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

Project funded by the European Union

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

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

Legislation, operating criteria and precautions for operating WW NTSs

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

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Introduction

- Legislation on Wastewater
  - Wastewater legislation in Europe
    - Directive on Urban Wastewater Treatment 91/271/EC
    - Wastewater reuse criteria within the European Union
  - Wastewater legislation in Italy
    - Italian national standards for wastewater discharge (D.lgs 152/2006)
    - Italian national standards for reclaimed wastewater (D.M. 185/03, 2003)
  - WHO guideline for the safe use wastewater in agriculture

Wastewater legislation in Europe

- **The first directives**, adopted in the **mid-1970s**, established a series of **quality standards** aimed at protecting:
  - human health and the living environment, including surface water used for drinking, bathing, fish, shellfish, groundwater and water for human consumption.
  - However, the quality standard approach proved insufficient for protecting Europe's waters from pollution
- When **eutrophication became a major problem** in the North and Baltic seas and parts of the Mediterranean in the late **1980s,** the EU started to focus on the sources of pollutants.
  - This led to the **Directive on Urban Wastewater Treatment 91/271/EC**

Directive on Urban Wastewater Treatment 91/271/EC

- Directive 91/271/EC is one of the major water policy tools in Europe.
- Its objective is to protect the environment from the adverse effects of discharges of urban wastewater from settlement areas (cities/towns) and of biodegradable industrial wastewater from the agro-food sector (e.g. milk processing industry, meat industry, breweries etc.)
- The Directive:
  - requires the appropriate collection of sewage and
  - regulates discharges of wastewater by specifying the minimum type of treatment to be provided and
  - sets maximum emission limit values (organic load and nutrients)

- In Article 12 it states that "treated wastewater shall be reused whenever appropriate". The term "appropriate" means that reusing treated wastewater is possible as far as it is not forbidden or restricted by any other EU legislations

Directive on Urban Wastewater Treatment 91/271/EC

- The specific requirements depend on the size of the so-called “urban agglomerations”, and on how sensitive are the waters into which they discharge.
- “Sensitive areas” (natural freshwater lakes, other freshwater bodies, estuaries and coastal waters which have to be designated by Member States) are eutrophic areas or areas at risk of eutrophication, where the wastewater discharge could have strong negative effects on the environment .

Normal Areas

Parameter	SECONDARY TREATMENT	
	CONCENTRATION	% REDUCTION
BOD_5 (mg/L O_2)	25	70-90
COD (mg/L O_2)	125	75
Suspended solids (mg/L) (optional)	35	90

Sensitive Areas
(They must also comply with the stipulations for normal areas)

Parameter	REMOVAL OF N and P	
	CONCENTRATION	% REDUCTION
Total Phosphorous (mg/L)	2 (10,000 -100,000 p.e) 1 (>100.000 p.e)	80
Total Nitrogen (mg/L)	15 (10,000 -100,000 p.e) 10 (>100,000 p.e)	70-80

Less sensitive areas

Parameter	PRIMARY TREATMENT
	% REDUCTION
BOD_5 (mg/L O_2)	20
Suspended Solids (mg/L)	50

Maximum values for treated wastewater discharge to the environment established in the Directive 91/271/EC.

Directive on Urban Wastewater Treatment 91/271/EC

- The Directive has set deadlines, which Member States must adhere to, for the provision of collection and treatment systems for urban wastewater in agglomerations corresponding to the categories laid down in the Directive. The main deadlines are as follows:
  - ***31 December 1998***: all agglomerations of ***more than 10,000*** "population equivalent" (P.E.) which discharge their effluent into sensitive areas must have ***a proper collection*** and ***treatment system (Article3)***;

Implementation of the Directive 91/271/EC

- **Collecting systems**: Most of the EU Member States collect their wastewaters at very high levels ***(Article3)***
- **secondary treatment**: In 2009/2010, a total of 82% of the wastewaters in the EU received secondary treatment complying with the provisions of the Directive ***(Article4)***
- **More stringent treatment**: there were particular delays in implementation of more stringent treatment in EU-12 Member States where only 14% of waste waters are treated appropriately ***(Article5)***

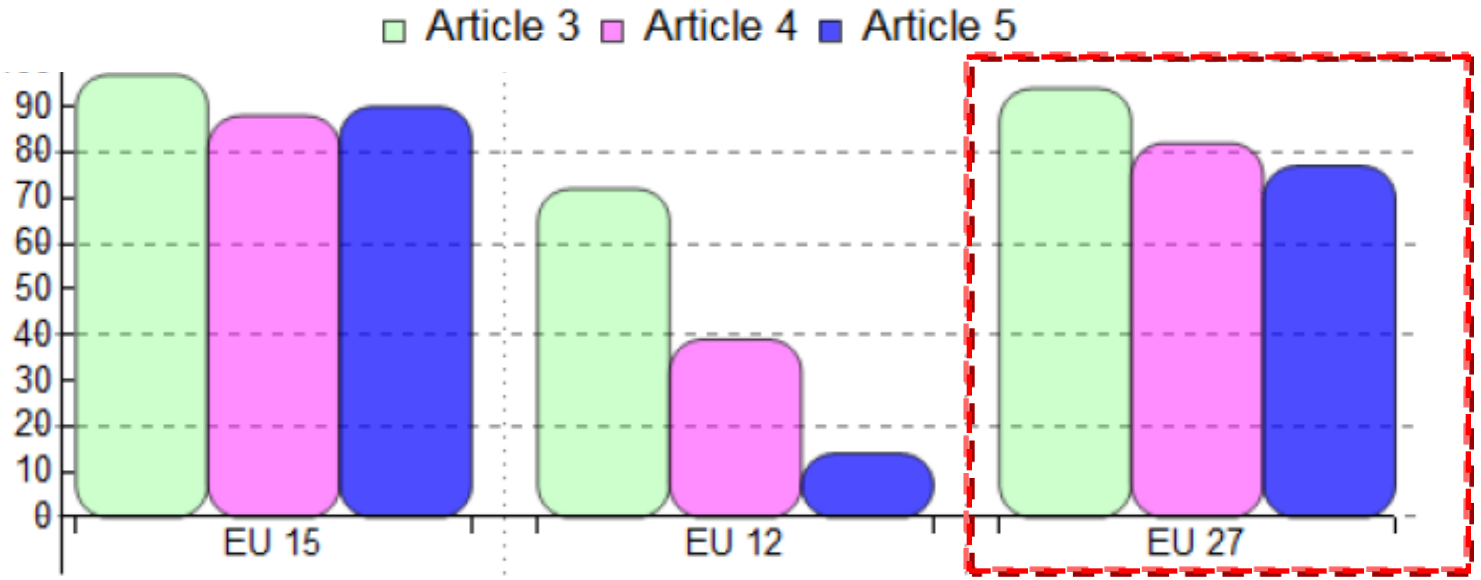


Figure 1: Compliance results at EU-27, EU-15 and EU-12 level regarding article 3 of the Directive (collection), in green, article 4 (secondary treatment), in pink and article 5 (more stringent treatment), in blue. Average values are reflected, weighted by size of MS.

Italian standards for Urban Wastewater Treatment (D.lgs 152/2006)

- With the enforcement of the D.Lgs 152/99 and **subsequently 152/2006 (Environmental Code),** the European Directive 91/271 (Urban waste waters treatment) and the Directive 91/676 (Pollution by nitrates from agricultural activities) were implemented in the Italian legal framework.
- The main objective set by the national legislation is to achieve a good chemical and quantitative status by 2016 which corresponds to the goals assumed by the WFD.
- To protect water resources against pollution, D.Lgs 152/06 fixes water quality objectives, imposes the monitoring of water bodies and assumes the same threshold values for treated wastewater discharge to water bodies as established in Directive 91/271/EEC.

Normal Areas

Parameter	SECONDARY TREATMENT	
	CONCENTRATION	% REDUCTION
BOD_5 (mg/L O_2)	25	70-90
COD (mg/L O_2)	125	75
Suspended solids (mg/L) (optional)	35	90
Coliform bacteria (optional)	2 (10,000 -100,000 p.e.)	
(They must also comply with the stipulations for normal areas)		

