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How to Overcome Barriers for Wastewater Agricultural Reuse in Sicily (Italy)?

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Abstract: This study reports an up-to-date summary of the principal barriers still limiting reclaimed water use for agriculture in Italy, and particularly in Sicily. Moreover, it provides a geographic informative system (GIS)-based procedure for evaluating the potential treated wastewater (TW) reuse in the Sicilian region as a decision support system for its management. The survey, based on possible economic, morphologic, and design solutions, evidenced a feasible integration of several wastewater treatment plants (WWTPs) with irrigation areas, allowing the water availability enhancement. Overall, the potential volume of TW by WWTPs (connected to irrigation districts) is 163×10^6 m^3 $year^{-1}$, while the water deficit is 66×10^6 m^3 $year^{-1}$. The feasibility of TW reuse in Sicily was also analysed at the light of the World Health Organization microbial risk assessment. *Escherichia coli* (*E. coli*) analyses mostly accomplished these guidelines while conflicting with the restrictive Italian standards. Despite several limiting factors (restrictive legislations, high distance and unfavourable slope between WWTPs and irrigable areas, high monitoring and distribution costs) still hamper the exploitation of reclaimed water use in Sicilian agriculture, some solutions were identified to implement this practice.

Keywords: agricultural reuse; barriers; GIS-based management; irrigation districts; Risk assessment; treated wastewater

1. Introduction

Worldwide, arid and semiarid areas have increasingly experienced water scarcity. Such regions mostly use water for agriculture and crop irrigation (up to 70% of total water extracted), relying in particular on groundwater and surface water sources [1]. To reduce stress on limited freshwater resources, non-conventional water like urban wastewater (TW), constitute an important solution for promoting and enhancing the sustainable use of the available water, as evidenced by [2]. The same authors also highlighted the great potential of TW for irrigation of agricultural fields close to urban centres, also providing a considerable input of required nutrients for plants and reducing their net discharge on sensitive surface waters. As reported by [3], among institutional and socioeconomic causes, a key drawback for agricultural TW reuse practice advancement and its public acceptance is the absence of an adequate international legislation, leading in many cases inhomogeneous quality standards and fairness issues. In fact, as mentioned by [2], and discussed in other studies [3,4], the suitability of reclaimed water for specific applications depends on its quality and usage requirements. Generally, in irrigation practices water quality controls should mainly consider factors such as salinity, heavy metals, and pathogens for minimizing any detriment to human, plants, and soils. Beyond the normative barriers, more general factors related to wastewater treatment plants (WWTPs) siting have to be considered [5]. Among those, some authors [6] reported the following: long distances between treatment facilities and agricultural demand areas; construction and maintenance costs of conveying pipe systems; necessity to store TW during fall-winter periods, since TW are continuously produced throughout the year, whereas irrigation demand is generally concentred during crops growing season of dry-summer periods. Moreover, the controversy on the possibility to estimate the true costs of freshwater supply, with respect to the intrinsic value of water [7], may consequently result in economic disadvantage for the production of recycled water.

In the attempt to develop their own recycling and reuse criteria, usually proceeding by the most advanced ones (e.g., California and Australia), Mediterranean member states, like Italy, Greece, and Spain, enforced "semiscientific" and too stringent regulations to be really applied [3]. In light of this the EU (European Union) recognized the need to implement a common water reuse regulatory instrument at the international level and it is working towards both minimum quality requirements and health and environmental risk-based policies [8]. On 28 May 2018 a "Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse" was issued [9]. However, in the perspective to adopt the new EU guidelines for reclaimed water use at the national level, many constraints will probably remain for a long time, mostly referring to physical and economic ones. In Italy, all previously described issues strongly limit the agricultural use of reclaimed water (RW). Several studies already evidenced the need to enhance TW sustainable reuse and to promote management plans for available water resources in Sicily [10–12]. The same authors in fact discussed how, in Sicily, relevant irrigation demand [12] is not satisfied mainly because of the increasing drought periods, the impairment of water body quality, and the rising civil demand.

Among the aforementioned legislative limitations, the restrictive Italian standards [13] lack of quality guidelines for diversified agricultural reuse sectors and a microbiological risk-assessment approach in line with the World Health Organization [14], but present a list of overabundant water quality parameters (e.g., chemical and microbiological compounds) to be analysed [15], with consequent high monitoring costs, mainly for small treatment facilities (Figure 1). Additionally, total costs for developing TW reuse in agriculture are not sustainable and user-friendly when considering the construction, operation, and maintenance of "additional" processes for tertiary and disinfection treatments and RW distribution networks.

