

WASTEWATER REUSE POTENTIAL FOR AGRICULTURAL 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. In addition, often 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 wastewater (WW) reclamation and reuse, especially for agricultural irrigation, that is becoming a common and rapidly increasing practice in Mediterranean regions, notwithstanding law restrictions and local acceptance. In Italy, WW reuse is regulated by a quite restrictive approach (Ministry Decree, M.D. 185/03), especially for some chemical compounds and microbiological parameters; this approach has led some difficulties in promoting WW reuse. On the other hand, at international level, the *Guidelines for the safe use of wastewater, excreta and greywater*, issued by the World Health Organization in 2006, can be used as a basis for the development of standards and regulation to manage the health risk from hazards associated with wastewater use in agriculture.

The main aim of the present paper is the evaluation of WW reuse potential in Sicily. In order to achieve the objective, a Geographic Information System (GIS) at regional level was built to quantify and locate the available WW volumes. In particular, the characteristics of the wastewater treatment plants (WWTPs) (location, altitude, person equivalent, treatment level, working state, treated volume...) were integrated, through the GIS, with data on irrigation district areas (surface, location, altimetry, crop water needs, available water resources, distance to the nearest WWTP). Moreover, in order to evaluate the Italian approach for WW reuse in agricultural irrigation, the water quality of different WW treated effluents, were analysed on the basis of both the Italian standard law and the WHO guidelines. The microbiological quality standards of the M.D. 185/03 were too restricted.

1 INTRODUCTION

Water resources in Europe are currently subject to strong pressures caused by the awareness that water is a limited resource, thus legal and operational instruments must be developed to face these challenges. The Water Framework Directive (WFD) of the European Commission extends the scope of protection to all water uses (EC, 2000). In this direction numerous researches have studied the WFD, either in terms of water

management structures in Europe (Dirksen, 2002), or in terms of the implications of this standard for the agricultural sector (Berbel and Gómez-Limón, 2000) and for irrigation districts (Kallis and Butler, 2001). The WFD aims to prevent water pollution at source by establishing control mechanisms that guarantee sustainable management of all the sources of pollution. In order to fulfil this aim, wastewater (WW) coming from civil and agricultural uses must be recycled or returned to nature (Wrigley, 2004).

In Italy, the restrictive approach for WW reuse (Ministry Decree, M.D. 185/03) in agriculture has led some difficulties in promoting this practice. The Italian standards are overabundant and quite restrictive for some chemical and microbiological compounds. Recent researches (Aiello et al., 2011) has, in fact, evidenced that although *Escherichia Coli* (*E.Coli*) content of WW is over the limits set by Italian law, the hygienic quality of the irrigated product is preserved accordingly to the World Health Organization (WHO, 2006) guidelines.

Another hampering factor to the development of WW reuse is related to the total cost (construction, operation and maintenance) requested for reclamation, in addition to the cost for reclaimed water distribution and the monitoring of the whole reuse system. The reclamation cost is sustainable only for medium to large WWTPs (> 5,000 PE). The restrictive approach of Italian WW reuse standards has, in fact, reduced the benefit of reclaiming water and hampering the development of wastewater reuse practices for smaller WWTPs; moreover, several successful reuse activities, operating in small communities of southern Italy inland areas, have to face management and monitoring problems due mainly to the lack of technical knowledge. According to the Italian law (article 12, Ministry Decree 185/2003), real costs for the distribution of recycled wastewater (power, labour, network maintenance, monitoring,...) are covered by the final users (farmers, owners of golf course, etc.), meanwhile the additional costs to achieve WW Italian standards are covered by WWTP holders, this means that the final users of water services pay an extra cost on the water tariff. In addition, the treatment cost increase could raise conflicts between civil (paying for the treatment) and agricultural (benefiting from unconventional waters) sectors.

The economical sustainability of the agricultural sector in Sicily (southern Italy) has to cope with the availability and management of water resources for irrigation. Crop water requirements are, generally, unfulfilled for relevant percentages (from 30 to 50%) and the need to use alternative water sources, like treated urban wastewater, is urgent. Moreover, reusing these discharged effluents can, significantly reduce or completely remove the impact of these effluents from receiving environments. In addition, the WW reuse for agricultural irrigation reduces the amount of water that needs to be extracted from environmental water resources. WW can often contain significant concentrations of organic and inorganic nutrients for example nitrogen and phosphate that may be used as a fertilizer source when the water is recycled for irrigation.

