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Current situation of sanitation and wastewater treatment in small Spanish agglomerations

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ABSTRACT

Since the 1st of January of 2006, all the agglomerations in the EU Member States must have a collection and treatment system for urban wastewater. The large and medium size populations were the first in being provided by treatment infrastructures, according to the 91/271/EEC Directive's schedule, meanwhile the small populations (less than 2,000 population equivalent) have been pushed into the background. One of the objectives of the Spanish Programme on Sanitation and Wastewater Treatment (2007–2015) is to address the sanitation and treatment of small populations. However, the information regarding the status of sanitation in those populations is limited and not clear. In order to moderate this lack of information, the Centre for Studies and Experimentation of Public Works and the Centre for New Water Technologies, commissioned by the former Ministry of Environment, have conducted a study based on the compilation and analysis of both diverse official documents and direct inquiries to the responsible authorities in the matter. According to the information compiled, it can be concluded that the coverage of sanitation and wastewater treatment in small Spanish populations is less than 50% and it is estimated that more than 6,000 small size wastewater treatment plants should be built in the near future where long-term solutions must be promoted.

Keywords: Sanitation; Wastewater treatment; Small populations; Spain

1. Introduction

In Spain, the construction of infrastructures for collecting and treating wastewater in urban settlements with more than 2,000 population equivalent (PE) has been priority until now, following the timetable imposed by the 91/271/EEC Directive. The actions carried out under the frame of the National Programmes for Sanitation and Purification 1995–2005 and 2007–2015, in conjunction with the associated regional programmes, have allowed to increase the Spanish level of conformity with the above mentioned Directive from 40% in 1995 to 78% at the end of 2007 (Fig. 1). The Ministry of Agriculture, Food and Environment estimates that this percentage has exceeded 91% at the moment, considering the sanitation and treatment infrastructures that are currently under construction.

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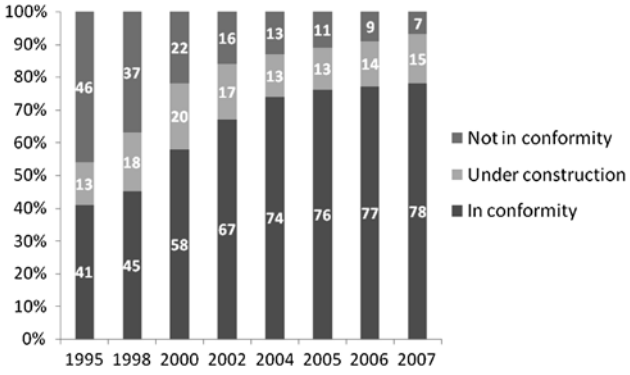

Fig. 1. Level of conformity with the 91/271/EEC Directive.

The current "National Plan for Water Quality (NPWQ): Sanitation and Purification (2007–2015)" is addressed to achieve both the objectives not concluded by the previous National Plan for Sanitation (1995–2005) and the new needs arise from the application of the Water Framework Directive (2000/60/EC) and the Programme A.Q.U.A (Actions for the Management and Use of Water). With this plan, the Ministry is pursuing the ultimate fulfilment of the 91/271/EEC Directive and contributes to achieve the good ecological status defined by the EU Water Framework Directive for 2015.

The NPWQ devotes special attention to the purification of wastewater in small urban and rural areas. In fact, one of the priorities of the above mentioned Plan is to provide with sanitation and treatment infrastructures all the small agglomerations with less than 2,000 PE. However, those agglomerations, for which the 91/271/EEC Directive calls for an "appropriate treatment", have not been sufficiently studied. To increase the awareness of the sanitation and treatment of the small populations, the Centre for Studies and Experimentation of Public Works (CEDEX) and the Centre for New Water Technologies (CENTA), have conducted a study on *"The sewage treatment in small agglomerations"*, with three basic objectives:

- The study of the current trends in wastewater treatment in small settlements and rural areas in Spain, other European countries and elsewhere.
- The analysis of the situation of R&D activities on sanitation and wastewater treatment in small populations establishing both the strengths and weaknesses on that sector.
- The establishment of guidelines for the implementation of appropriate and sustainable treatment systems for small agglomerations.