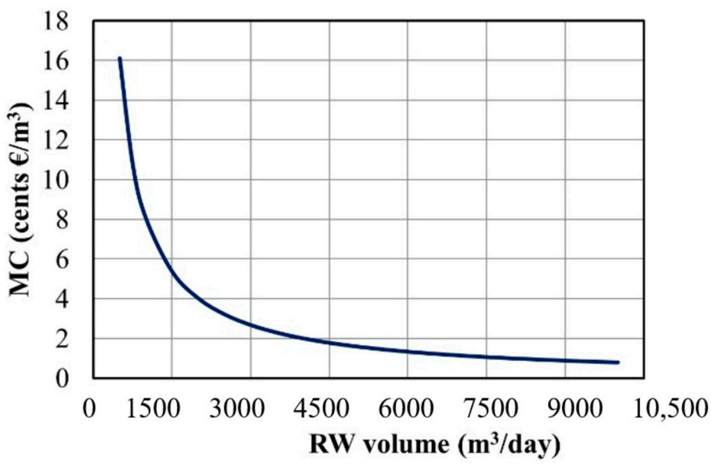


Figure 1. RW monitoring cost (MC) vs. RW volume.

The aims of this study are:

1. To evaluate the factors hampering the RW agricultural use spreading in Sicily;
2. To provide a GIS-based procedure for evaluating the effective potential of RW use in the Sicilian region as a decision support system for its management; and
3. To ascertain feasible possibility of RW use in Sicily, with regard to RW physico-chemical and microbiological characteristics. In particular, the restrictive Italian microbial standards for reuse [13], were compared with the findings of the World Health Organization (WHO) microbial risk assessment [14].

2. Materials and Methods

2.1. WWTPs in Sicily

The Sicilian WWTPs scenario herein presented is an up-to-date survey of the previous one reported in [12]. With respect to the 259 WTTPs in operation in the early study, more treatment facilities are herewith reported (Table 1), with a total of 459 urban WWTPs, enclosing also those not in operation and planned.

Table 1. Classes of WWTPs for P.E.

P.E.	Wastewater Treatment Plants		
	In Operation	**Not in Operation**	**Planned**
<2000	87	31	19
2001 ÷ 5000	80	17	9
5001 ÷ 10,000	77	11	4
10,001 ÷ 100,000	95	11	7
>100,001	9	1	1
Total	348	71	40

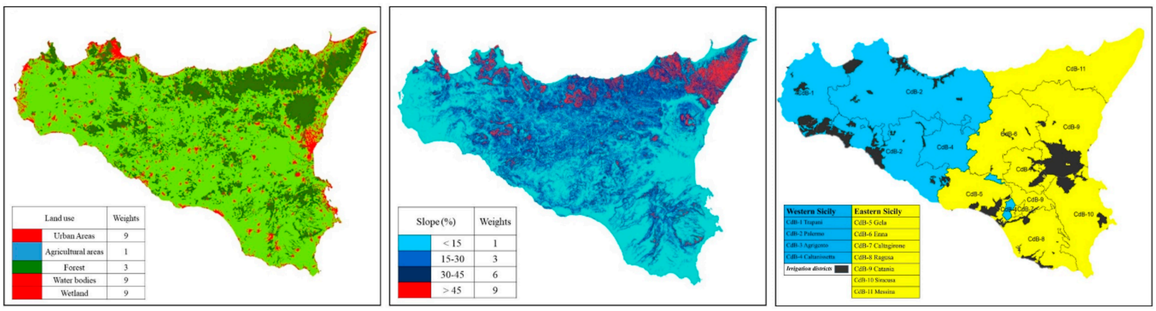
Most of the WWTPs in operation (70%) treat wastewater of communities lower than 10,000 P.E. (person equivalent), only 3% serve urban communities greater than 100,000 P.E.; while more than 47% of the planned WWTPs serve communities with P.E. lower than 2000. A certain discrepancy is detected between the hydraulic load capacity of the existing WWTPs (of about 320 $\times$ 10^6 m^3) and the produced volume of TW (about 222 $\times$ 10^6 m^3). Regarding the location of WWTPs, 93 systems are in the province of Messina (North-Eastern Sicily), 73 in the province of Palermo (Western Sicily), 33 in Trapani (Northwestern Sicily), 40 in Agrigento (South-Western), 15 in Siracusa (Southeastern Sicily) and 31 in Catania (Eastern Sicily). The treatment processes consist of: preliminary treatments, employed in 314 of the Sicilian WWTPs, primary sedimentation, used in 303 of the WWTPs, activated sludge process, the most common type of secondary biological process, covering about 83% of the systems; the trickling filter technology covers 20.5% of WWTPs. Tertiary treatments, such as coagulation-flocculation, and micro-filtration processes are applied for 30% of the systems, treating wastewater for communities greater than 10,000 P.E, and the secondary sedimentation process is operated in 55.4% of WWTPs. Most of the analysed systems discharge into neighbouring rivers. Chemical-physical and bacteriological data on existing WWTPs were available just for a limited number of study cases. Data easily available consist of biochemical oxygen demand (BOD_5, mg L^{-1}), chemical oxygen demand (COD, mg L^{-1}) and total suspended solids (TSS, mg L^{-1}). Analyses of available data evidenced BOD_5 concentrations generally below the threshold of 25 mg L^{-1} fixed by the Italian law [16], BOD_5 concentration within the range of 25–50 mg L^{-1} in 34% of $WWTP_s$ under study and concentrations over this range for 31% of the systems. COD values were below the Italian law fixed limit of 125 mg L^{-1} in 73% of WWTPs; in the 22% of the systems COD was in the range of 125−350 mg L^{-1}, and only 5% of the studied cases highly exceeded the Italian threshold fixed for discharge in water bodies. In 49% of WWTPs, TSS was below the limit of 35 mg L^{-1} fixed by the mentioned standards; 23% of the systems reported TW within the range of 35–70 mg L^{-1} and the remaining 28% greatly exceeded the fixed limit.