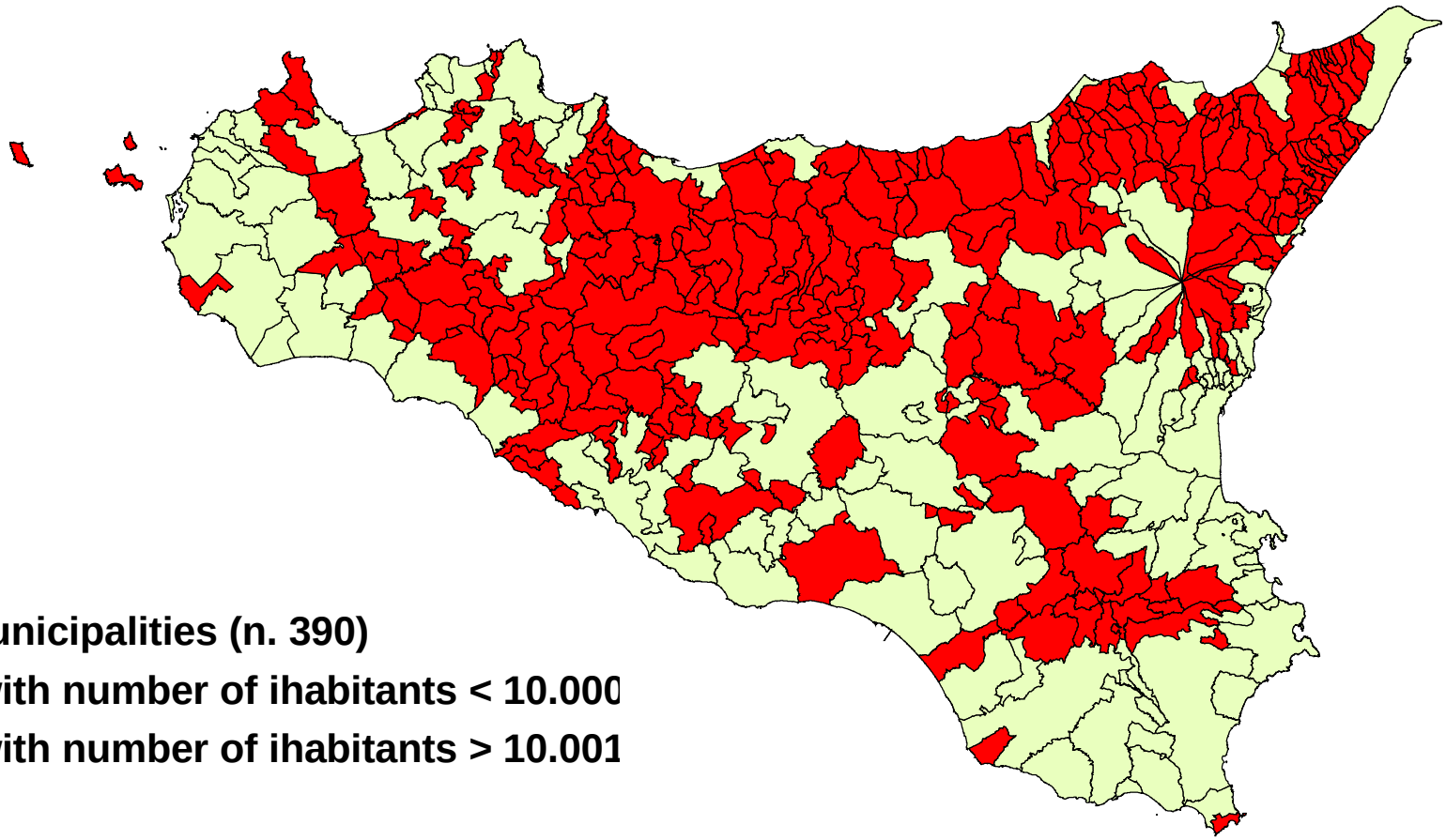
Parameter	REMOVAL OF N and P	
	CONCENTRATION	% REDUCTION
Total Phosphorus (mg/L P)	2 (10,000 -100,000 p.e.)	80
Total Nitrogen (mg/L N)	15 (10,000 -100,000 p.e.)	70-80
	10 (>100,000 p.e.)	

Less sensitive areas

Parameter	PRIMARY TREATMENT
	% REDUCTION
BOD_5 (mg/L O_2)	20
Suspended Solids (mg/L)	50

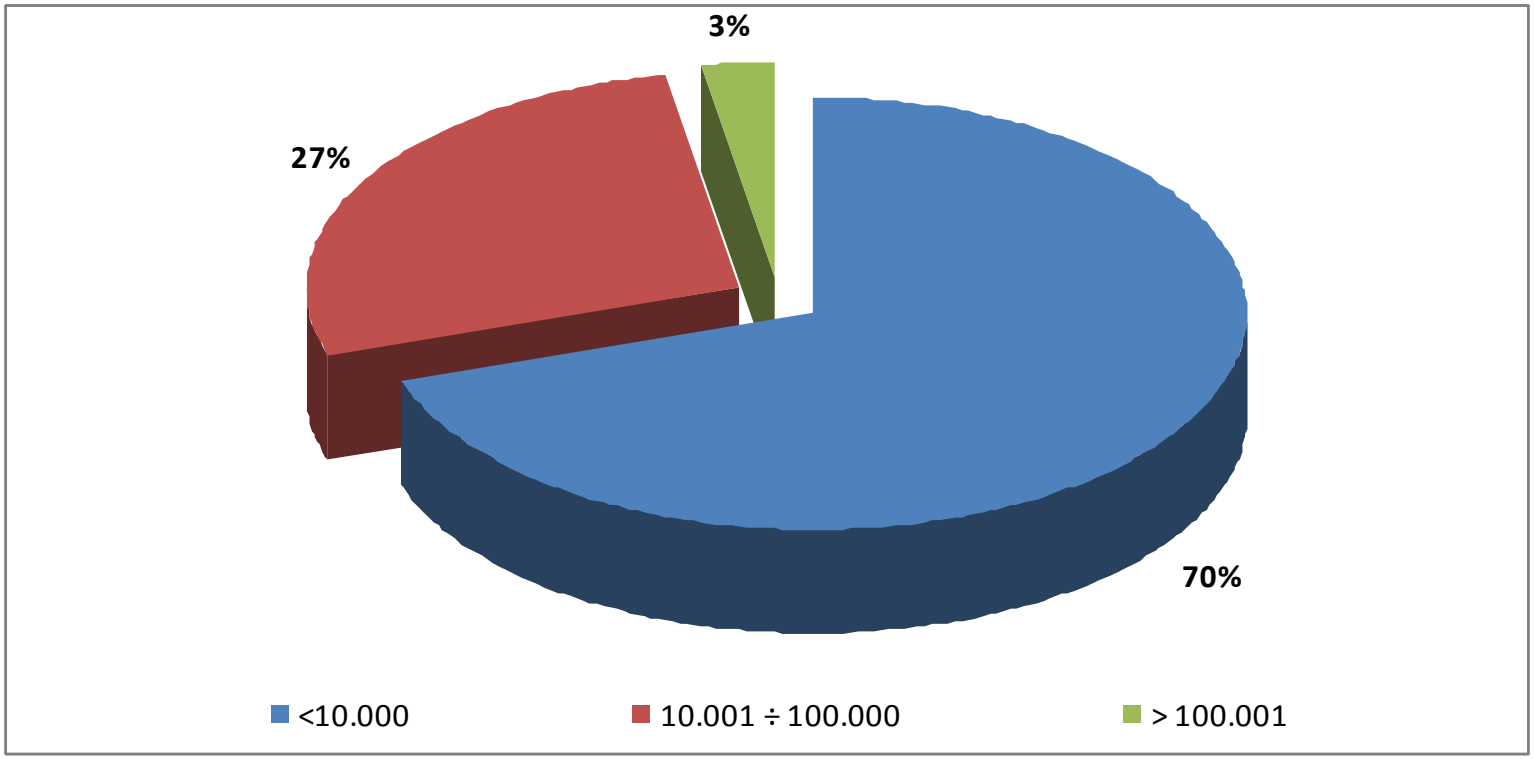
- It provides measures to promote wastewater treatment and for the fist time, **constructed wetlands and stabilization ponds and "officially" recognized and endorsed as an efficient treatment technologies** and/or complementary to existing ones. In particular, law refers to constructed wetlands for the treatment of the wastewater of communities as small as 2,000 P.E. whereas it is endorsed for those up to 25,000 P.E. as "appropriate treatment" for wastewater which has already been treated by traditional WWTPs.