To achieve these objectives, the first step is to analyse the current state of sanitation and wastewater treatment in small agglomerations in Spain, identifying the sanitation coverage on that population range and the technological solutions commonly implemented. In this manuscript, the main results and conclusions of this analysis are exposed.

2. Methods

A revision of general literature concerning to the state and trends in the purification of wastewater in small populations was carried out initially. Concretely, that revision included the regional programmes for sewerage and purification promulgated by the diverse Spanish Regional Authorities with responsibilities in the matter, as well as the Official Reports of the Former Ministry of Environment and the European Commission. In addition, international publications and legislative documents related to wastewater treatment in small agglomerations have been consulted for depicting the general trends on small size wastewater treatment plant (WWTP), including both the different technologies implemented and the managing options.

As a key element for having an exact approach to sewage treatment in the small Spanish populations, direct information and opinions from the regional authorities with responsibilities in sanitation and wastewater treatment were collected by both questionnaires and workshops.

Specifically, the information that has been compiled with regard to the following issues:

- The regulation of sanitation and wastewater treatment in small populations, not only in Spain but also in other countries, mainly the Euro-Mediterranean ones, due to their similarities with the Spanish case.
- The PE living in agglomerations with less than 2,000 PE with sanitation coverage (including wastewater collection and treatment) in the different regions of the Spanish Kingdom.
- The PE included in current regional programmes on sanitation and wastewater treatment to be provided by sanitation infrastructures in Spain.
- The wastewater treatment technologies employed in small size WWTP, both those which are currently implemented and those listed on the sanitation and wastewater treatment programmes of the regional authorities and to be implemented in the near future.
- The managing options for the operation and maintenance (O&M) of small size WWTP.

3. Results

First of all, a revision of the legal framework for sanitation and wastewater treatment in small populations is made comparing the Spanish regulations and the ones established by other countries which are considered of interest. Later, the status of sewage treatment in small Spanish settlements is depicted indicating the level of sanitation coverage and describing the technologies implemented. Finally, a section focusing on the managing of small size WWTP is presented.

3.1. Legal framework

According to the 91/271/EEC Directive, wastewater in populations with less than 2,000 PE must receive an "appropriate treatment", which means *the treatment of urban wastewater by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives*. The inclusion of references to other legal texts and Directives and the non-definition of concrete discharge limits make the concept of appropriate treatment quite difficult to be implemented, according to the responsible authorities' opinion. When authorising the release of treated water in small WWTP, two different trends have been observed in European countries, regarding the discharge limits imposed. On one hand, some countries directly apply the same discharge limits as those laid down by the 91/271/EEC Directive for medium and large cities (>2,000 PE). That is, 125 mg/L or 75% of COD removal, 25 mg/L or 70–90% of BOD_5 removal and 35 mg/L or 90% of suspended solids (SS) removal. Spain can be included in this first group. This fact has entailed numerous legal failures since achieving the limits defined by the Council Directive, commonly, seems to be quite difficult in small agglomerations. This is due to both the lack of economic and technical resources and the problems encountered in the O&M of small WWTP, as mentioned by the authorities and operators involved in this study. On the other hand, other European countries have established a specific legislation for the regulation of wastewater treatment in small populations. France [1], Poland [2], Austria [3], Finland [4] and Denmark [5] are included in this second group. In the case of France and Poland, the required discharge limits for small populations are lower than those for the major agglomerations (the ones imposed by the EU-Directive). As an example, in Table 1, a comparison of the discharge limits of both the 91/271/EEC Directive and the French Decree concerning sewage treatment in decentralised WWTP treating more than 1.2 kg BOD_5/day (*Arrêté du 22 juin 2007*) is exposed. The French case has been analysed with special emphasis because of the closeness and geographical similarities with Spain.