Above discussed chemical-physical data revealed a weak pollutants removal capacity for the surveyed WWTPs; it is, thus, necessary enhancing the efficiency of these systems by introducing natural treatment systems, such as constructed wetlands and storage reservoirs.

2.2. GIS Approach Description

A regional scale GIS-based procedure was implemented according to the methodology described in [12]. The input data were:

- Land use/land cover data [17] (scale: 1:100.000); land uses were classified into five general categories: urban areas, agriculture areas, forest and semi-natural area, open water bodies and wetlands. Most of the mapped area is 'Agriculture' (69%), being 'forest and semi-natural' the second land use (26%). 'Urban areas', 'water bodies', and 'wetlands' habitats contribute to the remaining land surface area (Figure 2a).
- 20-m resolution DTM (digital terrain model) [18] (Figure 2b);
- Characteristics of the Sicilian "irrigation public agency" (from now on named as Irrigation Consortia (IC)) (source: specific surveys at the IC); In Sicily, the water for agriculture use is mainly supplied by 11 IC, divided into Eastern IC and Western IC, with a total of 37 irrigation districts (Figure 2c). The Sicilian region, through the IC, promotes and organizes reclamation actions for water resources and environmental defence, the conservation, the valorisation, and the protection, as well as for the development of territory and the agricultural production. The irrigation area extent is about 18×10^4 hectares, of which 7×10^4 hectares are actually irrigated. Irrigation resources are manly derived from artificial reservoirs, providing about 160×10^6 m^3 per year. Actually, 31 artificial reservoirs supply Sicilian irrigation networks; 3 new reservoirs are under construction and they will provide an extra water resource of about 107×10^6 m^3 per year. For each district, irrigation demand was derived by multiplying the actual irrigated area (ha) and the water volume (m^3 ha^{-1}) fixed by the IC for each crop during the irrigation season. By comparing the water volume availability with irrigation demand, the annual water deficits/surplus were determined for each district [12];



(a) (b) (c)

Figure 2. GIS-reclassified land use map (**a**); slope map of Sicily (**b**); and IC plus irrigation districts (**c**).

Data were geo-referenced at the same projection (WGS84-UTM zone 33N) and integrated with GIS spatial overlay analysis functions. TW coming from WWTPs in operation were attributed to the corresponding irrigation district with the aim to integrate its collective (by IC) water resources.

A step forward consisted on the definition of a feasibility study based on elevation and land use characteristics at Sicilian regional scale. Therefore, within GIS tools, the "cost-distance" [19] function was applied for connecting WWTPs to the irrigation districts on the basis of the nearest distance (Figure 3).