The study, herein presented, aims to evaluate the potential of WW reuse in Sicily by adopting instruments such as a Geographic Information System (GIS), which allows to determine and integrate information on irrigation areas, land use changes, wastewater treatments plants features, wastewater pollution loads, etc... The hypothesis to integrate conventional water sources with urban treated WW was examined for selected irrigation areas. In addition, for selected wastewater treatment plants, reliable data on bacteriological quality of the effluents were analysed and discussed by comparing the very restrictive approach adopted by the Italian legislation for WW reuse (M.D.

185/03) with WHO (2006) guidelines application for risk assessment.

In relation to the large monitoring protocol requested by the Italian WW reuse regulation, (where more than 50 parameters must be checked) WW users should be organized as private or public irrigation systems. The latter, organized in 11 *Consortia* under the Sicilian Regional Government control, could play a fundamental role to promote WW reuse due to their legal status and specific abilities.

2 METHODOLOGY

2.1 The study area

Sicily, like most areas of the southern Mediterranean shore, is subject to a substantial reduction of annual rainfall which greatly affects the economic sustainability of the agricultural sector. The general decreasing trend for water supply and the need for sustainable use of the available water resources make essential to find alternative water sources like treated urban wastewater through reuse practice.

The agriculture context in Sicily is supplied by 11 *Irrigation Consortia* that distribute irrigation volumes to 37 irrigation districts at fixed intervals (Figure 1). Maximum irrigation area is about 180,000 hectares, even if water availability decreasing reduces it to an actual irrigated area of about 70,000 hectares. Irrigation volumes are mainly supplied by river systems regulated by artificial reservoirs, which provided a mean annual volume released for irrigation of about $160 \cdot 10^6 \text{ m}^3$. These data were collected through specific surveys at the *Irrigation Consortia*.

The survey carried out in Sicily (Cirelli et al., 2010) highlighted the potential presence of 523 urban wastewater treatment plants (WWTPs), of which 259 actually in operation, 89 not in operation, 32 abandoned, 47 under construction and 96 just planned by the public administration (Figure 2).

The investigated WWTPs serve mainly small and medium communities, with less than 10,000 inhabitants. In particular, as evidenced by Table I, 49% of WWTPs in operation treat WW coming from urban areas with person equivalent (PE) (e.g. evaluated on the basis of the organic load) between 2,000 and 10,000, while more than 60% of the planned WWTPs will serve urban communities smaller than 2,000 PE.

2.2 Geographic Information System (GIS) implementation

Nowadays, scientific studies on water management need a combination of vector data with GIS for updating data. GIS provides the opportunity of an integrated evaluation of graphical (vector) and raster data. In this study, a vector-raster data transformation was successfully implemented on the Sicilian agricultural context. Hydrological data on water basins, land-use, irrigation districts information and WWTPs locations data were presented as fitted vector data into classified images. A digital elevation model (DEM) of the study-area was further implemented on the basis of regional technical maps at 1:10,000 scale. The data-base was built by using vectors and other ground truth attribute data and includes the following main information collected at irrigation district level:

- Maximum irrigation area (ha);
- Actual irrigated area (ha);
- Mean altitude (m);

- Annual water volumes released for irrigation ($\text{m}^3 \cdot 10^6$);
- Annual irrigation water requirements ($\text{m}^3 \cdot 10^6$);
- Annual water deficit ($\text{m}^3 \cdot 10^6$).

Legend

- Irrigation Consortium
- Irrigation districts
- CB: Irrigation Consortium

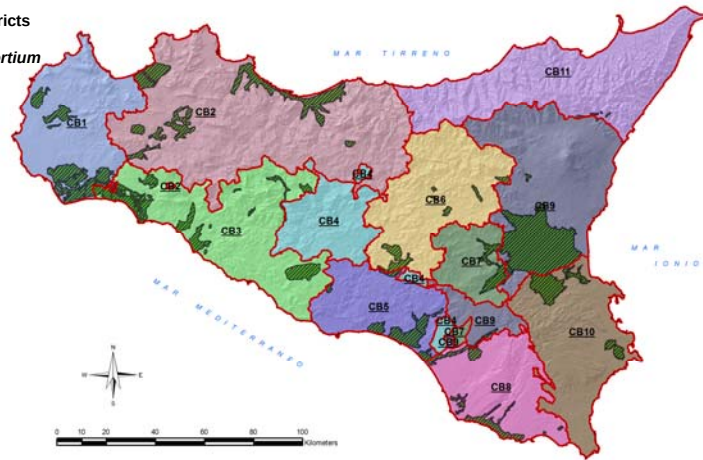


Figure 1. Sicilian irrigation districts supplied by collective water distribution networks

