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Depuranat project: sustainable management of wastewater in rural areas

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ABSTRACT

The Urban Wastewater Directive is aiming to implement adequate treatments of collected wastewater before 31 December 2005 in small communities with a population until 2000 equivalent-inhabitant. Within the framework of the DEPURANAT project, co-financed by the European Interregional Cooperation Programme (Interreg IIIB Atlantic Arc), several Natural Reclamation Systems (NRS) based upon no-conventional technologies of wastewater treatment, have been studied from different points of view in rural areas: their effectiveness for producing regenerated wastewater of acceptable quality for several reuse options and vegetal biomass for different purposes, their environmental integration or their potential of implementation. Most of these treatment plants achieved high mean removal efficiencies: TSS (73–96%); BOD_5 (74–94%); COD (53–90%); *E. coli* (2–3 log units); *Enterococci* (1.5–4 log units). The environmental impact of the systems was determined using an adapted life cycle assessment methodology and the economic analysis of the systems was focused on analysing the financial indicators, empirical cost functions, and the potential market for these technologies. Furthermore, maps of potential implementation of these systems and a support tool for deciding upon the installation of conventional or NRS were designed with the aim of promoting them.

Keywords: Natural reclamation systems; Rural areas wastewater; Sustainable management; Life cycle assessment; Sanitary risk; Biomass; Wastewater reuse; Market studies

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1. Introduction

In the rural areas of Spain, Portugal and France, inside, or in the vicinity of protected natural reserves, the population settlements are usually disperse and often an adequate wastewater treatment is not available. In other cases, the wastewater treatment plants installed do not work at all or malfunction and to achieve the required quality effluent for reuse can be unavailable due to economic or technical reasons [1]. On the other hand, the centralised wastewater treatment plants and their associated costs, both in terms of investment and maintenance, where there are also limited financial and management resources, is not the only possible solution to the wastewaters in rural areas. Therefore, to develop low installation and operation cost technologies for wastewater treatment that allow water reuse and biomass utilisation can be an opportunity for socio-economic development in rural world [2].

The European Water Framework Directive [3] encourages the implementation of systems of water resources management efficient and totally environmentally integrated. These aims are specially related with the wastewater treatment systems which allow to protect the large masses of water from pollution and to optimise the financial resources of exploitation. In this legal framework DEPURANAT project was born in order to promote the development of decentralised wastewater treatment systems using technologies of natural treatment and low energetic consumption and cost, and which include the re-use, with total guarantees, of the water, the nutrients and the bio-mass generated. Moreover, DEPURANAT project's global aim was that the designed and operated systems were totally integrated into the environment and involved the direct participation of the local population.

DEPURANAT project was established in February 2003 and co-financed by the European programme INTERREG III - B "Atlantic Area". This three year project was developed by French, Portuguese and Spanish entities of diverse nature: local authorities, research centres and technological development, together with private companies and associations, led by Canary Islands Institute of Technology (ITC). More information is published in http://depuranat.itccanarias.org/.

The partners of DEPURANAT called the wastewater reclamation systems monitored as Natural Reclamation Systems (NRS) such as these did not consist merely in facilities for treating the water, completely divorced of other environmental considerations. Otherwise, NRS were conceived as a way of reproduction of natural processes of wastewater treatment which would allow for a close-knit fit between the activities generating of wastes, the local population, the environment and the use of secondary products of wastewater reclamation, as vegetal biomass.

In spite of the apparent advantages contributed by a NRS, including its simplicity and the efficiency of the support technology, these are not always implemented under adequate safety conditions, or with guarantees of success. In fact, some authors indicate that constructed wetlands (CW) have not up to now been considered as a treatment option by the administration but mainly due to the absence of previous experiences on pilot plants [1] and in this sense, García et al. [4] also noticed the lack of results from real experiences about constructed wetlands in south Europe and the necessity of research and investment in these technologies in order to define the influence of climatological conditions and quality wastewater on performance of these. As a result, the development of this type of treatment systems requires pilot projects to be implemented previously in order to establish successful experiences, methods and sufficient tools to dispel any further uncertainties and generate confidence in the results. This has been the main objective of DEPURANAT project in its areas of influence [5].