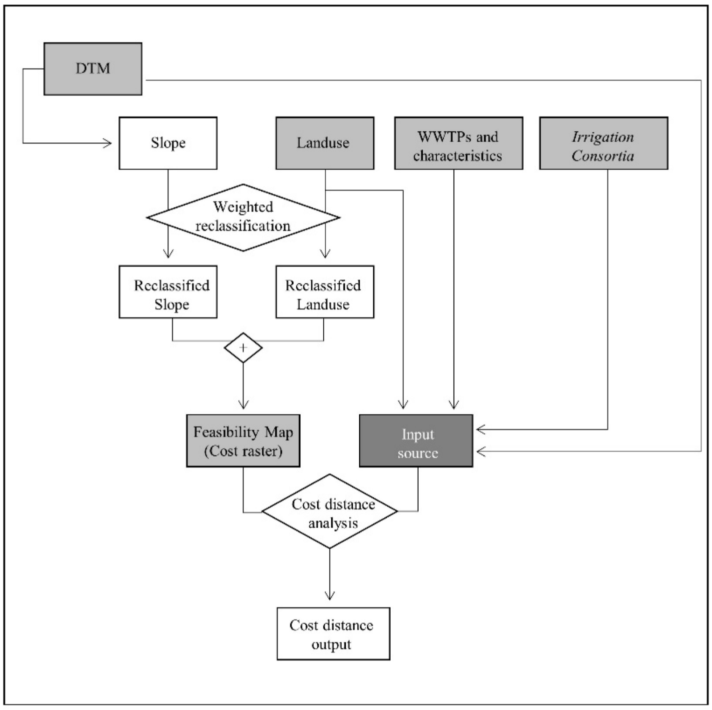


Figure 3. GIS spatial analysis and the cost-distance procedure scheme.

The hypothesis for building a feasible irrigation distribution networks connecting WWTPs with irrigation districts was conditioned by a maximum acceptable slope of 45% (Figure 2b, obtained by a DTM reclassification); the mean elevation of the irrigation districts was defined as the mean elevation of the image pixels falling into each irrigation area. The adopted rules implied also that each WWTP in operation, supplying communities higher than 5000 P.E., was assigned to just one irrigation district. Furthermore, D was the minimum GIS-based distance accordingly to the landscape morphology and the presence of natural obstacles (lakes, urban areas, etc.). On the basis of the different categories of land coverage to be crossed by the distribution networks and depending on the most favourable rout, an economic assessment of pipeline construction can be done.

In order to take into account only significant treatment systems and feasible solutions, WWTPs were selected for TW reuse accordingly to the below reported criteria:

1. served communities greater than 5000 P.E., with a corresponding flow rate of about 10 L s^{-1} considering 150 L $P.E.^{-1}$;
2. maximum distance (D) between WWTP and the nearest irrigation district according to the potential volume (Q), as:
   - $D \leq 5$ km if 10 L $s^{-1} \leq Q < 15$ L s^{-1};
   - 5 km $< D \leq 10$ km if 15 L $s^{-1} \leq Q < 30$ L s^{-1};
   - 10 km $< D \leq 20$ km if $Q \geq 30$ L s^{-1};
3. TW, exceeding the irrigation request of the nearest district, may be shared between neighbouring IC, exhibiting water deficit conditions; and
4. WWTP elevation higher than the mean elevation of the irrigation district or WW pumping (ΔH) up to 50 m.

When ΔH was over the fixed limit of 50 m, the reuse possibility was evaluated case-by-case, depending on the relevance of the WWTP under study and the presence of areas, within the same district, with altitudes lower than the limit.

2.3. Microbiological Analysis of TW

In the study, particular emphasis was given to microbiological concentrations found in TW to evaluate the potential risk assessment; to this end, on selected WWTPs, having a minimum dataset of available microbiological data, *E. coli* concentrations were analysed by comparing the quite restrictive Italian approach for TW reuse [13] and WHO guidelines [14]. Briefly, the latter is based on a tolerable maximum additional burden of disease of one million of a DALY loss per person per year (1×10^{-6} DALY loss pppy). According to the adopted approach [12], the model exposure scenario of 'unrestricted irrigation', based on the consumption of TW-irrigated lettuce [20,21], was considered. The selected scenario corresponds to the controlled use of TW to grow crops that are normally eaten raw. For this scenario, results of quantitative microbial risk analysis-Monte Carlo simulation show that the required rotavirus reduction (the pathogen with the highest infection risk compared to the other two pathogens selected in the WHO guidelines) from TW to lettuce ingestion is of 6 log units. This total reduction is achieved by both wastewater treatment and a selection of post-treatment health-protection control measures (i.e., low-cost drip irrigation techniques, pathogen die-off, produce washing and peeling, etc.). If at least 2–3 log unit reduction due to rotavirus die-off between the last irrigation and consumption is considered, TW with *E. coli* concentration up to 1×10^4 CFU 100 mL^{-1} are associated with an acceptable median infection risk for rotavirus infection of 10^{-3} pppy [14,22–25].