Table I. Classes of WWTP_s for PE

P.E.	WWTP _s *			
	in operation	not in operation	under construction	planned
< 2,000	69	29	13	63
2,000÷10,000	128	42	16	25
10,000÷100,000	60	18	15	6
> 100,000	2	0	3	2
Total	259	89	47	96

*Abandoned plants data are not available per PE

The mean altitude was calculated by means of the GIS analysis as the average altitude of image pixels falling into each irrigation area. For each district, irrigation water requirements were derived by the product between actual irrigated area (ha) and water volume ($\text{m}^3 \text{ ha}^{-1}$) fixed by the *Irrigation Consortium* for each crop during the irrigation season. By comparing water volumes availability with irrigation water requirements, annual water deficits were determined for each irrigation district.

For each WWTP in operation or under construction data on location, elevation and annual treated WW volume were analysed. In order to take into account just significant treatment systems and feasible solutions, WWTPs were selected for effluents reuse if they satisfy the following selection criteria:

- served communities upper than 5,000 PE (corresponding to a flow rate of about 10 L s^{-1} considering 150 L PE^{-1});
- WWTP_s elevation higher than the mean elevation of the nearest irrigation district or WW lifting (ΔH) up to 50 m;
- maximum distance (D) between WWTP and the nearest irrigation district according to the treated volume, as:
 - D up to 5 km if treated WW flow (Q) is $< 15 \text{ L s}^{-1}$;
 - D up to 10 km if $15 \leq Q < 30 \text{ L s}^{-1}$;
 - D up to 15 km if $Q \geq 30 \text{ L s}^{-1}$.

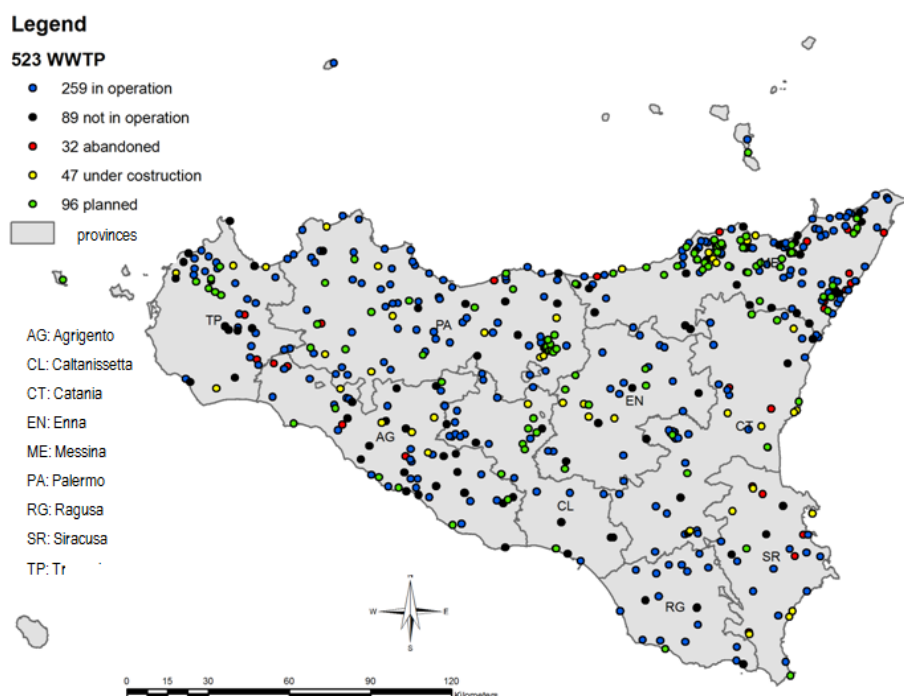


Figure 2. Location of the 523 urban WWTPs in the 9 Sicilian provinces

The latter criterion was evaluated by calculating D as the minimum distance on the basis of the morphology and of the presence of natural obstacles (lakes, hills, etc...) between WWTP_s and the nearest irrigation district.