By contrast, Austria has imposed discharge limits more stringent than those defined by the 91/271/EEC Directive, although it makes some distinctions according to the agglomerations' size, being more permissive for the smaller populations. Finally, there is a third group of countries (Finland and Denmark), characterised for having a notably percentage of population outside the sewerage network (14–20%) [http://unstats.un.org/unsd/environment/wastewater.htm], which has established a specific legislation for decentralised (on-site) systems that serve populations with less than 30 PE. For instance, the Finnish regulations establish that the nutrient discharges must be reduced by 90% regarding organic matter (BSF_7), by 85% regarding phosphorus and by 40% regarding nitrogen in comparison to untreated wastewater. It is remarkable that most of these countries have actually prepared guidelines enabling technologies to achieve the required effluent quality [6].

Finally, all on-site systems designed for treating domestic wastewater up 50 PE, and to be sold in the EU territory, have to meet the Certification EN 12566-3, which regulates a minimum standard of operation reliability.

3.2. Sanitation and wastewater treatment in small Spanish agglomerations: current status and future trends

In Fig. 2, a map of the regional division of the Spanish territory is shown indicating the total population that lives in agglomerations with less than 2,000 PE and the population with sanitation (wastewater treatment) coverage. Those data have been obtained from the direct inquiries and workshops with the regional Spanish authorities with competences in sanitation.

According to the information compiled, it can be concluded that the sanitation and treatment coverage in populations with less than 2,000 PE is, in general, low in all the Spanish regions. Concretely, around 40–50% of the population that lives in small agglomerations has adequate sanitation coverage. The population not served by a WWTP at the moment has been estimated in 3–4 million PE, although they are provided by sewerage networks. Despite the pollution load is not high in comparison with the total Spanish load (74 M PE, approximately), the corresponding number of agglomerations is considered to be above

Table 1
Discharge limits for COD, BOD_5 and SS in populations with less than 2,000 PE

Parameter	EEC 91/271 Directive	Arrêté du 22 juin 2007
COD	125 mg/l	60%
	75%	
BOD_5	25 mg/l	60%
	70–90%	35 mg/l (70 mg/l in exceptional cases and overflows)
SS	35 mg/l	50%
	90%	

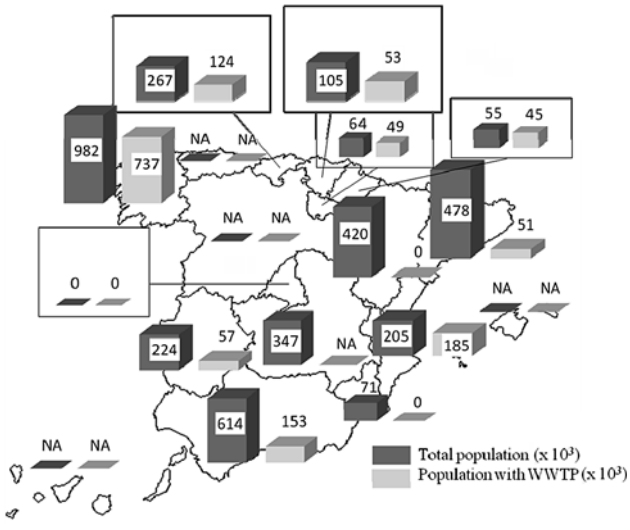

Fig. 2. Total PE and population served in small Spanish settlements. Note: NA = not available.

6,000. In fact, in Galicia, Catalonia and Castilla-La Mancha more than 2,400 agglomerations with less than 500 PE have been identified, most of them without WWTP. Therefore, this is the number of wastewater treatment facilities to be constructed in the next future, most of them in very small villages.