3. Results and Discussion

3.1. GIS Results on Wastewater Reuse

In Sicily, a large amount of wastewater is treated in WWTPs of small–medium size (i.e., 244 WWTPs are below 1×10^4 P.E. and 95 under 1×10^5 P.E.). The mean annual volume of TW (about 222×10^6 m^3) is around 30% of the irrigation water yearly requested by the IC (about 750×10^6 m^3); TW volume could reach 340×10^6 m^3, corresponding to the available design capacity of these systems. Table 2 summarizes at IC basis the potential of RW use for irrigation purpose in Sicily.

Table 2. Potential availability of TW at the consortium level.

Irrigation Consortia	Mean Altitude (m a.s.l.)	DS * (10^6 m^3)	WWTP (#)	Annual TW Volume (10^6 m^3)	MinD (m)	MaxD (m)	Mean ΔH (m)
CB1-Trapani	59.3	4.4	4	11.8	20	2745	36.6
CB2-Palermo	311.0	5.3	21	46.6	0	15,719	53.9
CB3-Agrigento	214.1	6.1	16	12.8	0	5193	40.8
CB5-Gela	155.2	0.9	6	5.7	0	14,723	22.7
CB6-Enna	343.0	0.8	7	5.8	369	16,651	0.0
CB7-Caltagirone	145.7	−0.5	3	6.9	1460	4380	0.0
CB8-Ragusa	106.5	−7.3	12	20.2	0	14,647	62.0
CB9-Catania	181.4	42.9	7	33.0	40	13,712	22.3
CB10-Siracusa	56.6	13.1	5	19.4	508	15,831	43.6
CB11-Messina	537.6	0.1	1	0.6	5280	-	0.0
Total		**65.8**	**82**	**162.8**			

* DS: annual water deficit (+) or water surplus (−).

Within each IC, data were analysed at the irrigation district level (data not shown). Within the WWTPs database, only those systems satisfying the selected criteria were analysed. Among 37 existing irrigation districts, 25 resulted eligible for receiving TW coming from 82 WWTPs in operation (Figure 4). For the remaining areas, no feasible design or economical solutions were defined, showing these areas a limited water deficit, corresponding to about 5% of the water demand.

Within the CB2 of Palermo (Western Sicily), the San Leonardo district shows the highest number of WWTPs (14) that could be connected with; other significant cases are in the districts of Scicli (CB8 Ragusa) with eight WWTPs, Garcia-Arancio (CB3 Agrigento) with seven WWTPs, and Salso-Simeto-Ogliastro (CB9 Catania) with six WWTPs supplying resources. The remaining areas within each IC are potentially supplied by WTTPs in a number ranging from 1–5. The maximum distance (D) between the selected WWTPs and the irrigation districts varied from zero to 16.6 km.

The analysis revealed a potential volume of TW coming from plants connected with irrigation districts of 163 × 10^6 m^3, and a deficit of water resources of 65.8 × 10^6 m^3.

The IC of Ragusa and Caltagirone seemed to be able to completely meet the water demand for irrigation. In these cases, water surplus could be eventually used to enlarge the irrigated area, to save high quality water for other uses (civil, environmental, etc.) or to avoid aquifer overexploitation. Notwithstanding the high volume of TW that could be used in the CB9 of Catania, its water deficit remains quite high. In the case of CB9-Catania, the treated volume could be increased up to 48 × 10^6 m^3 $year^{-1}$ with the ongoing revamping of Catania WWTP.