Each WWTP with the above mentioned characteristics was thus selected and attributed to the nearest irrigation district to integrate collective irrigation volumes with WW effluents. The available WW volumes would then allow to fill water deficit conditions and/or to enlarge the irrigated areas up to the maximum extend.

2.3 Microbial risk assessment evaluation

The health risk associated with the use of WW was evaluated for three WWTPs located in Siracusa (100,000 PE), Lentini (50,000 PE) and San Michele di Ganzaria (6,000 PE), following the Disability-Adjusted Life Years (DALYs) tool (WHO, 2006).

The DALYs index calculates the time lost because of disability from a disease compared with a long life free of disability in the absence of disease. The three indexes pathogens selected were Rotavirus (a virus), Campylobacter (a bacterium) and Cryptosporidium (a protozoan). Results of the QMRA (Quantitative Microbial Risk Analysis, WHO 2006) were used to determine the total pathogen reduction targets to be achieved by a combination of wastewater treatments and a selection of post-treatment health protection control measures, based on a tolerable maximum additional burden of disease of one-million of a DALY loss per person per year (10^{-6} DALY loss ppy).

In the adopted approach, the model exposure scenario of “unrestricted irrigation”, based on the consumption of wastewater-irrigated lettuce (Shuval et al., 1997), was considered within the “planned WW use” definition. The selected scenario corresponds to the controlled use of treated WW to grow crops that are normally eaten raw (WHO, 2006). At this point, results of the QMRA-Monte Carlo simulation were adopted to estimate the required minimum total pathogen reductions, such that the tolerable maximum additional burden of disease is not exceeded. The WHO Guidelines showed that the risk of Rotavirus infection was higher than those of Campylobacter and Cryptosporidium and thus Rotavirus infection risk must be used to assess the safety of WW irrigation practice. In this case, the median design risk for Rotavirus infection is taken as 10^{-3} ppy for a wastewater quality of 10^3 - 10^4 *E.Coli* per 100 ml. Following the WHO procedure, for the selected tolerable Rotavirus infection, the log-unit reduction by treatment (to achieve *E.Coli* concentration of Table II) must be supplemented by post-treatment health-protection control measures (i.e. drip irrigation techniques, pathogen die-off, produce washing, etc...) totalling 2 log units for not-root crops. In the study, results of the WHO Guidelines application on the quality of WW effluents withdrawn from the analysed WWTPs were compared with the very restrictive approach adopted by the Italian legislation for WW reuse (Ministry Decree, 185/03).

Table II. Unrestricted irrigation: median infection risks from the consumption of wastewater-irrigated lettuce estimated by QMRA-Monte Carlo simulation (WHO, 2006)

Wastewater quality (<i>E.Coli</i> per 100 ml)	Median infection risk ppy		
	Rotavirus	<i>Campylobacter</i>	<i>Cryptosporidium</i>
10^3 - 10^4	1.0×10^{-3}	2.6×10^{-5}	3.1×10^{-5}

3 RESULTS AND DISCUSSION

3.1 Wastewater reuse potential

The WW volume produced by WWTPs in Sicily amount to $155 \cdot 10^6$ m³ (plants in operation) and $48 \cdot 10^6$ m³ (plant under construction). Total volume available in the short term was therefore about 27% of the irrigation needs of the island, estimated at about $750 \cdot 10^6$ m³/year, taking into account areas served by both collective irrigation operated by Consortia and private water sources.

In Table III the main characteristics (irrigated surfaces, mean altitude, available water volumes, irrigation requirements, water deficit) of the irrigation districts supplied

by collective water distribution networks were reported. The data highlighted that the annual irrigation requirement was about $230 \cdot 10^6 \text{ m}^3$ and that most of irrigation districts had a negative annual water imbalance, ranging from about $0.1 \cdot 10^6 \text{ m}^3$ to $40.5 \cdot 10^6 \text{ m}^3$ (Salso-Simeto district), with a total deficit of about $68 \cdot 10^6 \text{ m}^3$ /year.