2. Methodology

DEPURANAT project was structured in four different scientific and technical programmes. Moreover, two further programmes were designed to give broad publication to the results of the project and to promote training and generate employment. The scientific-technical programmes can be summed up under the following headings:

1. Experimentation and demonstration of the technological, social and environmental aspects of the wastewater reclamation by NRS.
2. Market study, and economic and environmental feasibility of the NRS.
3. Methodology to define the potential application of the NRS in any given territory.
4. Development of support tools for decision-making.

2.1. Experimentation and demonstration of the technological, social and environmental aspects of the wastewater reclamation by NRS

The different works of this programme were based upon the monitoring of several NRS operated in Portugal, Andalusia and the Canary Islands according to the following methodology:

Firstly, it was established the criteria and the information to be collected for choosing new locations where to built new NRS. Also, it was decided the pre-existent wastewater treatment plants to be included in DEPURANAT project, within the geographical sphere of the project. The main design or selection criteria were the use of low-cost energy technologies and allow the evaluation of the generated products. Then, it was designed the basic layouts and exploitation programme of the new NRS and the proposals for re-adjustment of the pre-existing plants. Simultaneously, a shared protocol of analytic monitoring was established in order to evaluate the performance of the wastewater treatment plant and to supervise the correct operation of all the systems.

In the case of Canarian NRS, the absence of previous work in this subject promoted the development of specific studies: the evaluation of sanitary risks and agronomical quality associated to wastewater and secondary products reuse or disposal. The production and classification of the wood and vegetable biomass generated in the NRS, mainly in constructed wetlands, also were evaluated. Moreover, a continuous monitoring of environmental parameters was realized, in order to detect malfunction and environmental integration of the NRS. In parallel to all these works, it was analysed ways and methods for enhancing the social acceptance of the NRS and the participation of local stakeholders in the decision-making processes, operations and benefits of the systems.

The twelve demonstrative pilot plants of NRS submitted to sampling and monitoring twice a month, summarised in Table 1, were the following:

- A land application system (LAS) planted with *Populus nigra*, *Populus alba* and *Fraxinus excelsior* located in VilaVerde, a municipality in the North of Portugal, in order to improve the quality of reclaimed wastewater by a sequential batch reactor designed for 120 population equivalent (PE).
- 2 parallel functioning LAS in the Planta Experimental de Carrión de Los Céspedes (PECC) in Seville (Spain), designed for about 40 PE in winter and 120 PE in the summer months, using two species of trees: the poplar (clone I-214 of the *Populus euroamericana*) and the eucalyptus (*Eucalyptus camaldulensis*).
- 2 pilot installations for 125 and 80 PE, respectively, located in the Teno rural protected area, on Tenerife Island (Spain). These systems use a combination of anaerobic treatment (a septic tank with a high period of hydraulic residence) with a small sub-surface flow constructed wetland refilled of volcanic ashes as substrate and with a diverse number of macrophytes.
- 3 pilot plants using the combination of facultative ponds, channels and gravel filters with a diversity of aquatic macrophytes, two of them located at Gran Canaria Island and the third one, at Tenerife Island (Spain). These installations were designed for 40, 50 and 70 PE, respectively.
- 4 pilot installations with various combinations of wetlands (horizontal and/or vertical flow), inert substrates and mono-specific cultures of aquatic macro-

Table 1
Summary of main characteristics of the twelve demonstrative NRS submitted to monitoring in DEPURANAT project