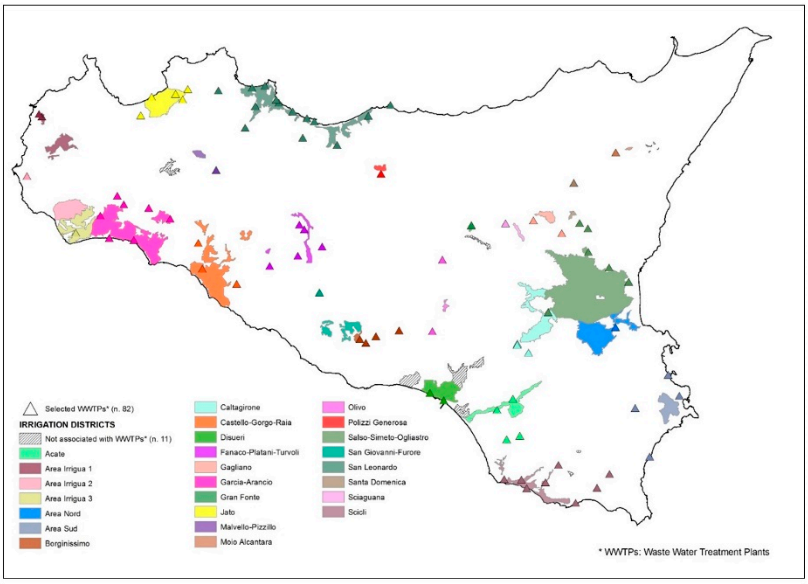


Figure 4. Irrigation districts and the corresponding WWTPs. Same colours indicate WWTP and the irrigation district associated with.

3.2. Results of the Risk Assessment Analysis for Selected WWTPs in Sicily

For 11 WWTPs, the health risk associated with the use of TW was analysed by following the referred WHO DALY tool [14]. The systems are located in Siracusa, Lentini, San Michele di Ganzaria, Giarre-Riposto, and in Caltanissetta Province (Bompensiere, Gela, Mazzarino, Mussomeli, Riesi, Serradifalco, Villarmosa, Villalba). Figure 5 reports *E. coli* data from the WWTPs by comparing the 2006 WHO guidelines and the Italian legislation (M.D. 185/03) [13] thresholds. The percentage of samples showing *E. coli* count lower than the Italian threshold of 10 CFU 100 mL^{-1}, requested for 80% of samples, was up to about 20% for all the selected WWTPs (being null for Caltanissetta Province and 14% and 19% for Lentini and Siracusa WWTPs, respectively). In the WWTP of S. Michele di Ganzaria, 23% of samples had *E. coli* lower than the Italian threshold of 50 CFU 100 mL^{-1}, required for 80% of samples in the case of natural treatments (i.e., in this case WWTP is integrated with constructed wetlands for tertiary treatment). In this system, 33% of samples had *E. coli* above the value of 10^4 CFU 100 mL^{-1} fixed by WHO in 2006 for the 'unrestricted irrigation' scenario; the WHO limit is intended for reaching a median design risk for rotavirus infection of 10^{-3} pppy, considering a 2–3 log units reduction due to rotavirus die-off between the last irrigation and harvest. On this regard Aiello et al. [26] evidenced, in fact, that although *E. coli* content of TW is over the limits set by Italian law, the hygienic quality of the irrigated product (i.e., herbaceous crops) can be preserved, according to the WHO. Similar results were obtained by [27], which reported values of *E. coli* concentration up to 80 CFU 100 g^{-1} for drip and sub-drip irrigated eggplant by FW.

In the other WWTPs the percentage of samples below the WHO limit decreases to 1.3% for Siracusa, 1.4% for Lentini and was null for the remaining systems.

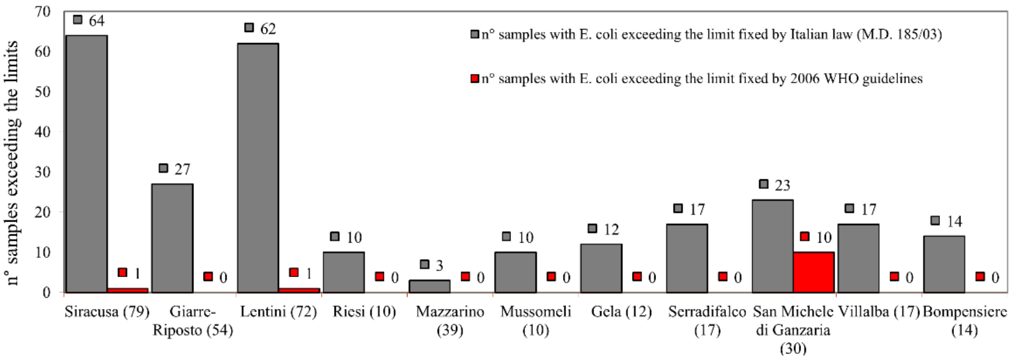


Figure 5. Percentage (%) of samples with *E. coli* concentration exceeding/lower than the limit fixed by the Italian law (M.D. 185/03) [9] (**left**) and by 2006 WHO guidelines [10] (**right**) for the selected WWTPs in Sicily. WWTPs in decreasing PE order and with the number of total samples in brackets.