In Table IV the irrigation districts that can be supplied by treated WW following the selection criteria were reported. In particular, the number of WWTPs for each irrigation district, available effluent volumes, distance of the nearest and farthest WWTP with respect to the district, WW lifting of possible network systems (ΔH) were evidenced.

On the basis of selection criteria, 24 of 37 irrigation areas were eligible to receive treated wastewater from 59 WWTPs. The remaining 13 areas that can not be served by WWTPs suffered for only 5% of the detected water deficit. The distance between selected WWTPs and irrigation districts varied from zero to 14.5 km, while the maximum foreseen ΔH is 45 m.

Overall, WW potentially reusable was about $87 \cdot 10^6 \text{ m}^3 \text{ y}^{-1}$, while water deficit was $65 \cdot 10^6 \text{ m}^3 \text{ y}^{-1}$. In particular, through the use of treated WW 10 districts could cover the deficit and gain a surplus of water resources, 8 districts having already not deficit could increase water availability, 6 districts could partially be able to meet water needs (Figure 3). Irrigation districts with a surplus of resources may enlarge their irrigated area or save high quality water for other uses (civil, environmental...) or avoid aquifers overexploitation.

Anyway, WWTPs excluded from the present study (due to low WW volumes or long distance to the investigated irrigation districts) can play a fundamental role for the private irrigation of agricultural areas (not included in *Irrigation Consortia*) close to WWTPs.

3.2 Risk assessment analysis

Wastewater contamination by *E.Coli* varied considerably from null values to $4 \cdot 10^4$ CFU 100 mL⁻¹ (for Siracusa and Lentini WWTPs) and to $4 \cdot 10^5$ CFU 100 mL⁻¹ (for San Michele di Ganzaria WWTP) during the monitoring periods (Figure 4). Only 25% and 14% of samples collected at Siracusa and Lentini WWTPs respectively showed an *E.Coli* count lower than the current threshold of 10 CFU 100 mL⁻¹ requested by the Italian legislation (M.D. 185/2003) for 80% of samples. For San Michele di Ganzaria WWTP, 30% of samples showed an *E.Coli* contamination lower than the current threshold of 50 CFU 100 mL⁻¹ requested for 80% of samples in case of natural treatments.

In the 2.7%, 1.3% and 16% of samples (for Siracusa, Lentini and San Michele di Ganzaria WWTPs respectively) *E.Coli* contamination was above the value of 10^4 CFU 100 mL⁻¹ fixed by the World Health Organization in 2006 for the “unrestricted irrigation” scenario, in order to reach a median design risk for Rotavirus infection of 10^{-3} pppy. According to WHO Guidelines (2006), wastewater reclaimed by the constructed wetland system could be used for irrigation by implementing some post-treatment health protection control measures. For example, irrigation should be stopped 1-2 days before the harvest phase to obtain at least 1 log unit of *E.Coli* reduction due to pathogen die-off. A further 1 log unit of microbial reduction could be achieved by the produce washing with clean water. The application of these post-treatment health-protection control measures assures the required log units reduction of *E.Coli* for the tolerable rotavirus infection risk.

Table III. Main characteristics of irrigation districts supplied by collective water distribution network in Sicily