Name	Location	Technology	Previous wastewater treatment	Design population equivalent (PE)
Vilaverde	Vilaverde, Portugal	Land application system	SBR[1]	120
Carrión de Los Céspedes	Andalusia, Spain	Land application system	Screening and degreasing	40 (winter) 120 (summer)
Carrizal Alto	Teno rural protected area, Tenerife Island, Spain	Subsurface horizontal flow constructed wetland	Septic tank	125
Bolico	Teno rural protected area, Tenerife Island, Spain	Subsurface horizontal flow constructed wetland	Septic tank	80
La Laurisilva	Gran Canaria Island, Spain	Combination of facultative ponds and grave and macrophytes filters	Imhoff tank	40
Campus de Tafira	Gran Canaria Island, Spain	Combination of facultative ponds and grave and macrophytes filters	Without previous treatment	50
Data del Coronado	Tenerife Island, Spain	Combination of facultative ponds and grave and macrophytes filters	Septic tank	70
Carrión de Los Céspedes	Andalusia, Spain	Two serial subsurface constructed wetlands (vertical and horizontal flow)	Imhoff tank	100
Ingenio de Santa Lucía	Gran Canaria Island, Spain	Two parallel SVFCW[2] and one SHFCW[3]	Imhoff tank	100
Temisas	Gran Canaria Island, Spain	One SHFCW[3]	Imhoff tank	15
Lomo Fregenal	Gran Canaria Island, Spain	Two parallel SHFCW[3]	Imhoff tank for 50 PE	25

[1]SBR: sequential batch reactor
[2]SVFCW: subsurface vertical flow constructed wetland
[3]SHFCW: subsurface horizontal flow constructed wetland

phytes, in the PECC, in Seville, and in three locations of Gran Canaria Island. Two systems were designed for 100 PE and the other two, for 15 and 25 PE, respectively.

Wastewater samples from influent and effluent of each NRS were collected fortnightly first and then, monthly. The analyses were made according to Standard Methods for the Examination of Water and Wastewater [6] and to International protocols [7,8]. The measured parameters were pH, electrical conductivity (EC), dissolved oxygen (DO), total suspended solids (TSS), COD, BOD_5, turbidity, $N\text{-}NH_4^+$, total Kjeldahl nitrogen (TKN), $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, PO_4^{3-}, total phosphorus (TP), *Escherichia coli* and total coliforms. Furthermore, agronomical parameters (calcium, sodium, magnesium, chloride, boron, carbonates) and nematodes were measured in the effluents.

On the other hand, the evaluation of the sanitary risk of Canarian effluents involved the following additional parameters: faecal coliforms were quantified according to Standard Methods for the Examination of Water and Wastewater [6], with membrane filters incubated on Chromocult® Coliform Agar (Merck). Presumptive *E. coli* were confirmed by overlaying the colonies with a drop of Kovac's reagent (indole test). *Enterococci* was quantified by ISO 7899-2 and *Clostridium perfringens* according to ED 12767/97/CE. While, somatic coliphages and F-specific RNA bacteriophages were made in accordance to ISO 10705-2 and 1, respectively. *Salmonella* sp. was identified using a multiplex PCR method described by Soumet et al. [9] while *Cryptosporidium* sp. and *Giardia* sp. were concentrated by an inorganic flocculation was carried out [10], followed by an immunofluorescence assay microscopy described by Ho et al. [11]. In the case of concentration and quantification of the nematode eggs, a method recognized by WHO was used [12].

In the absence of European or any regional guidelines for the evaluation of the agronomical quality of reclaimed wastewater for reuse, it the concepts of short-term limit concentration (LCC) and long-term concentration (LTC) were used as established by ANZECC [13] and USEPA [14] together with the draft of the Spanish Royal Decree for Wastewater Reuse [15]. The main parameters which are taken into account for these references are BOD_5, suspended solids, turbidity and coliforms together with the EC, N, P, K (potassium), B (boron) and SAR (sodium adsorption ratio).

In order to evaluate the macrophytes growth in the NRS, approximations were carried out using sampling units. In these sampling units, the ratio between length and weight from aerial part of selected individues was analysed. Firstly, the ratio length-weight from characterised individues and the total biomass in the sampling unit were calculated. From these data, a lineal ratio between real biomass and estimated biomass was obtained from a limited number of individues [16]. To quantify the biomass generated in the land application systems, the trees diameter were measured periodically at 1.30 m from the ground.

2.2. Market study, economic and environmental feasibility of the NRS

The economic analysis of the NRS requires the compilation of realistic data of each facility about investment and operation costs, and incomes associated to sewage disposal and the sale of recycled water. From this information, financial indicators were calculated and empirical functions of costs (investment and operation and maintenance per supplied population) were designed.

