

Contribution of non-conventional technologies for sewage treatment to improve the quality of bathing waters (ICREW project)

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Abstract

The new EU *Bathing Water Directive* (2006/07/EEC) suggests that for a better management of the quality of these waters is necessary to be established the coordination with others directives such as *The Urban Wastewater Directive* (71/271/EEC) aiming the adequate treatment of the urban wastewater.

Within the framework of the interregional European project “ICREW: Improving Coastal a Recreational Waters” nine small-scale wastewater treatments plants and a wastewater experimental plant in small rural areas were investigated in order to evaluate their effectiveness for treating municipal effluents. Suspended solids, organic matters and microbiological pathogen (*E. coli* and intestinal Enterococci) parameters were monitored during 12 months. Sewage treatment plants based on non-conventional and conventional technologies located in Occidental Andalusia and Canary Islands were compared.

Most of the treatment plants monitored present a BOD₅ and COD removal values higher than those established in the Directive 91/271/EC. The pathogen removal rates varied from one technology to another, fluctuating between 1.0 and 3.5 log units. The higher *E. coli* (more than 2 log units) and intestinal Enterococci (more than 3 log units) were achieved for Constructed Wetland, Stabilization Ponds and Rotating Biological Contactors with Sand Filters or Peat Filters. An entitled guide “Guideline of urban wastewater treatments for small communities” has been produced. The aim of this guide is to support the decision-making process in public or private organizations when selecting sewage treatment technology to obtain the final effluent quality required.

Keywords: Wastewater treatment; Bathing waters; Pathogen removal; Non-conventional and conventional technologies; Guideline

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1. Introduction

The impact of sewage on water quality is well known. Since the implementation of the EC Bathing Waters [1] and Urban Wastewater [2] Directives there has been substantial investment by all European member states in the improvement of existing and the provision of new, collective sewage systems and treatment plants. Inland and coastal water quality has improved as a result of this investment. Although there are numerous communities where their sewages are treated, there are still a lot of villages and sparse communities lacking Wastewater Treatment Plants (WWTP) or there are lots out of WWTP malfunctioning.

Even those plants producing an effluent of reasonable quality can often have a significant impact on bathing waters, whether coastal or inland. Collective systems with sewage pumping stations can malfunction, allowing untreated sewage to discharge and causing water quality problems, mainly algal growth due to excessive nutrients or bacteriological affecting Bathing Water Directive compliance. The control of diffuse sources of sewage pollution is of increasing importance particularly with a recent published new Bathing Waters Directive [3], with higher bacteriological standards, expected to be implemented in the next few years.

The ICREW (Improving Coastal and Recreational Waters) project was established in April, 2003, under the auspices of the Interreg III-B programme for the Atlantic Area of Europe. Led by the United Kingdom Environmental Agency, it also involves another 18 partners from across Spain, France, Ireland, Portugal and the United Kingdom. This is a 3-year project funded with a total of 8.6 million euros. The central objective of ICREW is to raise standards, help to implement the new Bathing Water Directive and contribute to the European Water Framework Directive [4], promoting pollution reduction and improving recreational waters in the different areas of the Atlantic Area. The Spanish's partners involved in

ICREW were the New Water Technologies Center (CENTA) and the Canary Islands Institute of Technologies (ITC). The aim of the activities performed by CENTA and ITC has been to evaluate the removal performance of pathogenic microorganisms (*E. coli* and intestinal Enterococci) and nutrients obtained with different small-scale, conventional and non-conventional, wastewater treatment technologies. It seeks to establish the most efficient methods for treating the wastewater in small communities and to contribute to reduce pollution problems thus facilitating social and economic development throughout the whole of these areas.

The search for appropriate technologies for rural areas is becoming more and more important in Europe due to the Urban Wastewater Directive [2] which forces communities below 2000 inhabitants equivalent to treat their wastewater. In the specific case of the autonomous region of Andalusia, 85% of its population have less than 2000 inhabitants [5]. For instance, in the autonomous region of Canary Islands, 83% of its populations have less than 2000.