Sicilian municipalities



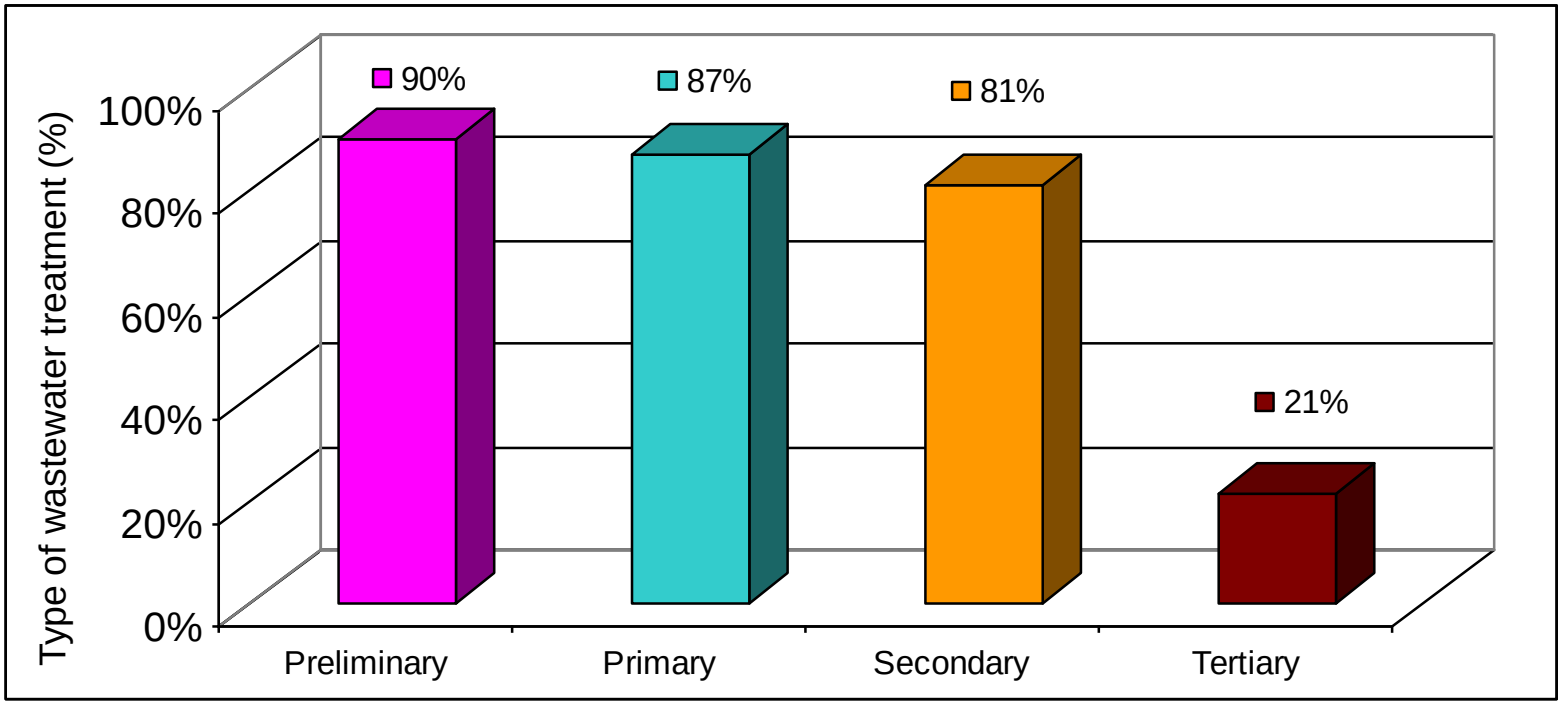
WWTPs in Sicily

- most of WWTPs (70%) treat wastewater coming from urban areas of less than 10,000 p.e., while only 3% served urban communities grater than 100,000 p.e.



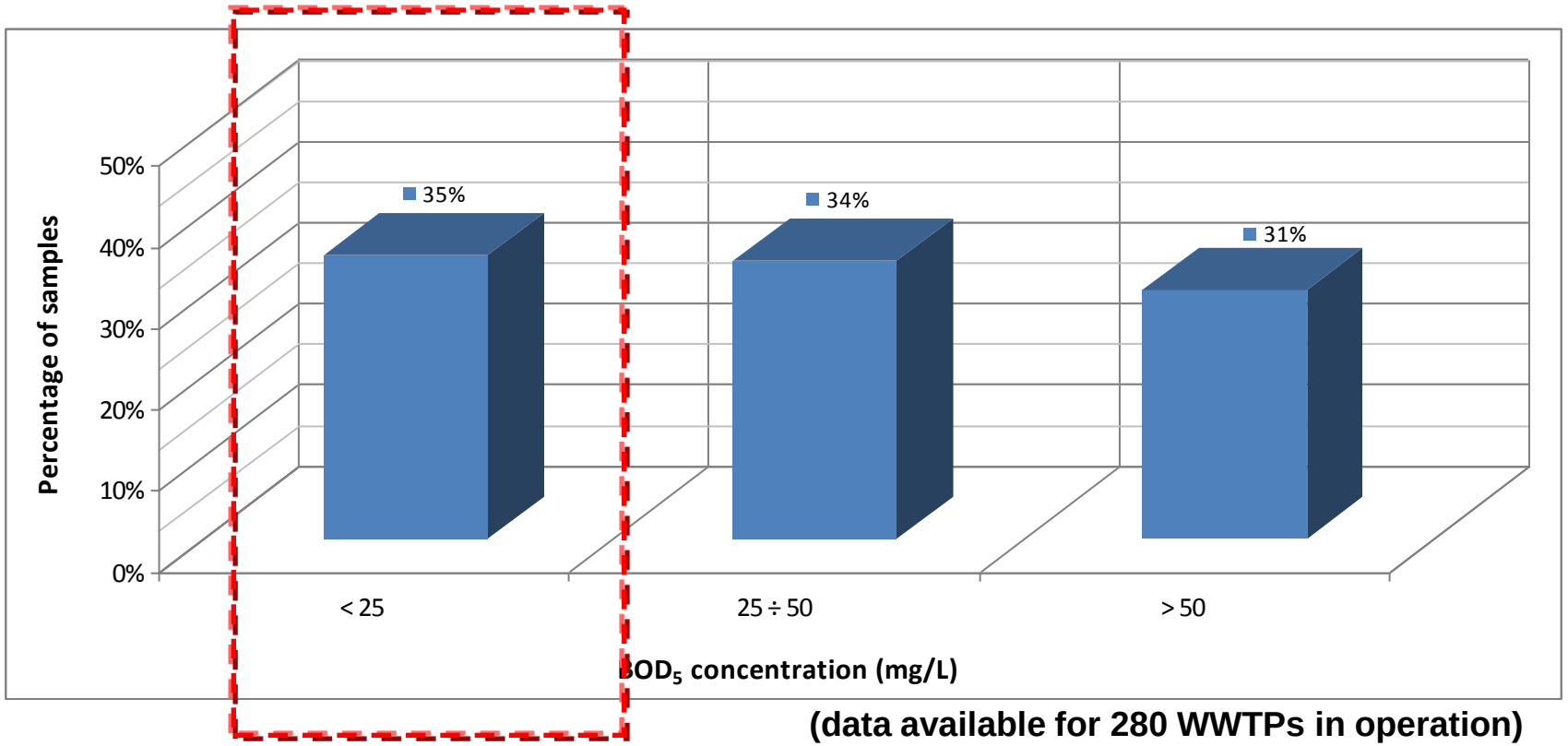
Type of WWTPs in Sicily

- In Sicily just 20% of in operation WWTPs served urban communities grater than 10,000 p.e. and provide tertiary treatment, mainly consisting of coagulation-flocculation, followed by filtration process



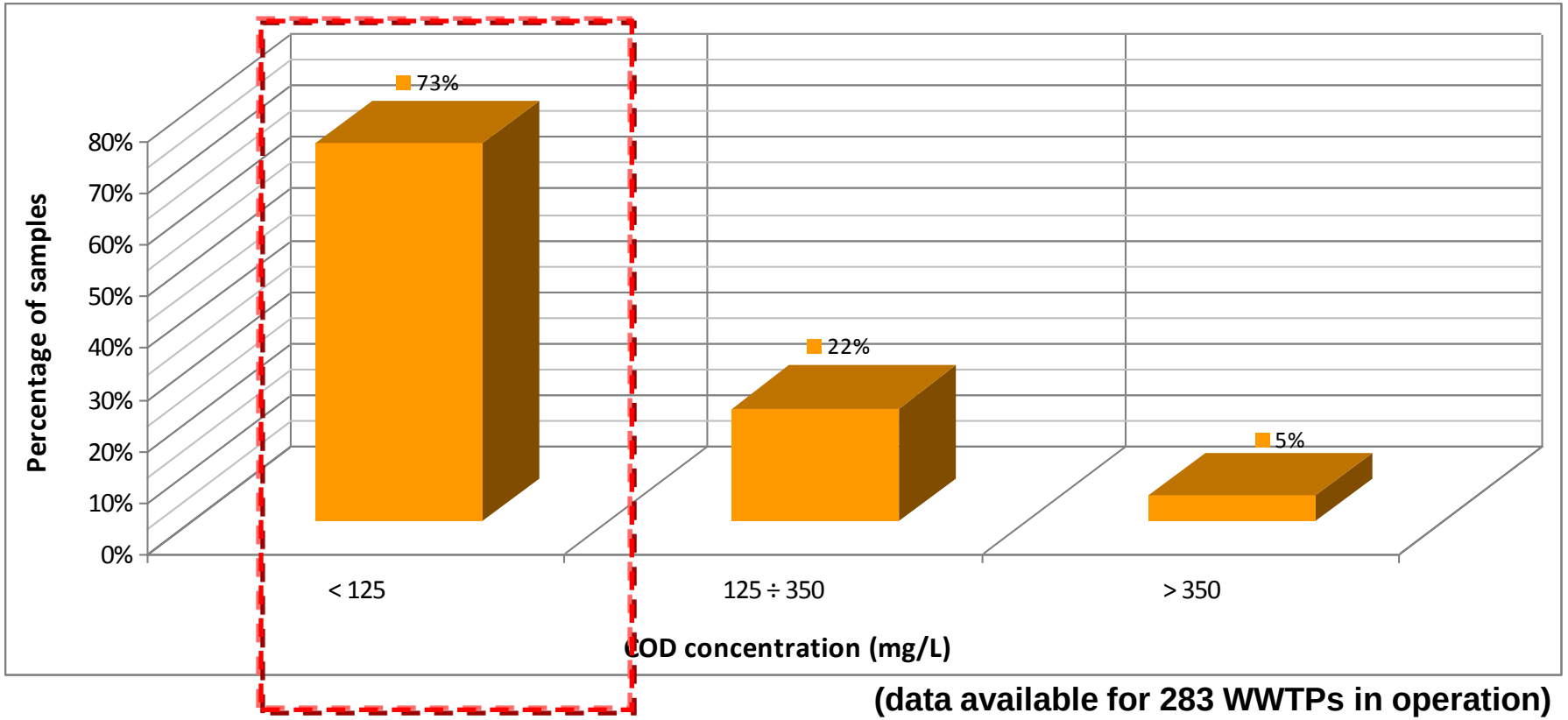
BOD5 parameter

- In the 35% of WWTPs effluents, BOD5 concentration was below 25 mg/L, the regulatory discharge limit set by Italian law (D.Lgs 152/2006)