In parallel, an evaluation methodology of the potential market for NRS based upon surveys to municipalities about wastewater treatment facilities and geological and climatic information was developed.

The environmental evaluation, furthermore monitoring in situ the environmental parameters, was carried out using the method life cycle analysis (LCA) of different usable technologies, above all the constructed wetlands, land application systems and activated sludge. The LCA included the stages of building, operation, maintenance and dismantling of the systems. The variation in the environmental impact of the different wastewater treatment systems tested (conventional or non-conventional) was reflected using several different descriptors, e.g. global warming or eutrofization.

2.3. Methodology to define the potential application of the NRS in any given territory

A tool was developed with the aim of drawing up maps of potential implementation of NRS, based on geographic information systems (GIS), which took into account the peculiarities and specific nature of the rural environments. These maps attend to the characteristics of the territory and are adapted to the wastewater characteristics. So, strategic variables such as the existence and location of small or medium-sized hamlets which do not have a general sewage system, or limiting ecological or geographical factors, such as the climatic conditions, the altitude, terrain orography, the types or uses of the land, are reflected in these maps.

With the aim of demonstrating the usefulness of the developed methodology for the drawing up of these maps, it was applied to the major Canary Islands, Tenerife and Gran Canaria islands. This demonstration required to locate small communities up to 500 inhabitants in both islands and the addition of complementary maps (soils, climate, sewerage, etc).

2.4. Development of support tools for decision-making

An integrating software of the experiences implemented in the project and the knowledge collected from the existing literature, about low energy cost and extensive wastewater reclamation technologies was developed. This software tries to help the professionals or technicians in the decision-making about the adequate technology of wastewater treatment, tackling all the problems associated to small-scale wastewater treatment as available space or soil permeability, quality requirements for effluent disposal or reuse, average costs, etc.

3. Results and discussion

3.1. Natural reclamation systems efficiency

In general, land application system located in Carrión de Los Céspedes achieved optimal removal efficiencies (Table 2).

On the other hand, the combination of subsurface constructed wetlands tested in Carrión de Los Céspedes has always operated at high removal efficiencies although it has been operated at different flowrate and organic load, which have oscillated between 6–18 m^3/d and 4–25 g BOD/m^2·d, respectively (Table 3). These operational changes were aimed to promote plants growing and to put up substrate adaptation to feedwater conditions.

Table 2
Removal efficiencies of Carrión de Los Céspedes's land application system at different depth

Parameters	% elimination		
	30 cm	60 cm	90 cm
BOD_5	69	85	90
COD	75	91	92
TSS	81	86	92
NH_4	91	91	92
Kjeldahl N	88	87	89
PO_4	66	76	85
Total P	57	73	86

The NRS based on combinations of facultative ponds and grave and macrophytes filters (Data del Coronado and Campus de Tafira) also operated with high efficiencies in terms of organic matter and solids removal (80–90% BOD, 70–80% COD, 70–80% TSS). However, the NRS located in Teno rural protected area (Carrizal Alto and Bolico) operated with lower efficiencies in terms of organic matter (70–80% BOD, 50–60% COD), probably due to the low pollution of feed water and the short dimensions of them. Table 3 summarises the quality of influents and effluents of CW in Carrión de Los Céspedes and some Canarian NRS in function of the seasons.

The high risk of blocking the substrates when NRS work with highly concentrated wastewaters concentrations, fact usually habitual in the small Andalusian and Canarian communities, was avoided using greater grain-size as recommend other authors [17,18]. The concentrations in the major part of the effluents of the different NRS were in accordance with the required levels of European Directive 91/271 [19], although it is not applicable to these treatment plants (Tables 2 and 3).

The microbiological quality of the effluent achieved in some NRS is shown in Table 4. The concentrations of *Escherichia coli* and total coliforms, expressed as arithmetic mean, indicate that the influent in Carrion de Los Céspedes are two or three logarithm unit higher than in the other NRS and Campus de Tafira showed the highest inactivation of all indicators.