In Spain, experience has shown that in small towns where economic and technical resources are often limited, there is a large number of WWTP that either do not work at all or malfunction [6]. The effectiveness of these small works is variable, and most of them provide an effluent of secondary treatment. Many are operated by unskilled personnel and some are poorly maintained. Better management is required to reduce water pollution.

Small towns and villages, where a lack of economic resources and trained personnel has a huge impact on the choice of treatment technology to be installed for wastewater, tend to aim at guaranteeing an effective operation in spite of large flow and load fluctuations, reducing energy consumption to a minimum, simplifying operation and maintenance processes and managing the sludge generated in the process. Therefore, the use of what are known as “*non-conventional*

technologies” could be a valid alternative for meeting these requirements [7].

2. Methodology

2.1. Evaluation of small treatment systems

An inventory of small-scale wastewater treatment systems in Andalusia (520) and Canary Islands (310) was done to evaluate the performance of the existing treatment plants with the collaboration of Andalusian Regional Ministry of Public Works and Transport and Water Island Councils.

2.2. Wastewater treatment plants selection

Nine sewage treatment plants and one experimental treatment platform (Experimental Plant of Carrión de los Céspedes: PECC) were selected for monitoring, based on a previous WWTP inventory done in each region. The name, location and characteristics of each selected WWTP are shown in Table 1. The initial selection criteria

were the degree to which the technology was representative, and its possible impact on recreational or bathing areas.

The WWTP located in Andalusia are non-conventional technologies, since the percentage of non-conventional sewage treatment plants in this region is 59%. Conventional technologies have largely been included in Canary Islands. Since Extended Aeration represents 70% of these facilities in this region, several types of WWTP have been selected in this study.

2.3. Sampling and analysis

Wastewater samples from influent and effluent of each WWTP were collected fortnightly during 1 year (2004–2005) and analysed according to Standard Methods [8] and to International protocols [9,10]. The measured parameters were pH, electrical conductivity (EC), dissolved oxygen (DO), total suspended solids (TSS), COD, BOD₅, N-NH₄⁺, total Kjeldahl nitrogen (TKN), and total phosphorus (TP) and the microbiological

Table 1
Urban WWTP and technologies studied within the ICREW project

WWTP	Island/Province	Technology	N° inhab-equiv.
La Coruña	Gran Canaria, CI	Extended Aeration	100
El Risco	Gran Canaria, CI	Extended Aeration	500
Casa Aguilar	Gran Canaria, CI	Extended Aeration	500
San Juan Rambla	Tenerife, CI	Extended Aeration	500
AENA Lanzarote	Lanzarote, CI	Rotating Biological Contactors	1650
Setenil de Las Bodegas	Cádiz, A	Peat Filters	3300
Cumbres Mayores	Huelva, A	Anaerobic Ponds + Trickling Filter	2820
Higuera de la Sierra	Huelva, A	Stabilization Ponds	2000
Lantejuela	Seville, A	Stabilization Ponds	3500
Carrión de los Céspedes	Seville, A	Peat Filter	450
Experimental Plant (PECC)		Stabilization Ponds	400
		Rotating Biological Contactor	100
		Anaerobic Pond + Trickling Filter	100
		Artificial Wetland	10

CI: Canary Islands; A: Andalusia.

parameters of *Escherichia coli* and intestinal Enterococci.

In Andalusia, sampling for physico-chemical analyses followed an integrated system. The samples were examined as soon as they had been obtained for pathogens. In the Canary Islands, samples both for physical-chemical and microbiological were taken when the sewage treatment plants were operating at the highest flow rates between 9.00 and 12.00 p.m.

2.4. Guide elaboration

At the end of the project a *Guideline for urban wastewater treatments for small communities* [7] has been elaborated and published. This guide is an instrument to support the decision-making process in public or private organizations when selecting sewage treatment technology to obtain the final effluent quality at required level.

