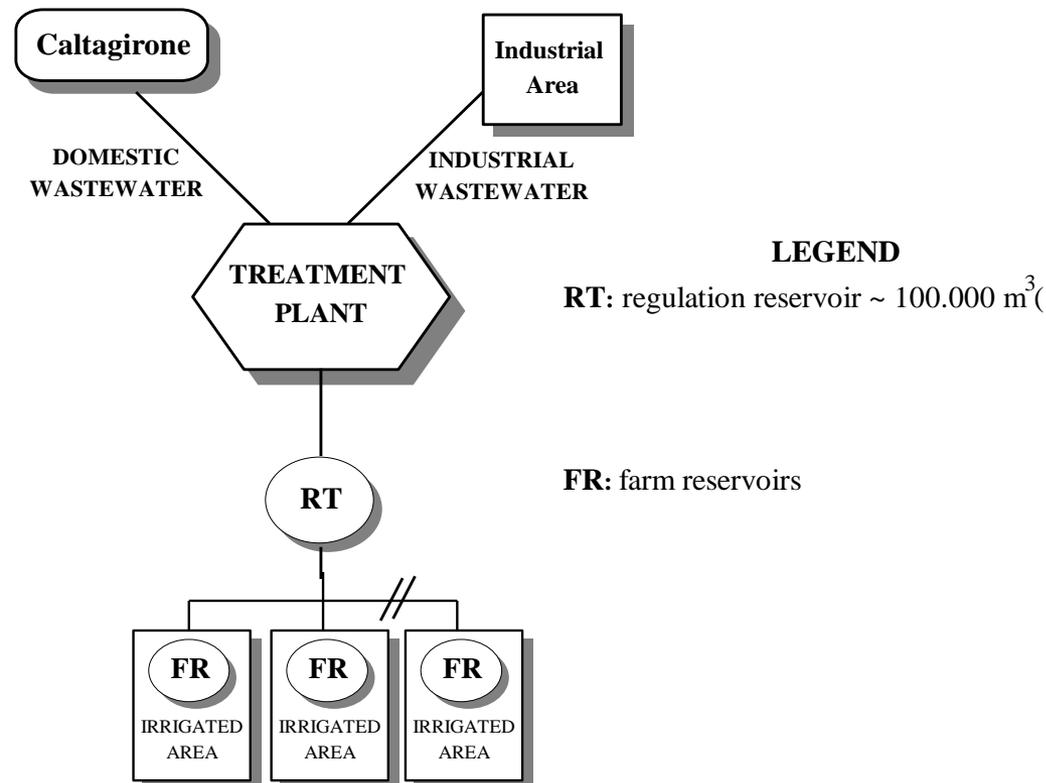
# upgrading of Grammichele reuse system



30 days HRT is optimum

# Caltagirone reuse systems

- The city of Caltagirone is equipped with a treatment plant (about 35,000 P.E., mean flow 60 L/s) where wastewater is subject to secondary treatment (activated sludge) and flowed through sand filters
- Wastewater flow (Q) of about 30 L/s is pumped, after secondary, treatment in a wastewater reservoir and used, after the storage, for irrigation of citrus orchards



# Caltagirone reuse systems

- ❑ wastewater reservoir, built in concrete, has the following characteristics
  - max capacity 80.000 m<sup>3</sup>
  - surface area about 2.1 Ha (140x140 m)
  - max depth 3.75 m
  - **Continuos modality** with a nominal detention time of about 30 days (about 2.500 m<sup>3</sup>/day)
  - $Q_{in}=Q_{out}$  a part of infiltration and evaporation losses

Reservoir before filling phase

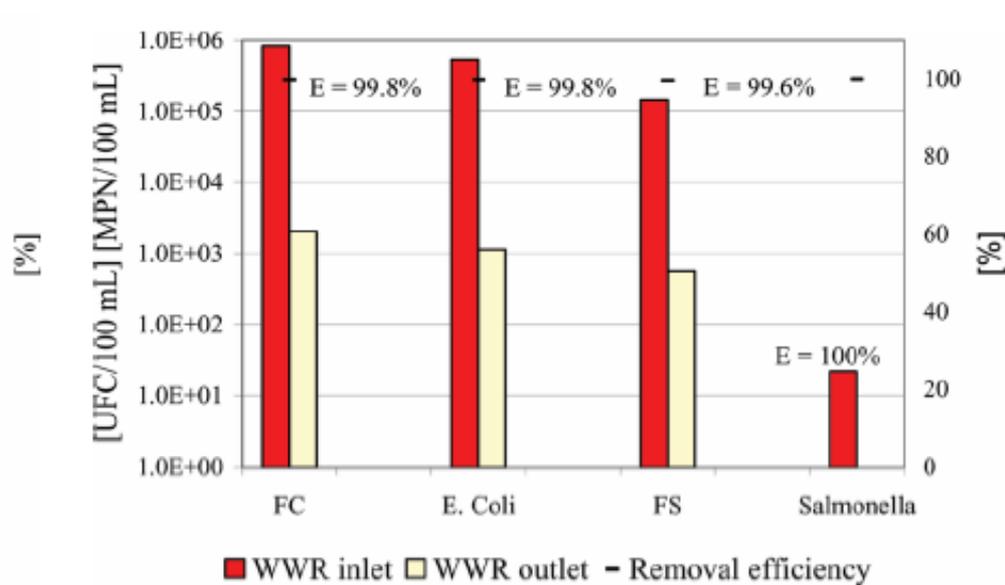
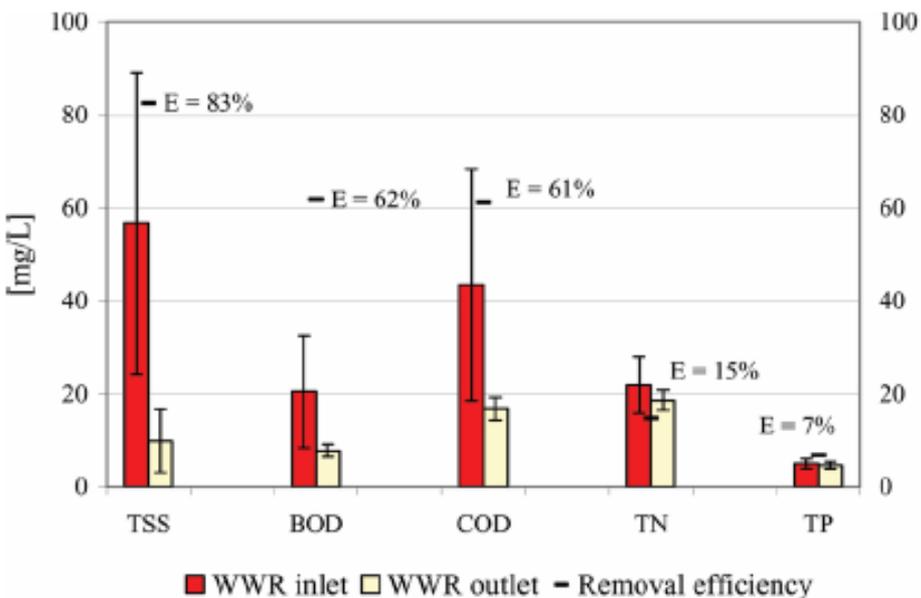


Reservoir after filling phase



# Results

- During storage period TSS, BOD<sub>5</sub>, COD and nutrient concentration in WWR outflow achieved the Italian legislation limits for agricultural reuse
- During storage period microorganism indicators showed an average decrease of 2-3 log units (removal 99-99.9%)



# upgrading of Caltagirone reuse systems