Regarding Canarian NRS efficiency, the average reductions of faecal indicators were between 97 and 99.9%, that is, between 3 or 4 log10 units for wastewater compa-

Table 3
Average physic-chemical quality of influent and effluent of some pilot NRS in function of seasonal period: spring/summer (S/S) and autumn/winter (A/W)

Parameters	Period	Carrión de Los Céspedes		Campus de Tafira		Data del Coronado		Carrizal Alto		Bolico	
		In	Out	In	Out	In	Out	In	Out	In	Out
TSS (mg/l)	S/S	280	24	132	7	300	80	18	52	15	77
	A/W	236	11	93	4	167	28	18	17	24	23
BOD_5 (mg O_2/l)	S/S	514	59	385	22	200	31	37	18	55	15
	A/W	541	57	68	<8	95	25	36	10	51	16
COD (mg O_2/l)	S/S	1027	117	648	104	970	281	140	85	140	80
	A/W	1028	118	189	67	423	199	105	42	148	58
Kjeldahl N (mg/l)	S/S	97	34	113	60	121	21	—	—	—	—
	A/W	120	44	52	18	45	16	43	31	—	—
Total P (mg/l)	S/S	15	6	16	11	49	14	23	12	—	—
	A/W	17	10	8	9	81	37	13	12	—	—

* Only non-conventional technology

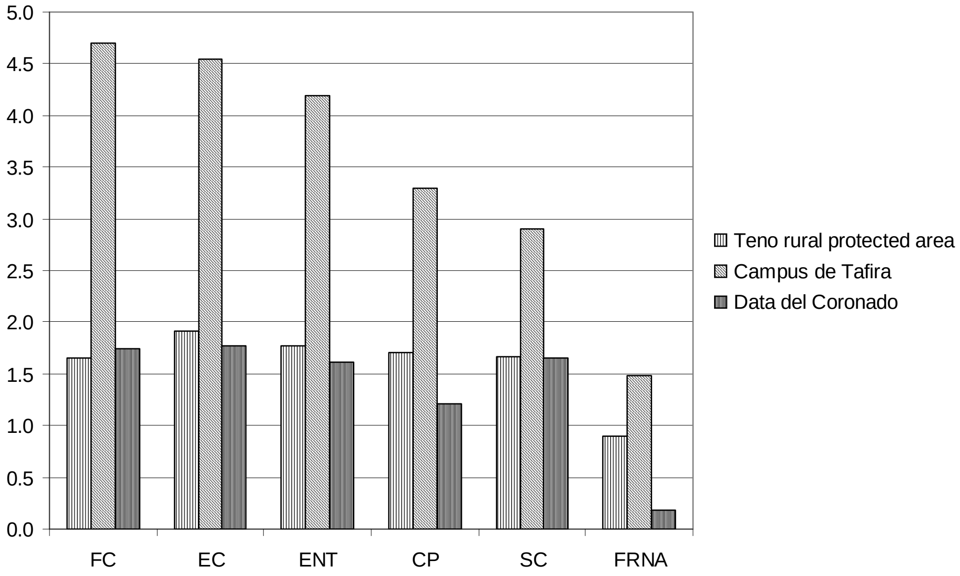

Fig. 1. Removal efficiencies (in log units) of faecal contamination indicators in Canarian NRS. FC: Faecal coliforms; EC: *Escherichia coli*; ENT: *Enterococci*; CP: *Clostridium perfringens*; SC: Somatic coliphages; FRNA: F-specific RNA bacteriophages.

Table 4
Microbiological quantity of effluent and removal of pathogens in some monitored treatment plants