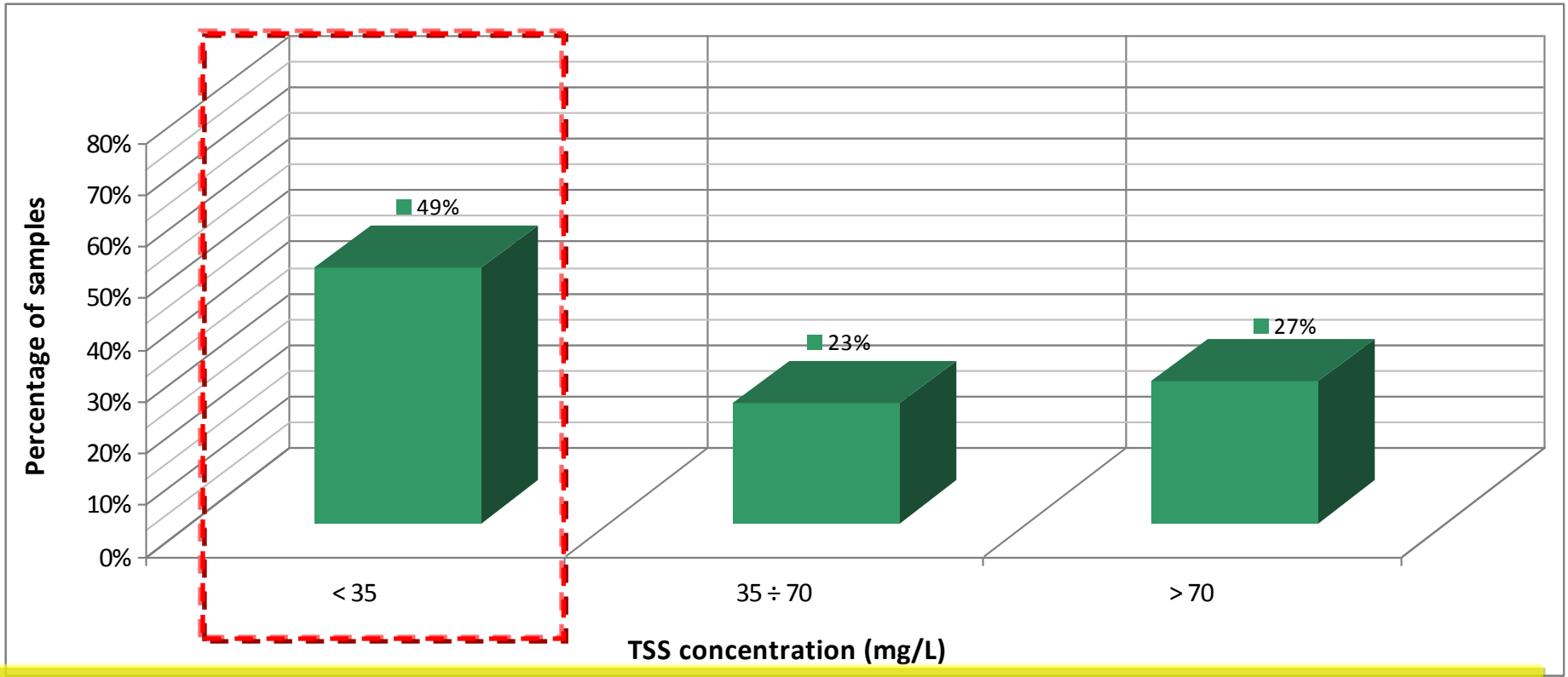
COD parameter

- The percentage of samples with COD concentration below 125 mg/L, the discharge limits set by Italian law, was 73%



TSS parameter

- In the 49% of WWTPs effluents TSS concentrations were below 35 mg/L, the discharge limits as set by Italian law



This limited capacity of BOD, COD and TSS removal detected in the Sicilian WWTPs highlights that further treatment should be necessary to better respect the environment. For example, the adoption of natural systems, such as constructed wetlands, combined with conventional treatment plants, could be a suitable solution for improving the water quality.

Wastewater reuse: European Union's Position

- The global framework defined through the **Water Framework Directive (WFD) (2000/60/EC - WFD)** establishes a legal framework to guarantee sufficient quantities of good quality water across Europe as needed for the different water uses and environmental quality.
- Its key aims are:
  - to expand water protection to all waters: inland and coastal surface waters and groundwater;
  - to achieve "good status" for all waters by 2015;
  - to base water management on river basins;
  - to combine emission limit values with environmental quality standards;
  - to ensure that water prices provide adequate incentives to use water resources efficiently;
  - to involve citizens more closely; and
  - to streamline legislation.
- It is expected that the promotion of an **integrated approach to water resources management** as it is spelled out in the WFD **will favour municipal wastewater reclamation and reuse** to be implemented on a larger scale, for both augmenting water supply and decreasing the impact of human activities on the environment.

Despite the European Union's wide encouragement to reuse treated wastewater effluent, no guidelines or regulations yet exist at the European level.

Existing water reuse criteria within the European Union*

Member state	Type of criteria	Comment
Belgium: Flemish Regional Authority	Aquafin proposal to the government (2003)	Based on Australian EPA guidelines
Cyprus	Provisional standards (1997)	Quality criteria for irrigation stricter than WHO standards but less than Californian Title 22 (TC < 50/100 ml in 80% of the cases on a monthly basis and < 100/100 ml always)
France	Art. 24 décret 94/469 3 1994 Circulaire DGS/SD1.D./91/n°51	Both refer as water reuse for agricultural purposes. Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set-back distances between irrigation sites and residential areas and roadways
Italy	Decree of Environmental Ministry 185/2003	Quality requirements are required for the three water reuse categories defined: agriculture, non-potable urban and industrial. Possibility for the Regional Authorities to change some parameters and implement stricter norms
Spain	Law 29/1985, BOE n.189, 08/08/85 Royal Decree 2473/1985	In 1985 the Government indicated water reuse as a possibility, but no specific regulation followed. A draft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. The proposed microbiological standards range is strongly similar to those of the Title 22 Regulations
Spain, Regional authorities: Andalucia, Balearic Is. and Catalonia	Guidelines from the Regional Health Authorities	Developed their own guidelines concerning wastewater recycling, in particular in the field of the irrigation, based on the WHO guidelines of 1989

**D. Bixio et al. / Desalination 187 (2006) 89–101*

Planned Spanish standards for the reuse of treated effluent*

Uses of reclaimed wastewater	Nematode eggs[1]	*E. coli* (cfu/100 mL)	SS (mg/L)	Turbidity (NTU)	Other criteria
Residential uses	<1/10 L	0	<10	<2	
Urban uses and facilities Greenhouse irrigation Irrigation of vegetables	<1/L	<200	<20	<10	*Legionella* spp. 100 cfu/100 mL
Irrigation of fodder Watering of crops eaten cooked	<1/L	<1,000	<35	No limit set	*Taenia saginata* and *T. solium* <1 egg/L
Irrigation of industrial crops	<1/L	<10,000	<35	No limit set	
Irrigation of wooden areas	<1/L	No limit set	<35	No limit set	
Industrial cooling	No limit set	<10,000	<35	15	*Legionella* spp. <10 cfu/100mL
Ponds, etc. for recreational purposes (public contact allowed)	<1/L	<200	<35	No limit set	
Ponds, etc. for recreational purposes (public contact is not allowed)	No limit set	<10,000	<35	No limit set	
Aquifer recharge: localized percolation	<1/L	<1,000	<35	No limit set	Total nitrogen <50 mg/L
Aquifer recharge: direct injection	<1/L	0	<10	<2	Total nitrogen <15 mg/L

standard for 14 possible applications of treated water

*F. Brissaud / Desalination 218 (2008) 24-33

Italian standard for reclaimed wastewater (D.M. 185/2003)

PARAMETERS	STANDARDS	PARAMETERS	STANDARDS
pH	6.0 ÷ 9.5	Sulphites [mg SO_3/L]	0.5
Sodium Adsorption Rate	10.0	Sulphates [mg SO_4/L]	500
Coarse solids	absent	Chlorine residual [mg/L]	0.2
TSS [mg/L]	10.0	Chlorides [mg Cl/L]	*250*
BOD_5 [mg/L]	20.0	Fluorides [mg F/L]	*1.5*
COD [mg/L]	100.0	Animal/vegetal oils & fats [mg/L]	10.0
Phosphorus [mg P/L] (total)	2.0	Mineral oils [mg/L]	0.05
Total Nitrogen [mg N/L]	15.0	Phenols [mg/L] (total)	0,1
Ar			
E			
Al			
A			
B			
B			
Ca			
Ce			
Cl			
Cl			
Iro			
M			
M			
Nickel [mg Ni/L]	0.2	Vanadium [mg V/L]	0.1
Lead [mg Pb/L]	0.1	Zinc [mg Zn/L]	*0.5*
Copper [mg Cu/L]	*1.0*	Cyanides[mg CN/L] (total)	*0.05*
Selenium [mg Se/L]	*0.01*	Sulphides [mg H_2S/L]	0.5
Tin [mg Sn/L]	3.0	*E. Coli* [UFC /100 mL] *(80% of samples)*	10*
		CWs & Stabilisation ponds	*50***
Thallium [mg Tl/L]	0.001	*Salmonellae* [UFC /100 mL]	absent

^ *for any single item;*

* *100 CFU/100 mL will be allowed as a maximum for a single isolated sample and for the first three years of application of the new Act;*

** *200 CFU/100 mL will be allowed as a maximum for a single isolated sample.*

54 parameters, *20% of them asks for the same quality as for drinking water*

E. Coli [UFC /100 mL] *(80% of samples)*	10*
CWs & Stabilisation ponds	*50***
Salmonellae [UFC /100 mL]	absent

* *100 CFU/100 mL will be allowed as a maximum for a single isolated sample and for the first three years of application of the new Act;*

** *200 CFU/100 mL will be allowed as a maximum for a single isolated sample.*

No distinction among different:

-alternatives of TWW reuse;

- irrigation option;

- crop types.