3. Results and discussion

3.1. Evaluation of the inventoried treatment plants

The highest number of inventoried WWTP in Andalusia is in Almeria province (141 WWTP). The distribution of these WWTP by provinces and technologies (conventional and non-conventional) is shown in Fig. 1. The highest percentage of

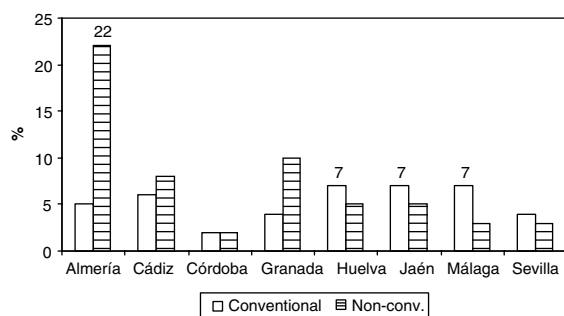


Fig. 1. Distribution percentage of inventoried wastewater technologies in Andalusia.

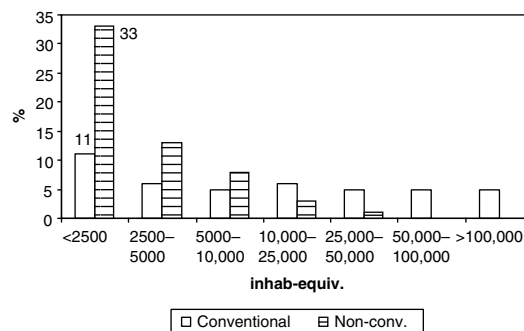


Fig. 2. Distribution percentage per population equivalent of inventoried wastewater technologies in Andalusia.

non-conventional technologies is in Almeria (22%) while the highest percentage of conventional technologies is in other provinces as Huelva, Jaén and Málaga (7%).

On the other hand, when the technology distribution is analysed by population equivalent (Fig. 2) the highest percentage of non-conventional technologies (44%) is in communities with a population size less than 2500 inhabitants equivalent, where non-conventional technologies present a percentage of 33% and conventional only 11%.

The operational status of inventoried WWTP in Andalusia is shown in Fig. 3.

Only 60% of these WWTP were operative. These values are from 2002, so that it is likely there be more operative WWTP nowadays.

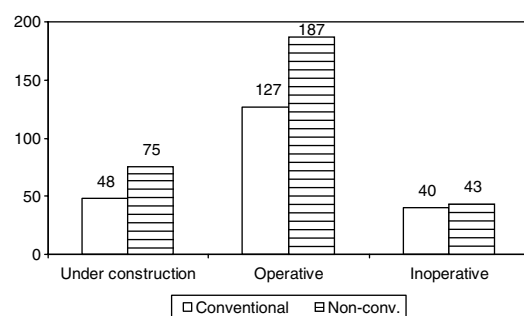


Fig. 3. Operational status of inventoried WWTP in Andalusia.

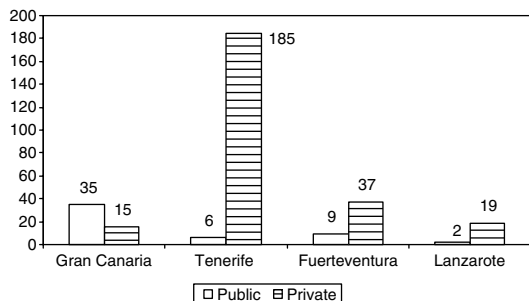


Fig. 4. Canary Islands inventoried WWTP distribution.

In Figs. 4–6, the status of the inventoried sewage treatment technologies in Canary Island is shown. The highest number of these plants is located in Tenerife (191), where is concentrated the 60% of total installations. More than 80% of these plants are privately owned. As seen in Fig. 5, the greatest treated flow is in Gran Canaria and Tenerife Islands, with a 32% and 31% of total respectively. Finally, as seen in Fig. 6, the predominant treatment technology is the Extended Aeration (70%).

3.2. Wastewater treatment plants efficiency

According to the reference values [11] for the typical composition of household wastewater, the waste treated in Extended Aeration plants during this trial is characterized by a strong and sometimes medium composition, as shown in Table 2.