N	Irrigation districts	<i>Irrigation Consortium</i>	Maximum irrigation area (ha)	Actual irrigated area (ha)	Mean altitude (m a.s.l.)	Annual water volumes released for irrigation (m ³ ·10 ⁶)	Annual irrigation water requirements (m ³ ·10 ⁶)	Annual water deficit (m ³ ·10 ⁶)
1	Acate	CB8-RG	5140	2300	151	4.6	5.4	0.80
2	Area Nord	CB10-SR	11000	5700	82	11	18.53	7.53
3	Area Sud	CB10-SR	4700	-	34	0	5.54	5.54
4	Area irrigua1	CB1-TP	6800	3300	73	5	4.95	-0.05
5	Area irrigua2	CB1-TP	6000	3500	42	4.3	5.3	0.95
6	Area irrigua3	CB1-TP	7137	2430	57	0.3	3.7	3.35
7	Biviere	CB5-Gela	900	413	19	1.4	1.3	-0.10
8	Borginissimo	CB5-Gela	220	123	290	0.5	0.12	-0.38
9	Caltagirone	CB7-CLG	8106	3500	140	11	10.5	-0.50
10	Castello-Gorgo-Raia	CB3-AG	17500	8267	70	0.61	0.89	0.28
11	Castiglione	CB11-ME	21.5	21.5	367	0.05	0.24	0.19
12	Cimia	CB5-Gela	1500	1500	55	1.28	2.1	0.82
13	Comunelli	CB5-Gela	2000	2000	30	1.25	2.8	1.55
14	Dagale-Renelli	CB2- PA	1077	431	190	0.2	0.9	0.70
15	Disueri	CB5-Gela	6000	2000	20	1.5	2.8	1.30
16	Fanaco-Platani-Turvoli	CB3-AG	1350	200	386	0.19	0.3	0.11
17	Fumari	CB11-ME	60	60	536	0.63	0.68	0.05
18	Gagliano	CB6-EN	1500	900	271	2.78	2.6	-0.18
19	Garcia-Arancio	CB3-AG	21200	8524	112	8.14	12.78	4.64
20	Gran Fonte	CB6-EN	83	83	452	0.28	0.27	-0.01
21	Ispica	CB8-RG	511	140	39	0.55	0.8	0.25
22	Jato	CB2- PA	7150	3100	136	1.9	7.8	5.90
23	Malvello-Pizzillo	CB2- PA	500	150	314	1.90	0.4	-1.50
24	Maroglio	CB5-Gela	300	170	112	1.2	0.24	-0.96
25	Moio Alcantara	CB11-ME	170	170	532	1.8	1.92	0.12
26	Nicoletti	CB6-EN	800	120	293	0.68	0.64	-0.04
27	Ogliastro	CB9-CT	4300	2900	120	11.5	14	2.50
28	Olivo	CB6-EN	2577	650	382	0.93	1.85	0.92
29	Polizzi Generosa	CB2- PA	700	480	636	3.2	1.2	-2.00
30	S.Giovanni-Furore	CB3-AG	6800	-	408	2.36	3.45	1.09
31	Salso-Simeto	CB9-CT	46323	16997	63	57.75	98.32	40.57
32	San Leonardo	CB2- PA	6065	-	144	0	2.93	2.93
33	San Paolo	CB11-ME	54	54	426	0.95	0.61	-0.34
34	Santa Domenica	CB9-CT	160.63	160.63	361	0.88	0.77	-0.11
35	Sciaguana	CB6-EN	1665	65	311	0.19	0.21	0.02
36	Scicli	CB8-RG	4100	3100	61	17.18	9.1	-8.08
37	Zangale	CB11-ME	5	5	552	0.11	0.06	-0.05
TOT			184475	73514	-	158	226	68

AG: Agrigento; CL: Caltanissetta; CLG: Caltagirone; CT: Catania; EN: Enna; ME: Messina; PA: Palermo; RG: Ragusa; SR: Siracusa; TP: Trapani