Wastewater reuse in Mediterranean countries

	Total population (1000 inhab) 2006 data [1] (A)	Total volume of treated wastewater reuse ($m^3 d^{-1}$)[2] (B)	Total Volume of treated wastewater per capita (C) = (B) / (A)	Types of Wastewater Reuse reported in different countries [3]
In Europe:				
Spain	43,887	1,117,808	25,470.14	Agriculture, Municipal, groundwater recharge, environmental
France	61,330	19,178	312.70	Agricultural, municipal, potable
Monaco	33	n/a	n/a	-
Malta	405	10,960	27.06	Agricultural, industrial
Italy	58,779	123,288	2,097.48	Agricultural, municipal, groundwater recharging, industrial
Slovania	2,001	n/a	n/a	-
Croatia	4,556	n/a	n/a	-
Bosnia-Herz.	3,926	n/a	n/a	-
Albania	3,172	n/a	n/a	-
Greece	11,123	28,000	2,517.31	Agriculture, industrial
Cyprus	846	68,493	80.96	Agricultural, municipal, environmental

(1) Source: FAO, 2009
(2) Source: studies referenced in this paper and U.S.EPA, 2004
(3) *Source: Asano and Jimenez, 2008*

Comments on guidelines and regulations in EU

- By comparing the guidelines and regulations in force, a number of conclusions can be made:
  - 1.Wastewater reuse is an accepted practice in Europe and the Mediterranean region and in some countries with limited rainfall and very limited water resources has become already an integral effective component of long term water resources management (e.g. in Jordan and Tunisia).
  - 2. The majority of the Mediterranean countries along with WHO consider treated wastewater suitable for agricultural purposes and to enhance the environment
  - 3.However, only a limited number of countries developed comprehensive water treatment and reuse standards, provide direction and encourage and finance wastewater reuse programmes.
    - Some countries without long term planning, have adopted less comprehensive and rigorous standards in order to reflect the actual reuse practice.
    - Often, too strict standards have led to only a few instances of legal reuse and a high number of illegal - and thus unmonitored - reuse practices in some countries

W.H.O. Position: Health Guidelines for Use of Wastewater in Agriculture and Aquaculture, 1989

- In the late 1980s, the World Health Organization (WHO 1989) , in order to prevent the transmission of these diseases, has recommended that:
  - only treated wastewaters should be used for crop irrigation;
  - and the treated wastewaters should comply with the microbiological quality guidelines given in the follow table

Category	Reuse conditions	Exposed group	Intestinal nematodes[b] (arithmetic mean no. of eggs per litre[c])	Faecal conforms (geometric mean no. per 100 ml[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation[f] of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Positions of World Health Organization, 2006*

- **The 2006 WHO Guidelines** propose combining a number of measures, commonly referred to as the "**Multiple-barrier Approach**", including ***treatment*** and ***non treatment options***, from the point of waste production through to the point of exposure for consumers, **in order to achieve the target level of health protection (expressed in Disability Adjusted Life Years, or DALYs**)
  - DALYs are a measure of the health of population or burden to a specific disease or risk factor.
  - One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.
  - Health-based target for wastewater reuse in agriculture **≤ 10^{-6} DALYs per person per year** (the same required for drinking-water)

***Guidelines for the safe use of wastewater, excreta and greywater, 2006**. Volume 2: Wastewater use in agriculture

Health-based target for wastewater reuse in agriculture*

Category A – "unrestricted irrigation" recommended the level of *Fecal Coliforms* less than 1.000 CFU 100 mL−1, refers to all crops grown for direct human consumption, including those eaten raw (e.g., lettuce, salads, cucumber etc.,) and irrigation of sports fields and public park

Category B – "restricted irrigation" recommended the level of Fecal Coliforms less than 100.000 CFU 100 mL-1 usable for cereal crops, industrial crops, fodder crops, pasture and trees (in the case of fruit trees, irrigation should stop two weeks before fruit is picked, and no fruit should be picked off the ground. Spray/sprinkler irrigation should not be used).

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤ 1 [b,c]
Onion		7	≤ 1 [b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤ 1 [b,c]
Labour intensive		4	≤ 1 [b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤ 1 [c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy).

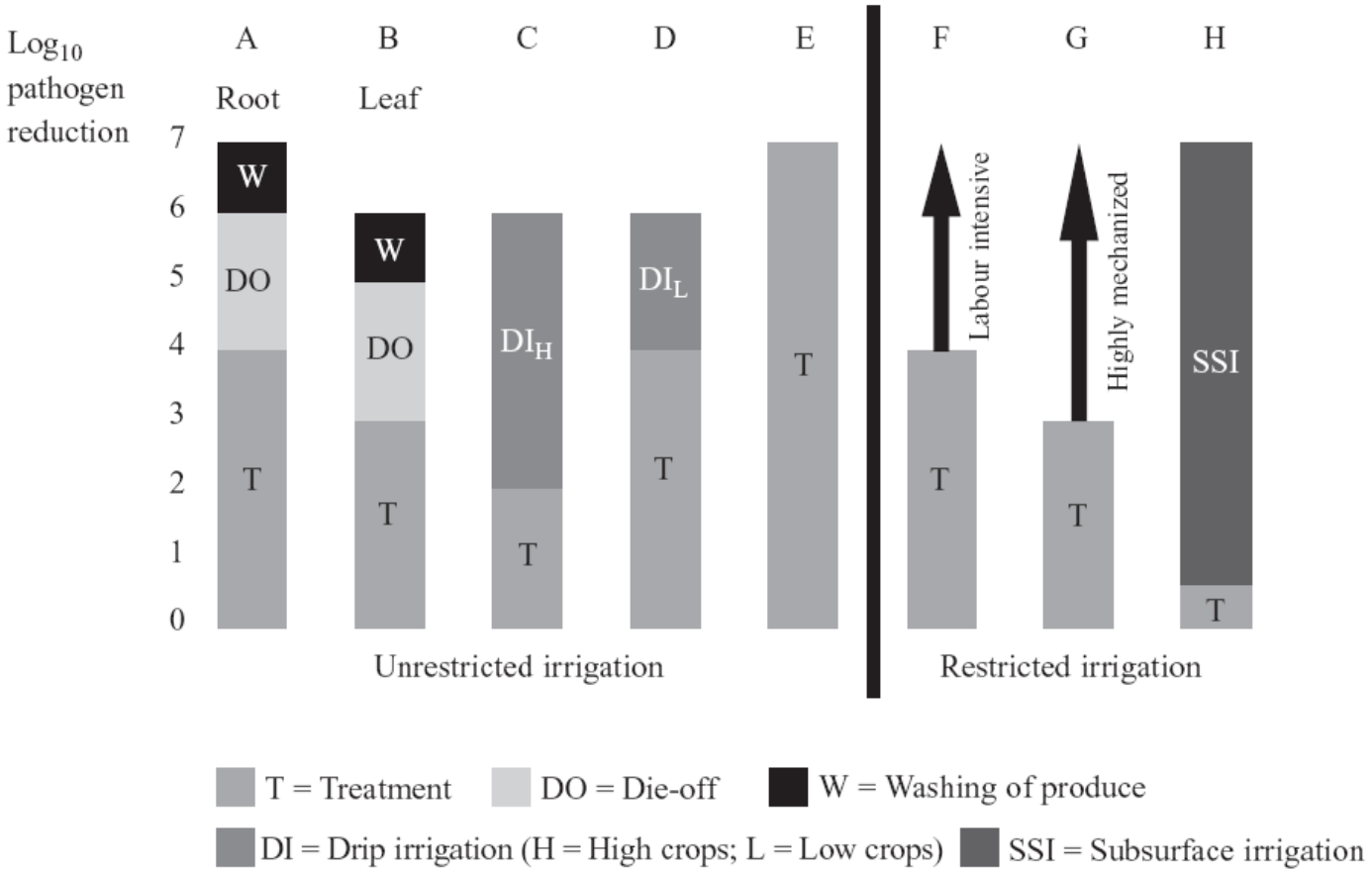
[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] No crops to be picked up from the soil.

***Guidelines for the safe use of wastewater, excreta and greywater, 2006.** Volume 2: Wastewater use in agriculture*

health-based protection measured to achieved required pathogen reduction

- Examples of option for reduction of viral bacterial and protozoan pathogens by different combination of health protection measures that achieve the health-based target of ≤ 10^{-6} DALYs per person per year



Our study: Analysis of treated wastewater reuse potential for irrigation in Sicily

- Objectives
  - to evaluate the potential of WW reuse in Sicily by adopting tools such as a Geographic Information System (GIS);
  - to evaluate the hypothesis to integrate conventional water sources with urban treated WW for selected irrigation areas.
  - to analyze the bacteriological quality of the effluents for selected wastewater treatment plants, by comparing the very restrictive approach of the Italian low (Ministry Decree n.185/2003) with WHO guidelines (2006) application for risk assessment.