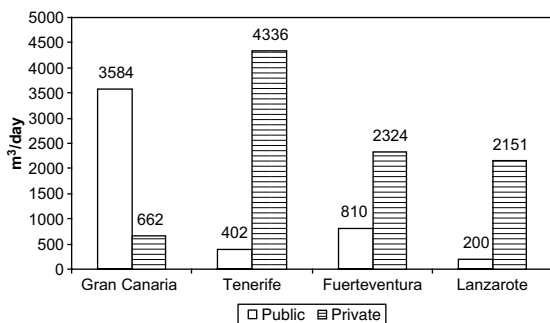


Fig. 5. Canary Islands inventoried WWTP distribution per treated flow.

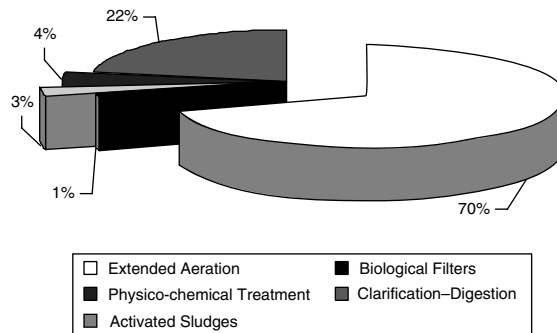


Fig. 6. Percentiles of wastewater technologies in Canary Islands.

The mean organic matter and suspended solids values are higher in Canary Islands wastewater composition than Andalusian, perhaps due to the localization of the treatment plants which are located in rural areas, with a mean population of 500 inhabitants.

Regarding wastewater treatments efficiency, although the requirements for urban treatment facilities are not applied to these plants, as established in Urban Wastewater Directive [2]. The major part of the treatment plants monitored presented a BOD₅ and COD reduction values in accord with those established in the directive, regardless of the technology employed, except for the plants at San Juan de la Rambla and Higuera de la Sierra. These anomalous values have been caused by inefficient operations as it could be checked during the visits to sewage plants.

Although a reduction in the TSS parameter is not compulsory but optional (90% reduction rate) established by the Directive 91/271/EC is only obtained in Casa Aguilar Extended Aeration plant and the Constructed Wetland in PECC. Cumbres Mayores plant and Rotating Biological Contactor in combination with Peat Filter in PECC, coming close to the required value (88–89%) (Table 2).

The microbiological quality of the influent of each WWTP is shown in Table 3. The

Table 2
Influent characteristics and sewage treatments efficiencies in Occidental Andalusia and Canary Islands plants

WWTP	Technology	Mean influent value (mg/L)*			Efficiency (%)		
		DBO ₅	DQO	TSS	DBO ₅	DQO	TSS
La Coruña	Extended Aeration (EA)	487	1148	428	87	80	74
El Risco	EA	1229	2552	635	93	87	73
Casa Aguilar	EA	1518	4527	3382	98	97	99
San Juan Rambla	EA	485	1206	346	57	58	59
AENA Lanzarote	Rotating Biological Contactors (RBC)	164	498	206	85	74	87
Setenil de Las Bodegas	Peat Filters	166	388	205	98	72	81
Cumbres Mayores	Anaerobic Pond + Trickling Filter	246	611	219	91	88	89
Higuera de la Sierra	Stabilization Ponds (SP)	196	372	97	75	54	57
Lantejuela	SP	310	667	245	87	78	73
Carrión de los Céspedes	Peat Filter	455	980	309	88	85	84
Experimental Plant (PECC)	SP				88	82	72
	RBC + Peat Filter				90	92	88
	Anaerobic Pond + Trickling Filter				94	91	86
	Constructed Wetland				94	94	90

*The values shown were obtained within a 95% confidence interval for the data range.

EA: Extended Aeration.