Most of the regional authorities have recently promulgated, or are in process, new sanitation and purification programmes or strategies that address a noticeable portion of their investments to the sewage treatment in small populations. When planning the sanitation of small communities, the first step is to define the agglomerations, grouping several villages in a single point of discharge where possible, to form larger clusters, or by connecting those small communities close to pre-existing agglomerations. However, in many cases the agglomeration process is technically, economically and environmentally unfeasible and the small populations remain scattered. Regarding this aspect, it is possible to establish a division between those Spanish regions with a high population density (such as Madrid, Murcia, Valencia and some of the Canary Islands) and those with a high level of dispersion (such as Galicia, Asturias, Castilla—Leon and Catalonia, in parts of its territory). In the first group, there is a clear tendency to create big agglomerations from the small populations, when feasible, resulting in a relatively low number of clusters with less than 2,000 PE.

The size of agglomerations directly influences on the typology of the treatment technologies applied. For instance, intensive technologies are commonly employed, and also recommended, for treating the sewage generated in high-density populations; meanwhile, in scattered regions, a wider range of technologies are applied (both intensive and extensive systems). In Table 2, the existing technologies in settlements with less than 2,000 PE in each of the Spanish regions are exposed, sorted by their level of implementation. As illustrated in Table 2, the extended aeration is widely used to treat the wastewater produced in small populations. This situation does not differ from the general trend observed in other European–Mediterranean countries. For instance, in Greece up to a 75% of the small treatment plants consists of extended aeration systems [7]. In France, most of the small WWTP are also based in the extended aeration system; in fact, there are more than 7,000 treating facilities working with that technological solution [8]. A more exhaustive analysis of the information compiled in this study reveals that the extended aeration is especially prevalent in populations over 1,000 PE, although they are also implemented in very small towns (with less than 500 PE). In addition, primary treatment systems (septic tanks and Imhoff tanks) have been applied in populations with less than 500 PE, commonly followed by infiltration systems.

From 500 to 1,000 PE, the variety of technologies applied grows (both intensive and extensive) and technologies such as stabilisation ponds, trickling filters or constructed wetlands can be found in WWTP. According to previous studies [9], the most applied extensive technologies in Europe are constructed wetlands and the stabilisation ponds, the first one over expanding, while the second in recession. Furthermore, constructed wetlands have been proved to be satisfactory solutions for urban wastewater treatment, both segregated and non-segregated, in the Mediterranean countries [10–13].

Future trends on sanitation and sewage treatment in small agglomerations can be found out by checking the Regional Sanitation and Wastewater Treatment

Table 2
Technologies applied in small Spanish populations in order of abundance

Region	1st technology (most applied)	2nd technology	3rd technology	Other technologies
Andalusia	Primary treatment	Extended aeration	Peat filters	RBC, stabilisation ponds, constructed wetlands and trickling filters
Aragon	Extended aeration	Trickling filters	RBC	Primary treatment
Asturias	Primary treatment	Extended aeration	Stabilisation ponds	Biological removal of N and P
Basque country	Primary treatment	Ditches, wells and filter beds, stabilisation ponds, peat filters	Extended aeration	
Cantabria	Extended aeration	Extended aeration + stabilisation ponds	Primary treatment	
Castilla-La Mancha	Extended aeration + stabilisation ponds	Extended aeration + stabilisation ponds	Trickling filters	RBC, primary treatment and green filters
Castilla-Leon	Primary treatment	Extended aeration	Septic tank + biological filters	Stabilisation ponds, trickling filters and peat filters
Catalonia	Extended aeration	RBC	Constructed wetlands, green filters, trickling filters	Stabilisation ponds, primary treatment
Extremadura	Extended aeration	RBC	Trickling filters	Stabilisation ponds
Galicia	Extended aeration	Trickling filters	Primary treatment	Physical–chemical
Rioja (La)	Extended aeration	Trickling filters	Stabilisation ponds	RBC
Madrid	Extended aeration	RBC	Peat filters	Green filters
Navarra	Primary treatment	Trickling filters	Moving bed biofilm reactor (MBBR)	Constructed wetland and sand filters + stabilisation ponds, extended aeration
Valencia	Extended aeration	Peat filters	RBC	Trickling filters

Note: Primary treatment (septic and Imhoff tanks); RBC = rotating biological contactors (discs).
Source: Regional plans of sewerage and water treatment.