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Analysis of treated wastewater reuse potential for irrigation in Sicily

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ABSTRACT

In Mediterranean countries, water shortage is becoming a problem of high concern affecting the local economy, mostly based on agriculture. The problem is not only the scarcity of water in terms of average per capita, but the high cost to make water available at the right place, at the right time with the required quality. In these cases, an integrated approach for water resources management including wastewater is required. The management should also include treated wastewater (TWW) reclamation and reuse, especially for agricultural irrigation. In Italy, TWW reuse is regulated by a quite restrictive approach (Ministry Decree, M.D. 185/03), especially for some chemical compounds and

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Analysis of treated wastewater reuse potential for irrigation in Sicily

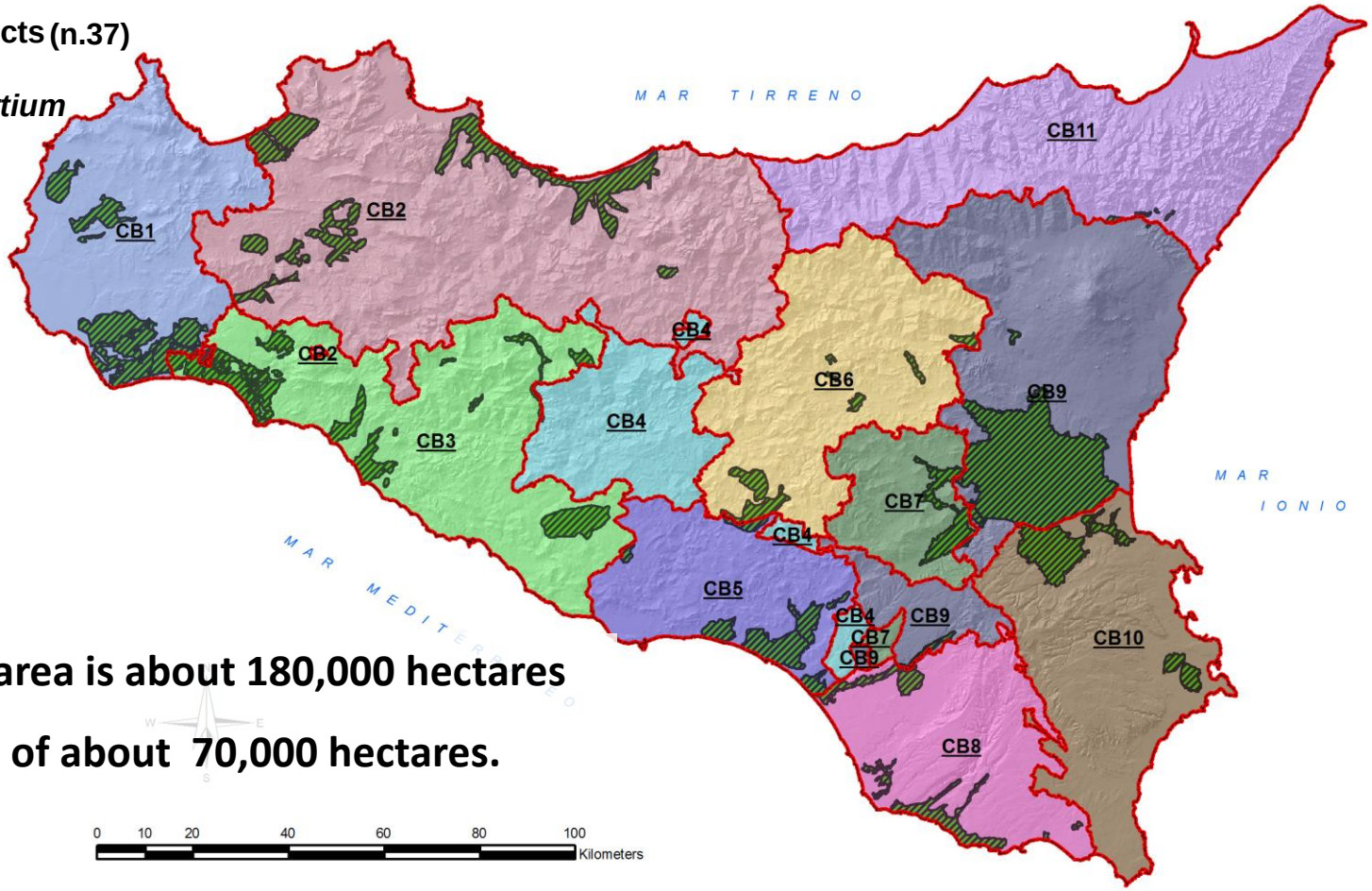
Methodology

Data collection: Irrigation Consortia

Irrigation Consortium (n.11)

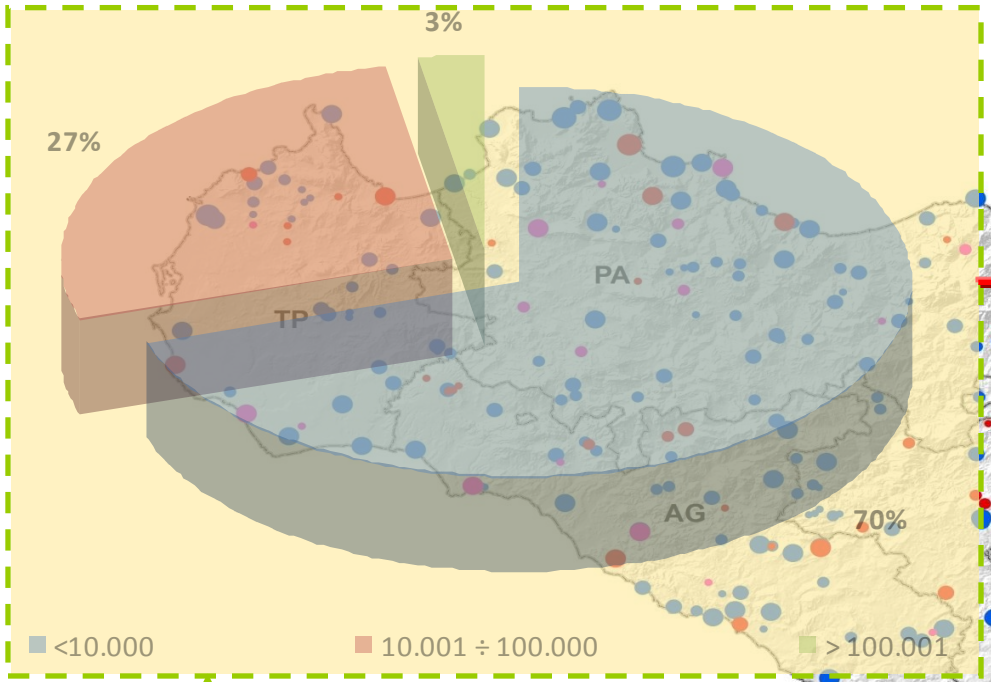
Irrigation districts (n.37)

CB*: Irrigation Cosortium*



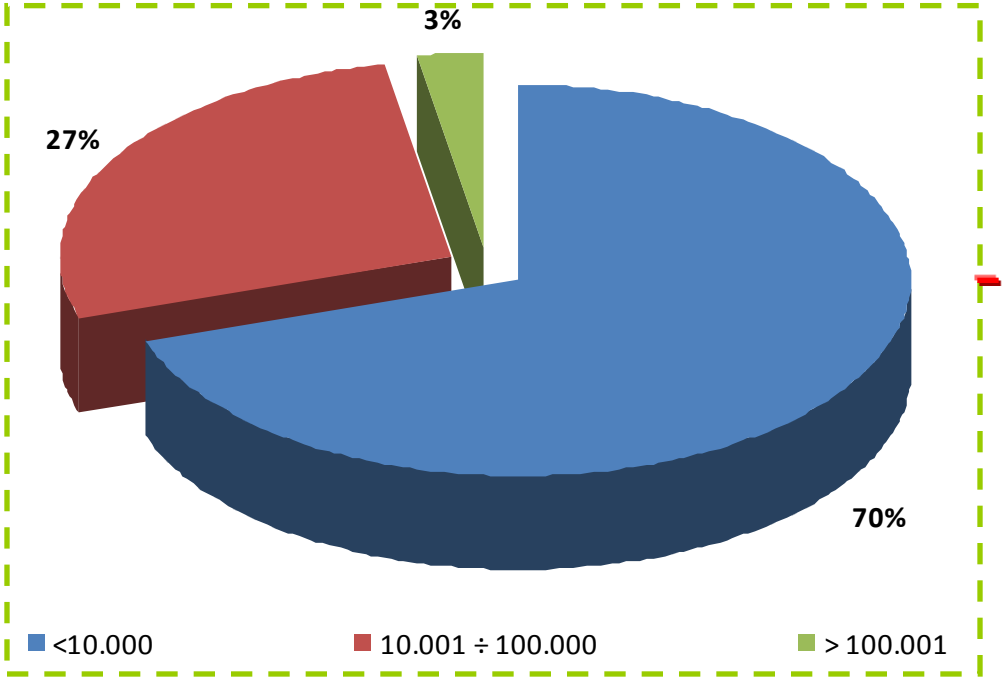
- **Maximum irrigation area is about 180,000 hectares**
- **Actual irrigated area of about 70,000 hectares.**