Table IV. Potential wastewater reuse for selected irrigation districts in Sicily

N	Irrigation districts	Irrigation Consortium	Annual water deficit ($\text{m}^3 \cdot 10^6$)	Wastewater treatment plants				
				N.	Annual wastewater volume ($\text{m}^3 \cdot 10^6$)	Min distance ¹ (km)	Max distance ² (km)	Max ΔH (m)
1	Acate	CB8-RG	0.80	3	2.48	0	14.4	3
2	Area Nord	CB10-SR	7.53	1	1.31	0	-	0
3	Area Sud	CB10-SR	5.54	2	8.76	2.9	14.5	33
4	Area irrigua3	CB1-TP	3.35	1	0.82	0.1	-	0
5	Borginissimo	CB5-Gela	-0.38	1	0.49	0	-	18
6	Caltagirone	CB7-CLG	-0.50	2	2.95	1.8	4.1	0
7	Castello-Gorgo-Raia	CB3-AG	0.28	2	1.48	0	2.4	0
8	Dagale-Renelli	CB2- PA	0.70	1	0.47	8	-	0
9	Disueri	CB5-Gela	1.30	1	4.28	0	-	12
10	Fanaco-Platani-Turvoli	CB3-AG	0.11	4	2.28	1.9	9.8	30
11	Gagliano	CB6-EN	-0.18	1	0.52	2.4	-	0
12	Garcia-Arancio	CB3-AG	4.64	2	0.87	1.4	3.1	0
13	Gran Fonte	CB6-EN	-0.01	1	1.27	0	-	0
14	Ispica	CB8-RG	0.25	3	4.02	6.7	14.1	24
15	Jato	CB2- PA	5.90	3	4.56	0.0	9.0	0
16	Malvello-Pizzillo	CB2- PA	-1.50	2	0.95	3.7	3.8	0
17	Moio Alcantara	CB11-ME	0.12	1	0.87	5.5	-	0
18	Nicoletti	CB6-EN	-0.04	2	2.30	1.7	9.6	0
19	Olivo	CB6-EN	0.92	3	6.44	0	10.4	0
20	S.Giovanni-Furore	CB3-AG	1.09	1	2.05	0.0	-	9
21	Salso-Simeto	CB9-CT	40.57	7	14.88	0.0	6.8	0
22	San Leonardo	CB2- PA	2.93	7	7.46	0.0	7.3	45
23	Santa Domenica	CB9-CT	-0.11	2	3.56	2.7	10.7	0
24	Scicli	CB8-RG	-8.08	6	11.50	0	9.4	29
TOT			65	59	87			

¹ Distance of the nearest WWTP with respect to the district² Distance of the farthest WWTP with respect to the district

AG: Agrigento; CL: Caltanissetta; CLG: Caltagirone; CT: Catania; EN: Enna; ME: Messina; PA: Palermo; RG: Ragusa; SR: Siracusa; TP: Trapani

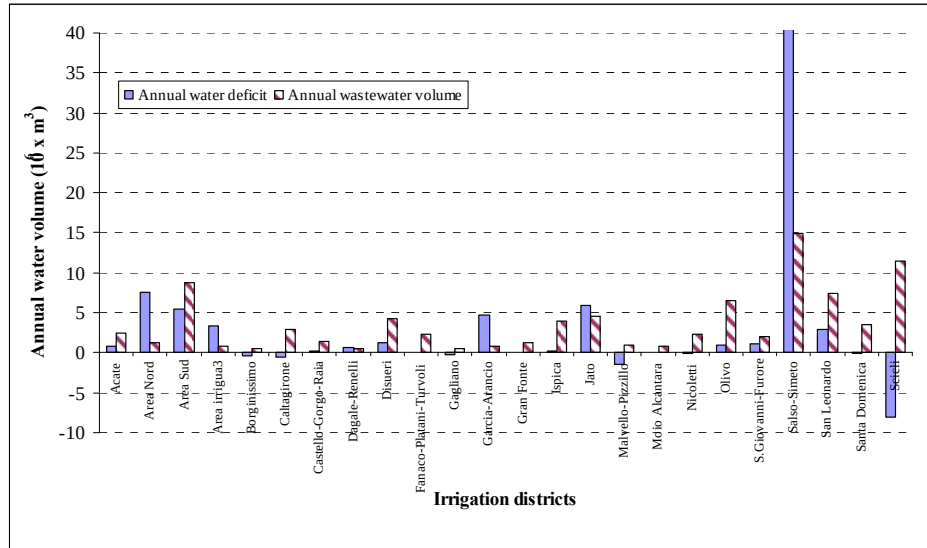


Figure 3. Annual water deficit and wastewater volume for each irrigation district

4 CONCLUSIONS

The present study reports the wastewater reuse potential for the 11 *Irrigation Consortia* that distribute irrigation volumes in Sicily. On the basis of selection criteria, 24 out of 37 irrigation areas were eligible to receive treated wastewater from 59 WWTPs. Overall, wastewater potentially reusable was about $87 \cdot 10^6 \text{ m}^3 \text{ y}^{-1}$, while water deficit was $65 \cdot 10^6 \text{ m}^3 \text{ y}^{-1}$. Obviously, by considering each district, deficit or surplus would still exist. The irrigation districts with a surplus of resources, may extend their irrigated area or save high quality water for other uses or avoid aquifers overexploitation. The WW volumes coming from the excluded 247 WWTPs (about 117 Mm^3) could be used to irrigate extra areas currently not irrigated, or served by private water supplies. This would represent a fundamental opportunity to improve the agricultural sector, to save fresh water, to preserve the environment and to develop the internal marginal areas of Sicily. Of course, this would imply a more accurate study to allocate in a correct way the non-conventional resources.