	E. coli		*Enterococci*	
	Effluent cfu/100 ml	log_{10} unit reduction	Effluent cfu/100 ml	log_{10} unit reduction
Carrión de Los Céspedes	5.2E+05	2.9	1.8E+03	4.1
Campus de Tafira	1.4E+02	2.6	4.0E+01	4.2
Data del Coronado	2.5E+02	1.8	1.4E+02	1.6
Carrizal Alto	3.7 E+02	2.3	5.5E+02	1.6
Bolico	4.0 E+03	1.3	5.3E+02	1.6

rable to domestic sewage (Fig. 1). The results obtained showed that the aquatic macrophytes channels produced the most significant reductions of bacterial indicators, influenced by filtration, oxidation, solar irradiation or predation processes, while grave and macrophytes filters acted on coliphages in these systems, through adsorption and inactivation processes. As a reference, we observed that nematode eggs or any other type of parasite helminth were no detected, except at the entrance of one of the pilot project which received effluents from a milking dairy. However, at the exit of this installation, only an average of 0.02 eggs per litre was isolated. Although sometimes, *Salmonella* sp., *Cryptosporidium parvum*, *Giardia duodenalis* and nematode eggs were detected in some influents of the monitored NRS, but they never were detected in the effluents.

The effluents showed levels of *E. coli* and nematodes eggs lower than guide-values of WHO recommendations [20] for reuse in agricultural irrigation and removal efficiencies of faecal indicators and pathogens were high.

According to our results, the options for reuse irrigation, in accordance with USEPA references [14], could be for crops of indirect human consumption, recreational uses not involving human contact, environmental uses and recovering of natural wetlands. Regarding to agronomical parameters, it is recommended, in general, that vegetable species with a high consumption of N and P are used, according to the original characteristics of the soil, and that they should also be averagely tolerant of B if it is high in the effluent (this only happens in one pilot project).

Table 5 shows the evolution of *Phragmites australis* in different locations compared with bibliographic data. The evolution in Campus de Tafira is similar to the bibliographic data; in the rest of locations the growth is lower. It is possible that climate factors were stopping the growth in the period. In the case of Carrión de Los Céspedes, the system was too young at the moment of the analysis.

3.2. *Social integration of NRS*

With regard to the work carried out about systems social integration, we should highlight, as the most tangible result, the organisation of various technical seminars with public participation. These seminars have al-

Table 5
Vegetal biomass in kg/m^2 generated by *Phragmites australis* in different NRS

Month, year	Bibliography*	Carrizal Alto	Data del Coronado	Campus de Tafira	Carrión de Los Céspedes
November 2005	1.39 ± 0.20	0.30 ± 0.02	0.74 ± 0.04	0.88 ± 0.09	
February 2006	1.49 ± 0.26	0.70 ± 0.06	0.68 ± 0.03	0.92 ± 0.06	0.44 (mean value)
March 2006	1.07 ± 0.13	0.73 ± 0.09	0.50 ± 0.01	1.02 ± 0.03	

(*) Ruiz-Martínez et al., 2005

lowed to get a glimpse of the overall perspectives of development and extension of the NRS and to establish a network of agents involved in their development and management. Furthermore, an analysis method and specific recommendations had been formulated to improve social integration of the pilot projects. These recommendations draw attention to the need of establishing optimum parameters of maintenance and management using protocols and promoting the direct participation of local people.

3.3. The economic study

The economic study carried out showed the following aspects:

The investment costs are similar for the different types of pilot projects and the equipment costs, in general, constitute a very small fraction of investment costs (Figs. 2 and 3). The variation of the investment cost (€/PE) and operational costs (€/PE) tend to diminish as the population increases in according to the equations in Table 6.

As it was expected, the operational costs are lower than for conventional systems. Some pilot projects present considerably low operational costs when they are controlled by their own staff and carry out other tasks in the place, for example, the management of a hostel, the surveillance of a natural area or if the local population understand the advantages of managing the system and assumpt this labour.

Table 6
Experimental equations between specific costs [Y_1: investment cost per equivalent inhabitant; Y_2: operational cost per equivalent inhabitant) and population (X)]

Type	n	Regression equation	R^2
Investment	10	$Y_1 = 4406 \cdot X^{-0.628}$	0.72
Operational	10	$Y_2 = 1663 \cdot X^{-0.872}$	0.85

The price of water supply varies considerably between the regions and locations where the pilot projects have been set up. These differences are related to water resources scarcity and the costs of producing drinkable water (seawater desalination or aquifers exploitation). This is a decisive factor for the economic feasibility of the pilot projects as generating of reclaimed wastewater for reuse.