WWTPs in Sicily



224 Mm³/year

WWTPs in Sicily

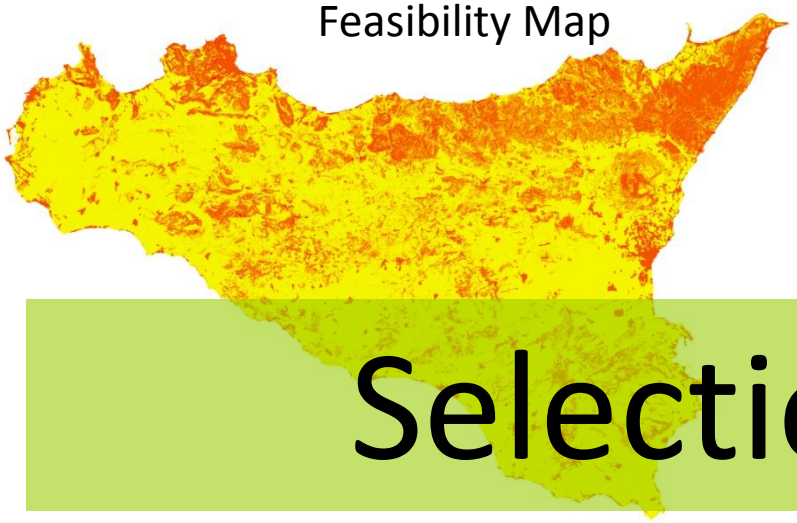


224 Mm^3/year

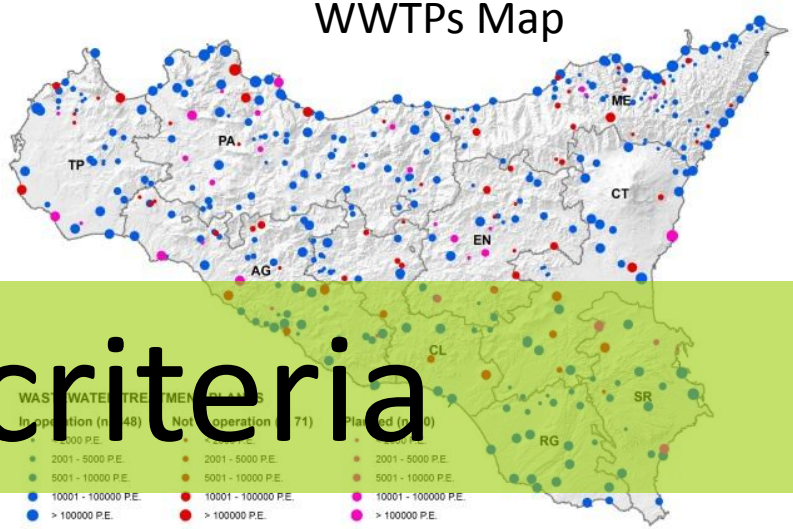
is about 30% of the irrigation needs of the island, estimated at about $750 \times 10^6\ m^3\ y^{-1}$, taking into account areas served by both collective irrigation, operated by Consortia, and private water sources. If the design treatment capacity is reach, the available treated wastewater volume will increase up to 340 Mm^3/year, corresponding to 45% of water demand in the irrigation sector.

Selection criteria

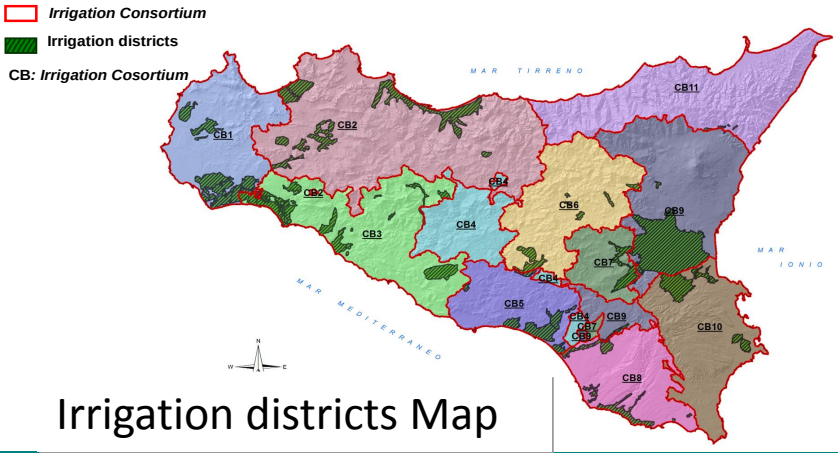
Feasibility Map



WWTPs Map



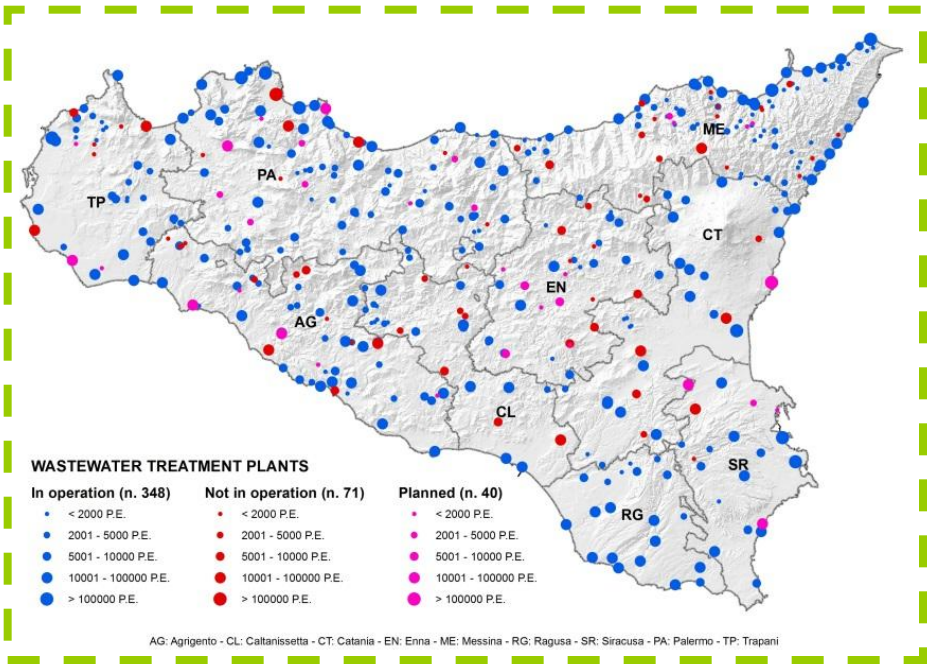
Selection criteria

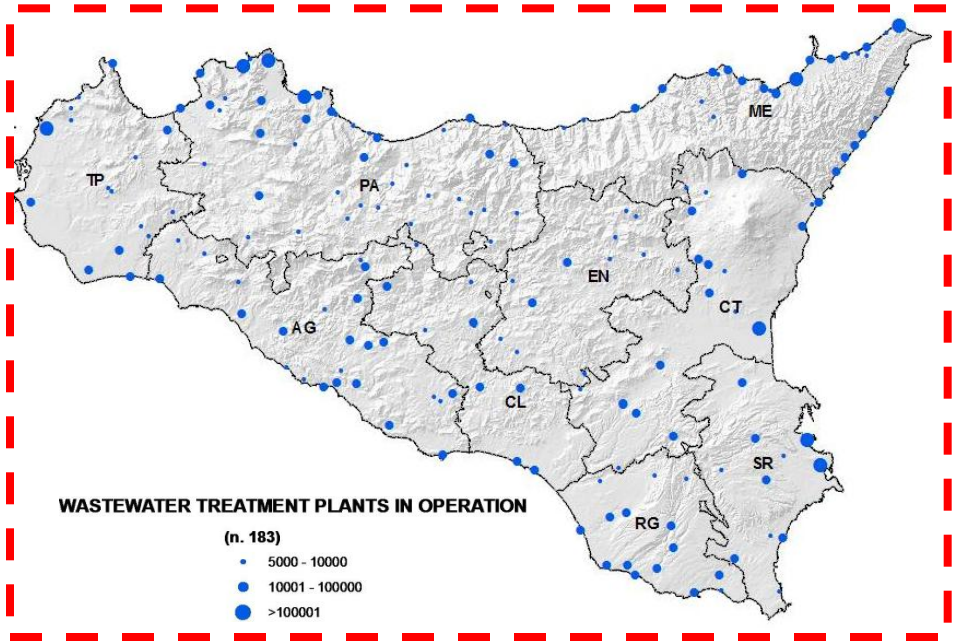


Irrigation districts Map

Selection criteria

1. WWTPs in operation that serve communities greater than 5,000 P.E.





348 WWTP

183 WWTP

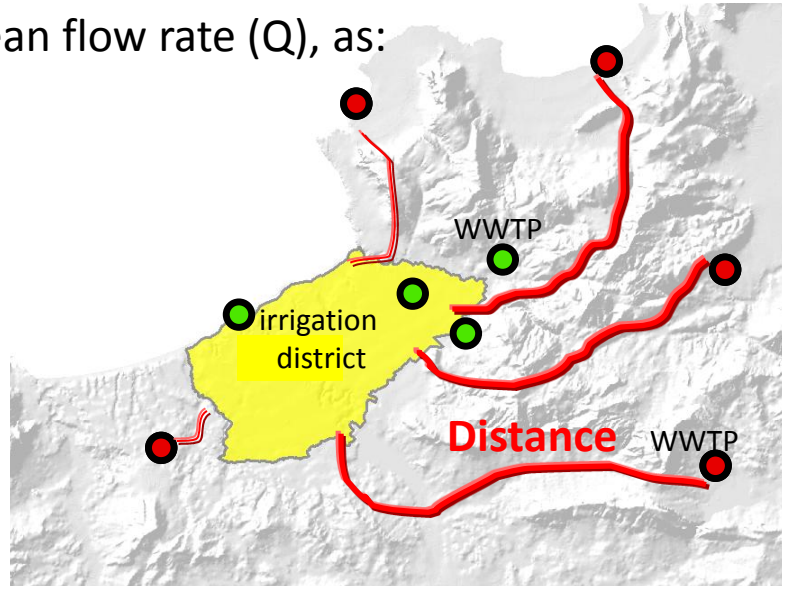
Selection criteria

2. maximum distance (D), based on the feasibility map, between WWTP and the nearest irrigation district according to the potential mean flow rate (Q), as:

   -D ≤ 5 km if Q ≥ 10 L s^{-1};

   -5 km < D ≤ 10 km if Q ≥ 15 L s^{-1};

   -10 km < D ≤ 20 km if Q ≥ 30 L s^{-1};



3. If the wastewater volume produced by the plants associated to the nearest Irrigation Consortium was more than its water requirement, WWTPs have been associated (if possible) to an other Consortium with water deficit, within criteria of the previous points. .