In addition, the presented study, showed that municipal WW may be successfully used, under specific experimental conditions, to irrigate and grow crops that are normally eaten raw. In particular, the risk assessment analysis, carried out by using the QMRA model according to WHO (2006) procedures, highlighted that by applying the post treatment health-protection control measures (such as product washing and/or the natural pathogen die-off after last irrigation), the acceptable Rotavirus infection risk was generally preserved, although *E.Coli* content of WW was often over the limits set by the Italian law.

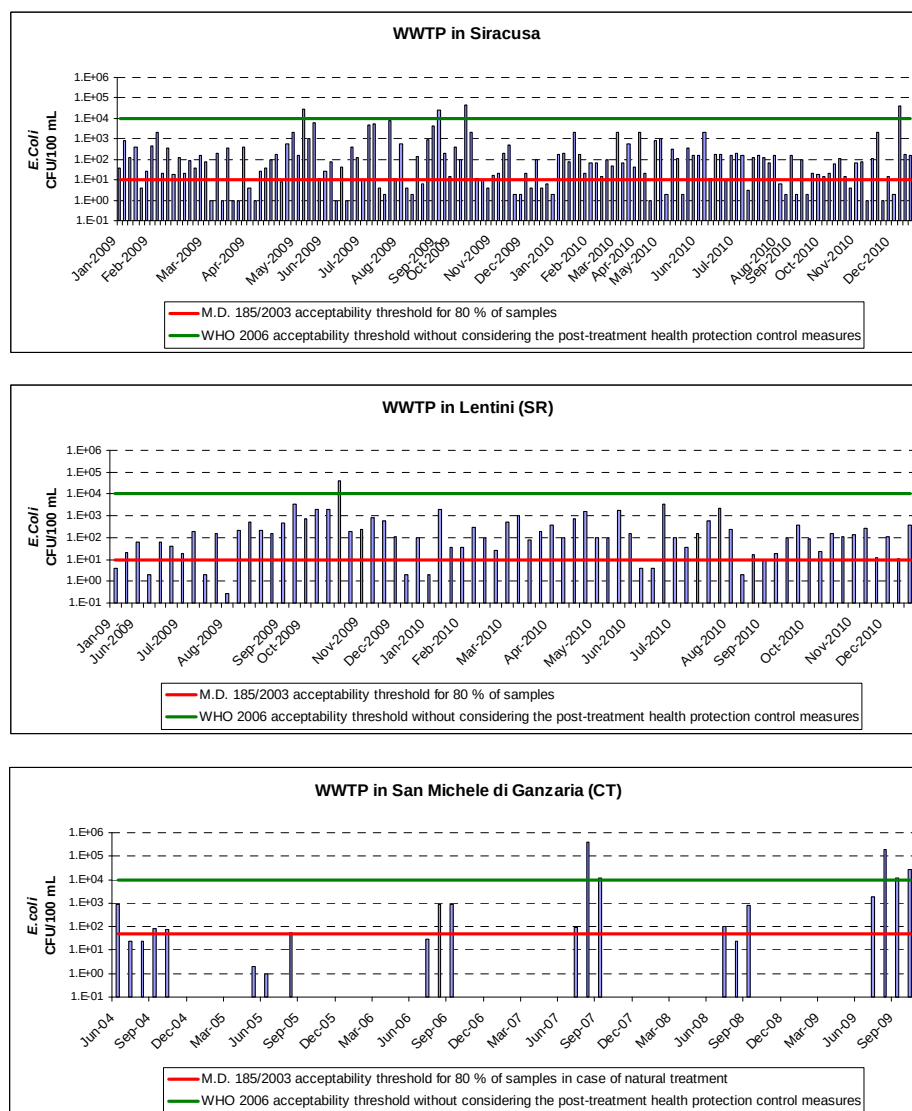


Figure 4. *E. coli* evolution observed during the monitoring periods in Siracusa, Lentini and San Michele di Ganzaria WWTPs and M.D. 185/2003 and WHO 2006 acceptability thresholds

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