Table 3
Microbiological quantity of influent and removal of pathogens in the monitored treatment plants

WWTP	Technology	Influent (Log ₁₀)		Removal (Log ₁₀)	
		<i>Ec</i>	IE	<i>Ec</i>	IE
La Coruña	EA	6.8	6.3	1.7	1.6
El Risco	EA	7.0	6.4	1.0	1.2
Casa Aguilar	EA	6.8	6.4	1.4	1.6
San Juan Rambla	EA	6.5	6.1	0.7	0.8
AENA Lanzarote	RBC + Sand Filter	6.3	5.8	2.1	2.3
Setenil de Las Bodegas	Peat Filters	7.9	7.0	1.0	1.2
Cumbres Mayores	Anaerobic Pond + Trickling Filters	8.3	7.1	1.7	1.7
Higuera de la Sierra	Stabilization Ponds (SP)	8.0	6.9	1.5	2.5
Lantejuela	SP	8.5	7.2	2.4	3.2
PECC	Pit Filter	8.5	7.8	1.4	1.8
	SP	8.7	7.9	1.6	3.4
	RBC + Peat Filter	8.8	7.8	2.0	2.8
	Anaerobic Pond + Trickling Filter	8.7	7.9	1.9	3.0
	Constructed Wetland	8.7	7.7	2.8	3.5

EA: Extended Aeration.

concentrations of *Escherichia coli* (*Ec*) and intestinal Enterococci (IE) are expressed in terms of arithmetic mean of the decimal logarithms of the total counts obtained. These values do not differ from a region to another, although it is approximately one logarithm unit higher in Andalusia than in the Canary Islands.

The efficiency for pathogen removal is also expressed in terms of logarithmic units. The elimination rate for each faecal indicator varies from one technology to another. The highest pathogen removal value was obtained for the Constructed Wetland, which achieved a 2.8 and 3.5 \log_{10} reduction for *Ec* and IE respectively. The Stabilization Ponds system, combination between Anaerobic Pond and Trickling Filter, and the RBC with Sand Filter (Aena Lanzarote plant in Canary Islands) or Peat Filter (PECC in Occidental Andalusia) also achieved important reduction values, higher than 2 \log_{10} , for both faecal organisms.

3.3. Guideline about urban wastewater treatments in small populations

There are no universal solutions for wastewater treatment. Before making a decision, we have to assess the priorities, objectives and factors affecting each specific case, such as the characteristics and seasonality of the wastewater to be treated, the landscape, the power demand, final use of the treated water, etc. These factors are even more important in small areas, where the distribution of the population and the use of land condition the type of solution adopted.

With these ideas on mind the Spanish partners elaborated and published a guide entitled “Guideline for urban wastewater treatment for small communities” [7]. This guide has been designed as a tool for the people who have to decide on the type of wastewater treatment technology to be installed on a specific site. Technical recommendations for wastewater management and for the technical staff in charge of the operation

and maintenance of the facilities are included in the Guideline.

4. Conclusions

The urban wastewater composition in small rural communities in Occidental Andalusia and Canary Islands during 2004–2005 period showed that the wastewater was very concentrated (strength), however, the data obtained presented that an appropriate rate of treatment performance and the effluents of each wastewater treatment plant complied with the reduction of physico-chemical parameters as well as pathogen microorganisms (*E. coli* and intestinal Enterococci) according the Urban Wastewater Treatment Directive [2].

The final effluent of all the treatment plants monitored present *E. coli* values higher than 1000 cfu/100 mL, which is the value recommended by the World Health Organization for unrestricted use for irrigation purposes. Due to the high bacterial load of the influents, and although considerable reduction values are obtained in some of the tested technologies, the microbiological values of the effluents are very high, and this represents a serious bias if they are disposed of on the coast, in ravines or in water resources where there could be contact with humans or animals. All these facilities should have an operative and correctly maintained disinfection system to ensure that there is no health risk.

Independently from the application zone concerned, as well as the end use of the water (agricultural, recreational, etc.), the advantages of non-conventional technologies are numerous in small rural communities. Among them one could highlight their low maintenance and operational costs, high purification rates, as well as their integration with the surroundings.

With a suitable study of water quality, the number of inhabitants involved and the action area, the introduction of such technologies can effectively reduce diffuse pollution and their use

are to be considered to improve the quality of receiving waters and to contribute to a better environment and quality of life in the region.

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