Programmes that have been recently approved. As an example, the Tables 3 and 4 show the technologies that are going to be implemented according to the population size in Catalonia and Galicia, respectively. It is observed that in both cases, the activated sludge system is suggested only for agglomerations over 1,000 PE for settlements with less than 500 PE less-energy-consumption systems such as constructed wetlands or trickling filters which will be implemented.

When planning the sanitation of new agglomerations the process of selection of the most suitable technology to be implemented is often complex, because not only regulatory issues must be considered but also economic, social and environmental aspects [14]. To cope with this complexity, some authorities have developed specific methods that allow providing guidance on the level of agglomeration desirable and the appropriate technology to treat the sewage produced. In Spain, the Water Agencies of Galicia and Catalonia, in collaboration with Universities and research groups, have developed satisfactorily tools for this purpose. From a starting list of variables and factors and using an array of impact (in the case of Galicia) [15] or a decision support system (in Catalo-

Table 3
Sewage treatment technologies proposed in the sanitation plan of Catalonia

PE	Proposed technologies			
<1,000	Constructed wetlands (horizontal subsurface flow)	Subterranean impermeable filters	Trickling filters	Green filter, infiltration–percolation
1,000–2,000	Activated sludge (low load)	Activated sludge (medium load)	Constructed wetlands (subsurface flow)	Infiltration–percolation

Table 4
Sewage treatment technologies proposed in the sanitation plan of Galicia

PE	Proposed technologies (for less than 1,000 PE)					
50–250	Constructed wetlands	Trickling filters				
250–500	Trickling filters	Biodiscs	Sand filter (with recirculation)	Biodiscs + CW	Trickling filter + CW	Trickling filter + CW
500–750	Biodiscs + CW	Trickling filter + CW artificial	Trickling filters	Biodiscs	Extended aeration	Aerated submerged beds
750–1,000	Trickling filters	Biodiscs	Extended aeration	Aerated submerged beds		

nia) [16,17], it is possible to select the technology(s) most appropriate for each of the agglomerations and particular conditions. In addition, CEDEX and CENTA have published a *Guideline for the implementation of wastewater treatment systems in small populations* [18], defining some criteria for supporting the selection process. This issue and others regarding urban wastewater treatment in small populations are now object of multiple R&D works [19].

3.3. Economic issues concerning sanitation and wastewater treatment in small populations

In Spain the construction of new wastewater treatment facilities is mainly financed through regional, state and/or European Regional Development Fund. Once built the facilities, their exploitation is, initially, responsibility of the municipalities. However, it has been observed that, generally, some of these treatment plants have ceased to function once they passed into the hands of the municipal administration, due to the lack of financial and human resources for their O&M. To solve those managing problems, the competent authorities have undertaken various solutions:

- Intermunicipal management, through associations or consortia, sharing technical and human resources and, therefore, reducing costs. Andalusia, Asturias, Basque Country, Extremadura and Rioja (La) are examples of Spanish regions where this management solution has been promoted.
- Management through regional public entities, which are responsible for collecting the sanitation fee that is employed to finance the O&M of the infrastructures. This alternative is commonly used in Valencia (EPSAR), Navarra (NILSA), Murcia (ESAMUR), Aragon (Aragonese Institute of Water), Castilla-La Mancha (Aguas de Castilla La Mancha) and Madrid (Canal de Isabel II).
- Management through public entities at a sub-regional level. There are some cases, not very numerous, especially in Andalusia (Cordoba and Malaga). Those entities have been created by the County Councils and are responsible for the management of the budgets associated to sewage treatment and the operation of the sanitation facilities of small and medium size agglomerations.
- Management through Water Agencies or similar entities, which have the responsibility for planning and control all the infrastructures at the water basin level (including the collection of the water fee) and, in some cases, for the management of sewerage and treatment facilities. This block includes the Balearic Agency of Water and