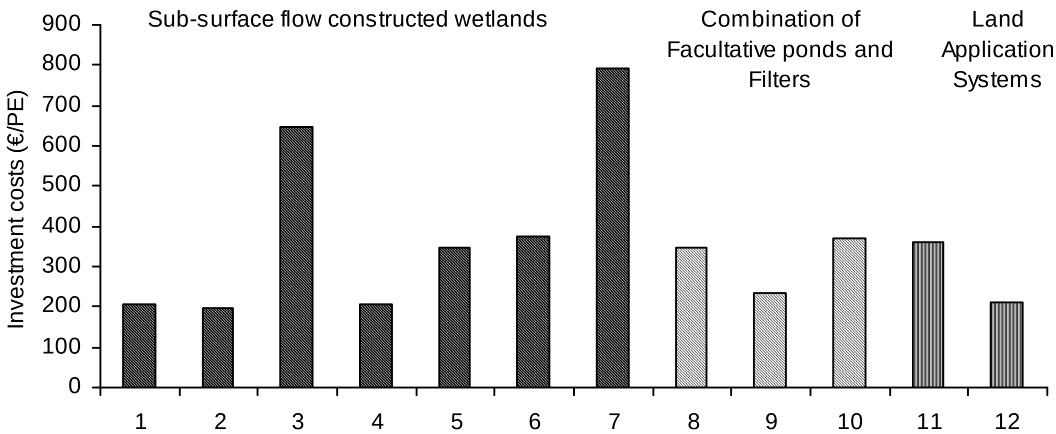

Fig. 2. Investment costs per PE in the different NRS. 1 Bolico, 2 Carrizal Alto, 3 Lomo Fregenal, 4 Carrión de Los Céspedes (CW of vertical flow), 5 Carrión de Los Céspedes (CW of horizontal flow), 6 Temisas, 7 Ingenio de Santa Lucía, 8 Campus de Tafira, 9 Data del Coronado, 10 Laurisilva, 11 Vila Verde, 12 Carrión de Los Céspedes.

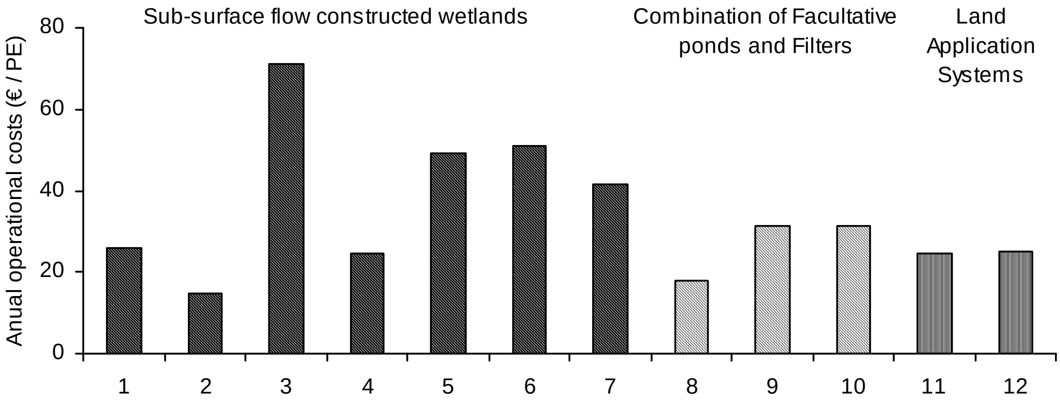

Fig. 3. Operational costs per PE in the different NRS. 1 Bolico, 2 Carrizal Alto, 3 Lomo Fregenal, 4 Carrión de Los Céspedes (CW of vertical flow), 5 Carrión de Los Céspedes (CW of horizontal flow), 6 Temisas, 7 Ingenio de Santa Lucía, 8 Campus de Tafira, 9 Data del Coronado, 10 Laurisilva, 11 Vila Verde, 12 Carrión de Los Céspedes.