Within the database of WWTPs, used in the study to assess the potential of the reuse practice in Sicily, 14 systems were analysed in terms of physical and chemical quality of the produced TW. Table 3 summarizes these results, showing the mean annual values of the pollutant concentrations.

In particular, during the monitored period 2010–2013, the percentages of samples exceeding the standard limits [13] (i.e., TSS: 10 mg L^{-1}) varied between 25% (Enna WWTP) and 100% (Gela, Riesi, and S, Michele di Ganzaria WWTPs); in the mean of the systems, TSS was over the limit for 73% of the analysed TW samples. 19% of the samples collected from the analysed WWTPs exceeded the threshold fixed for COD (i.e., 100 mg L^{-1}); the maximum was reached in the Bompensieri (CB5) WWTP with 53% of samples. On the average of the WWTPs, 23% of samples exceeded BOD_5 limit (i.e., 20 mg L^{-1}), with a maximum (50%) in the Giarre-Riposto WWTP.

The analysed Sicilian WWTPs showed fairly high percentages of samples exceeding the limits imposed by the Italian legislation for TW reuse on chemical and physical compounds. In particular, high TSS concentrations may affect the performance of the irrigation network in case of direct RW use for agriculture. To enhance TW quality characteristics, efficient cost/benefit solutions should be provided by improving the disinfection phase in existing treatment processes or introducing new eco-sustainable treatments, like natural systems. Some authors [28] found that the percentage of samples below the Italian threshold of 50 CFU 100 mL^{-1}, raised up to 67% and 80% by using two WW treatment options with different equipment after the constructed wetland system, the first, a natural-based solution, including a biological pond, a storage reservoir and sand and disk filters and the second, including an ultraviolet system besides sand and disk filters. Both options ETTS allowed to match WHO guidelines (2006) for the "unrestricted irrigation" scenario, as well as the B quality class as defined in the proposed European Directive on water reuse [9]. Moreover, *E. coli* contamination on tomato and eggplant never reached significant values by using WW by both option systems. Based on several experiences in different Mediterranean countries, it is expected that rapidly expanding water-recycling practices will quickly provide sustainable, low-energy, and cost-effective options to improve water availability based on criteria of quality and recycling capacity [29] but to provide a more comprehensive understanding of the health risks of wastewater use in agriculture, future research should consider multiple exposure routes, long-term health implications, and increase the range of contaminants studied, particularly in regions heavily dependent on wastewater irrigation [30].

Table 3. Chemical-physical characteristics of selected $WWTP_s$ in Sicily.

Selected Sicilian $WWTP_s$	Mean Values of Chemical-Physical Compounds in the Effluent of $WWTP_s$			Percentages Effluent Samples over the Limits (%)		
	TSS ($mg\ L^{-1}$)	COD ($mg\ L^{-1}$)	BOD_5 ($mg\ L^{-1}$)	TSS	COD	BOD_5
Villalba (CB5)	14	80	16	61	6	11
Mussomeli (CB3)	16	96	17	90	40	0
Bompensieri (CB5)	17	90	15	87	53	13
Serradifalco (CB5)	14	76	12	67	0	0
Gela (CB5)	19	94	17	100	46	38
Riesi (CB5)	18	89	16	100	10	0
Giarre-Riposto (CB9)	10	17	5	48	50	50
S. Michele Ganzaria (CB7)	21	28	19	100	13	35
Ragusa Consortium (CB8)	42	85	21	98	2	48
Ragusa Municipality (CB8)	31	66	23	90	0	33
Scicli-sea (CB8)	19	29	10	38	0	19
Assoro-Leonforte Consortium (CB6)	10	71	17	31	23	31
Enna (CB6)	7	47	10	25	0	32
Siracusa (CB10)	19	79	20	80	25	13
Mean values	**18**	**67**	**16**	**73**	**19**	**23**

3.3. Barriers Limiting TW Reuse in Agriculture

TW reuse in agriculture involves a careful evaluation of regulatory, socio-economical, health-safety protection, agronomic, and technical features, which makes even the most rigorous management approach very complex. As formerly evidenced [15], the Italian standard limits for water reuse [13] enclose 54 parameters to be monitored for TW quality assessment, 20% of which are the same fixed by the regulation for water human consumption (L.D. 31/2001) [31] while 37% are neither considered by the same law. The microbiological limits are also so restrictive to be in line with a zero risk approach. Moreover, different alternatives among which urban non potable, industrial and agricultural TW reuse are not accounted. Similarly, no attention is paid to differentiate between restricted and unrestricted irrigation (and the crop types), as well as among the irrigation options (drip irrigation, spray irrigation, etc.).