Table 5
Incomes from wastewater treatment fee in Spanish regions. Data 2010 (National Statics Institute, 2012)

	Wastewater treated in Spain (m^3/day)	Annual incomes from the sanitation and wastewater treatment fee (10^3 €)
Spain	13.326,802	1.991,090
Andalusia	1.838,496	296,192
Aragon	649,614	75,532
Asturias	335,400	44,613
Balearic islands	280,047	104,159
Basque country	830,902	104,810
Canary islands	339,630	55,936
Cantabria	279,236	23,743
Castilla-Leon	1.425,452	111,100
Castilla-La Mancha	581,596	67,355
Catalonia	1.894,845	371,912
Extremadura	409,066	33,022
Galicia	834,061	75,332
Madrid	1.549,957	266,204
Murcia	303,283	68,377
Navarra	207,969	37,561
Rioja (La)	143,244	11,335
Valencia	1.375,663	240,154
Ceuta and Melilla	48,341	3,753

Environmental Quality (ABAC), the Catalan Water Agency (ACA), the Galician Water Agency (AGA) and the Water Island Councils in the Canary Islands.

The costs of construction and O&M of the sanitary and treatment infrastructures are, normally, financed by the collection of a fee (water or sanitation fee). Normally, these fees are not defined according to the size of the population. In Table 5, the volume of wastewater daily treated and the incomes from sanitation in the different Spanish regions are summarised. From data in Table 5, it can be concluded that the sanitation fee in Spain varies from one region to another. The Spanish average is established in 0.41 €/m^3. The maximum value is observed at Baleares (1.02 €/m^3) meanwhile the minimum tariff is imposed at Castilla-Leon, Ceuta and Melilla (0.21 €/m^3). Currently, the debate is focused on the suitability of increasing that fee for covering the collection and treatment of wastewater.

4. Conclusions

This study presents an analysis of the current state of sanitation and wastewater treatment in small Spanish populations. For this aim, an exhaustive compilation of information from diverse databases has been made. In addition, part of the information has been obtained directly from inquiries made to the responsible authorities in sanitation of the different Spanish regions. This study has revealed that the access to information about the state of sewage treatment at small agglomerations is very limited. This lack of information has also been observed in other European countries. In fact, neither the Commission nor the Member States have evaluated the pollution load associated to communities less than 2,000 PE that is not properly treated.

The not clear definition of the "appropriate treatment" given in the 91/271/EEC Directive has motivated multiple and variable interpretations of the text. Some European countries have established concrete discharge limits for the small agglomerations, generally more permissive than those applied to the large ones. Spain has not adopted a concrete stance in this sense and, normally, the same limits are applied in both large and small agglomerations. In this sense, both the authorities and experts in sanitation in small populations that have taken part in this study, recommend the definition of specific discharge limits for small populations.

Regarding the technological solutions for wastewater treatment in small populations, it has been observed that both intensive and extensive technolo-

gies are able to be implemented. However, it seems that intensive solutions, such as extended aeration, are widespread in small populations, although their relatively high O&M costs. It is, therefore, of relative importance to identify adequate criteria to discern in which particular situations one technology is more suitable than other ones. It is also essential to improve the knowledge of each of the different treatment systems regarding their design, applicability, construction and O&M, in order to guaranteeing long-term solutions for small WWTP.

It seems clear that the management carried out directly by each municipality is ineffective, with few exceptions, due to the lack of economical and technical resources that characterises the small communities. Instead, it is advisable the inter-municipality management for sharing the operating costs and the technicians responsible for the O&M of the treatment facilities. Apart from these associations or consortia, it is desirable the constitution of a regional entity to conduct the monitoring of the sanitation infrastructures and the management of the funding instruments (collection and administration of the water fee).

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