4. WWTP elevation higher than the mean elevation of the irrigation district or WW lifting (ΔH) up to 50 m.

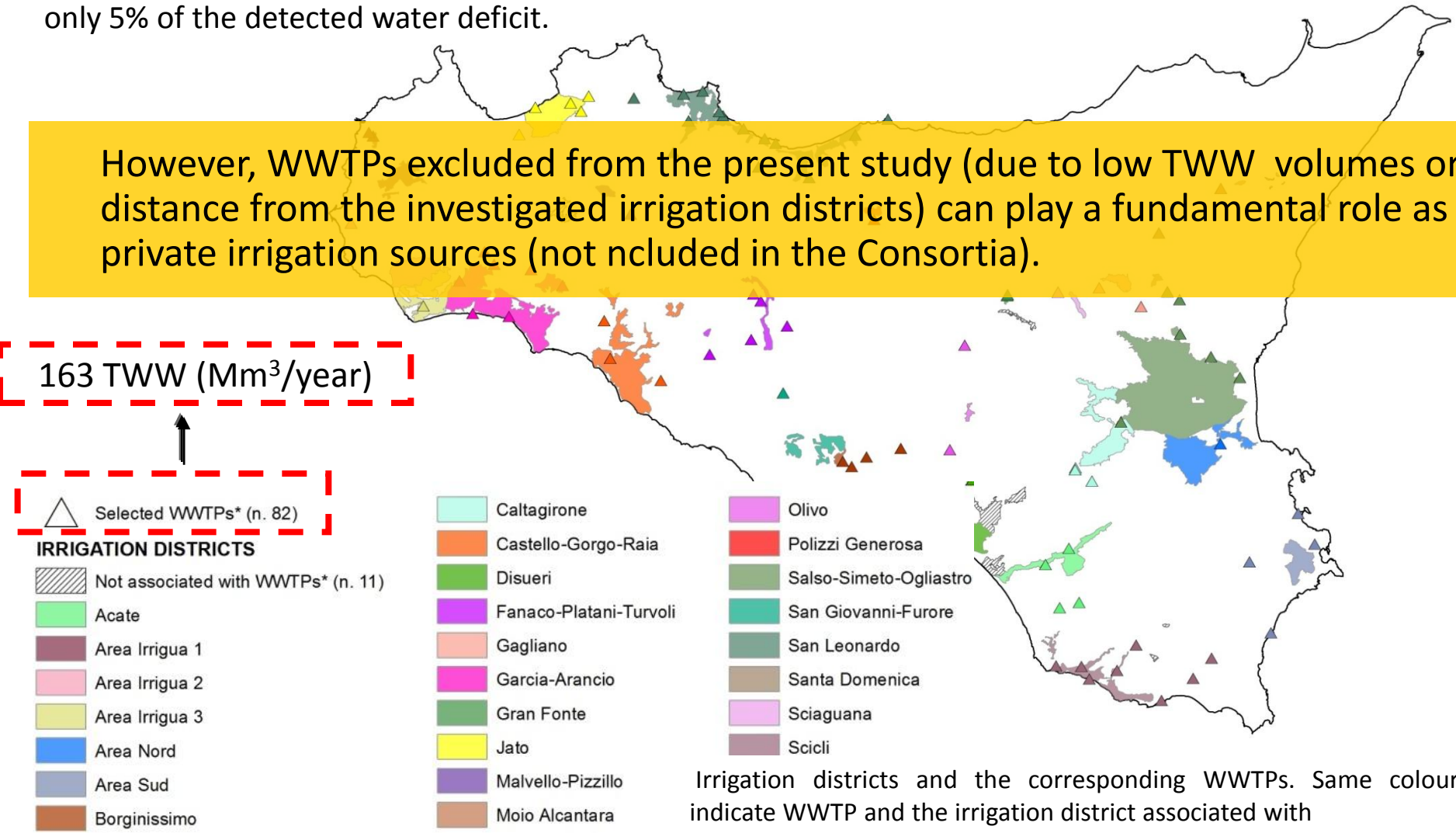
The use of reclaimed water for agriculture in Sicily, Italy

Results

Irrigation districts served and not served by WWTPs

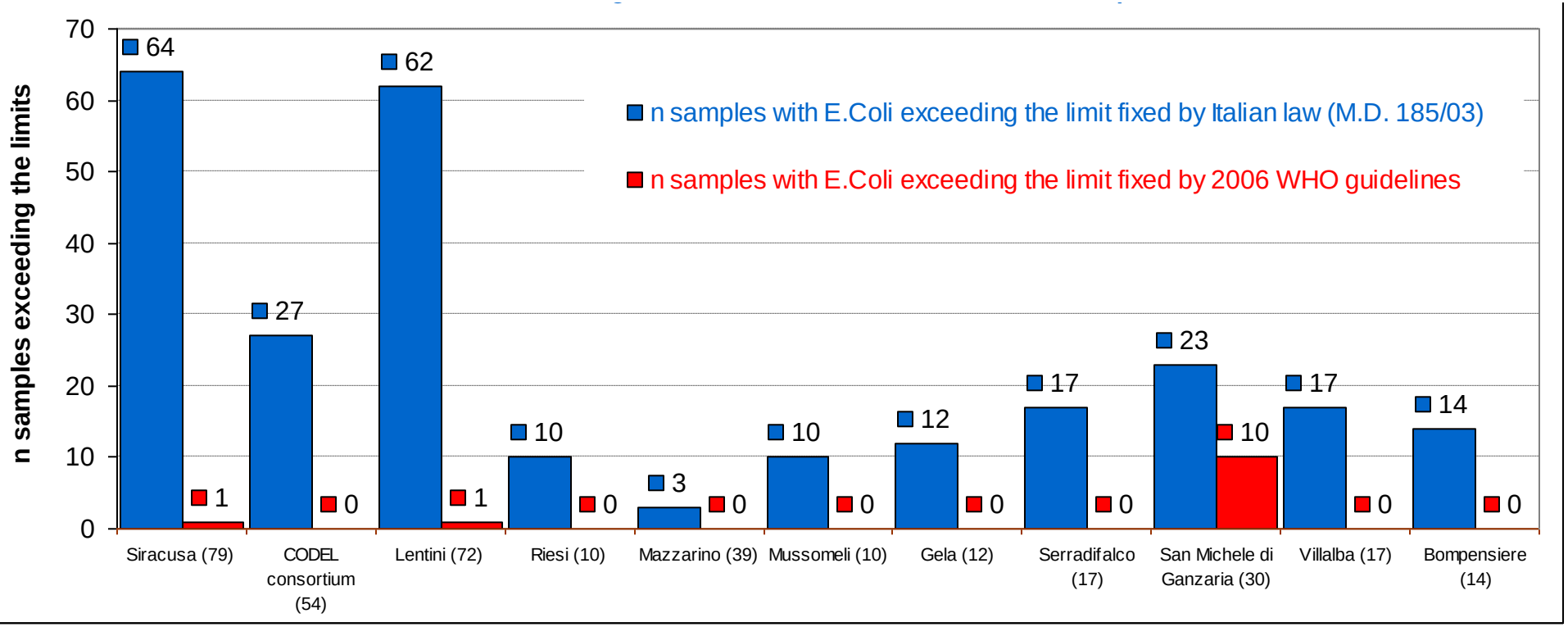
On the basis of selection criteria, 25 of 37 irrigation areas were eligible to receive treated wastewater from 82 in operation WWTPs. The remaining 12 areas that can not be served by WWTPs suffered from only 5% of the detected water deficit.

However, WWTPs excluded from the present study (due to low TWW volumes or distance from the investigated irrigation districts) can play a fundamental role as private irrigation sources (not ncluded in the Consortia).



Irrigation districts and the corresponding WWTPs. Same colours indicate WWTP and the irrigation district associated with

Microbiological characteristics of selected WWTPs in Sicily



data on *E.Coli* concentrations were, in most of the analysed cases, below the limit fixed by WHO (2006)

This results conflicts with the more restrictive rules imposed by the Italian legislation, that may be revised also in this sense