Temporal and spatial gaps, constituted respectively by the need for TW storage during the cold seasons and the WWTPs siting with respect to the irrigation areas open to important criticisms. In the first case, the six dry months of irrigation demand require reliable reservoirs for maintaining desirable quality effluent, since the storage systems could “rarely act as perfectly mixed reactors” [15]; in the second case treatment facilities are usually too distant and altimetrically unfavourable with respect to the eventual water distribution pipelines connected to the interested areas. The Italian law establishes that the additional costs (including operation and maintenance costs) related to reuse of wastewater treatment burden on citizens, while distribution and monitoring costs burden on the final users (farmers, golf courses, etc.). This is a hampering factor for the development of TW due to the fact that the users do not have direct benefits by reusing treated wastewater, but water tariff has to be increased to recover the water reuse costs (exceeding the actual mean of 0.13 €/m^3 for water supplies faced by farmers) [32].

Under these conditions, the total cost requested for reclamation, since the construction phase, to operation and maintenance ones, in addition to the costs for water distribution and reuse system monitoring, might result hardly determinable and really sustainable just for large WWTPs.

At the light of these considerations the key problems to be focused on are:

1. the reliability of the "offer" (based on a strengthened quality control system for incoming wastewater to the sewerage system);
2. the need to guarantee the TW quality (WWTPs efficiency and the adoption of effective refinement treatments); and
3. the certainty of the "demand" (based on TW reuse economic convenience for integrating or replacing conventional waters, and promoting reward and tax relief systems for users’ benefits).

In spite of all these barriers, perhaps, in Italy and in particular in Southern regions, TW cannot be considered an additional water resource, and their indirect reuse is widespread in many agricultural areas. Treated and untreated wastewater are in fact discharged into water bodies and taken further downstream for irrigation (in many cases only partially diluted with conventional waters).

Several strategies can be promoted to increase the effective reuse of urban TW. Among those, the collection and reuse of TW produced in urban cities located along the coasts, as well as in small and medium-sized urban sites all over the country. On this regard, meaningful examples can be found in Sicily, where about 80% of the population lives on the coastline, and about 70% of urban centres (such as in the rest of Italy) have a population of less than 1×10^4 inhabitants; all of these generally discharge into surface water bodies or directly into the sea. Additionally, the role of wastewater reservoirs, especially for small and medium urban cities located in the internal areas, can be central within a general water resources management and a wastewater reuse policy (more attention should be paid to reservoirs design, operations, and removal efficiencies). The zero risk approach for managing the health-safety issue in TW reuse, must be reconsidered because economically unsustainable, and specific interventions for minimizing the risk of infections could be adopted passing throughout accurate pre and post-harvesting microbial reduction procedures, as also suitable irrigation management and techniques depending on the specific crops.

Since the complex Italian legislation requires a strict control and monitoring of the TW reuse systems with a consequent increasing of the costs, potential users should rely on the support of private or public agencies. In fact, the Italian Irrigation Consortia should have a fundamental role in promoting the reuse of TW in relation to their legal and technical expertise.

4. Conclusions

The proposed GIS-based procedure confirmed its validity as a useful decision support system in TW reuse management. The implemented cost-distance spatial analysis allowed to evaluate a possible and desirable integration of WWTPs with the Sicilian collective irrigation districts, in order to increase water resources for the crop water demand fulfilment and to move conventional water resources to other uses (civil, environmental, industrial), substantially reducing water shortages. Overall, the potential volume of TW produced by the plants connected to irrigation districts is 163×10^6 m^3 $year^{-1}$, while water deficit is 66×10^6 m^3 $year^{-1}$. The feasibility of TW reuse in Sicily was also analyzed at the light of the microbiological risk potentially induced; data on *E. coli* concentrations were, in most of the analyzed cases, below the limit fixed by WHO for the contamination diffusion through the ingestion of products eaten raw. The results of the microbiological quality conflict with the more restrictive rules imposed by the Italian legislation, that may be revised also in this sense. Additionally, chemical-physical data did not fulfil the stringent national standards, particularly in the case of TSS, confirming the need to improve the actual treatment facilities with more effective tertiary conventional technologies or natural treatment systems. The work evidenced the strategic role that could be played by the IC for reclaimed water use implementation in Sicily. However, to this aim, the economic framework should be carefully evaluated for each district in order to select, among different reuse projects, those with the greatest potential for success and to better allocate public funds.

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