3.4. Environmental study and external factors

From the environmental analysis in situ, plus the analysis of the life cycle analysis (LCA), the following noticeable conclusions have been achieved:

The process of manufacture/production of the materials used in the building of the wastewater treatment systems is the main factor contributing towards their toxic and eco-toxic impact. There is also a high impact of the process involved in activated sludges which is associated to the emission of heavy metals, as a result of the process of steel production, used in the aeration system. On the other hand, the stage of dismantlement and final closing, the last in its life cycle, causes the least environmental impact over all the treatment systems analysed.

The high energy costs (forced aeration) are responsible of the environmental impact in the phase of operation and maintenance in the treatment by activated sludge, whereas in the case of the land application systems, the impact is associated to cutting down the eucalyptus trees, every five years, for then to be milled and used in the production of paper pulp.

The greatest impact of the constructed wetlands occurs in the first stage of the life cycle, the building and the assembly, whereas the lowest impact occurs during the operational phase, which is the longest. The NRS, specially those based on land application systems, contribute positively towards attenuation of global warming, since the absorption of CO_2 by the vegetable biomass is significant, whereas the process of activated sludge aggravates climate change.

The absence of nuisances such as unpleasant smells or mosquitoes, except in one or two cases and, due to malfunction of the pre- or primary treatment, was general. The NRS which included water sheets with a diverse number of riverside macrophytes normally showed presence of mosquito larvae in the favourable seasons. This circumstance normally also produces a proliferation of predator fauna such as dragon-flies, amphibious and insect-eater birds. And it is needed to control rodents and various invasive plant species.

The generation of waste is restricted to the cleaning of tanks, septic tanks and the remains of the construction work for adapting the pilot projects. The aquatic macrophytes which grow in the systems require harvesting twice or three times a year. The vegetable biomass generated and which has not been adequately exploited can be easily disposed as compost.

The landscape integration is adequate, producing positive visual impact in all of the cases. The visual aspect is considered to be a positive chractristic by all who visit the pilot plants.

3.5. Market studies and territorial potential

In general, in the European Atlantic area, the situation is identical, with a high concentration of small communities under 2,000 inhabitants. In Spain, 6,000 of 8,000 existing municipalities are under 2,000 inhabitants. In Andalusia, like in the Canary Islands, the percentage of population under 2,000 inhabitants is over 80%. In France, the data is similar with over 87% of the municipalities with less than 2,000 inhabitants. In the North of Portugal, 75% of the urban settlements have less than 500 inhabitants. In the case of Portugal it is been contemplated around 4,000 systems of sewage and wastewater treatment, with almost 70% of the same (approximately 2,800) in rural areas, and with no connection to a centralised wastewater treatment plant. In France, the various hypotheses of development reveal the need of between 800 and 2,000 new systems, applying extensive technology, from now until 2034.

The maps of territorial potential application of NRS to the rural areas of the most populated islands of the

Canarian Archipelago show that there are more than 225,000 homes without sewage systems, the great majority on Tenerife Island. Likewise, it is estimated that the wastes produced by cattle installations and agricultural product processing plants are particularly relevant and are becoming worrying. These wastes are usually decentralised and have special characteristics which open up a new line of market for the extensive technologies which allow advantageous re-use of the by-products of the installations themselves.

4. Conclusions

By way of overall conclusion, we should emphasize the holistic, multi-functional, multi-disciplinary and social focus which has been given to the treatment and productive reuse of reclaimed wastewater in rural environments and natural areas. DEPURANAT project has achieved collaboration and interaction of agents of varying characteristics: users, public authorities, businesses, professionals and researchers, who have exchanged information, ideas, methodologies and technologies around the NRS and the social and territorial integration of these. The trans-national cooperation established was basic to the exchange of experiences, know-how and methods between the various regions of the European Atlantic Area.

All the studied NRS have shown, in general, an adequate treatment of wastewater in terms of organic matter, solid and nutrients removal. The microbiological qualities of the analysed effluents are lower than the guide-values of WHO recommendations for reuse in agricultural irrigation and removal efficiencies of faecal indicators and pathogens were high in Canarian NRS.

From the agronomical point of view, the options for wastewater reuse, in line with USEPA guidelines are irrigation of crops of indirect human consumption, recreational uses not involving human contact, environmental uses and recovering of natural wetlands.

The NRS achieved acceptable landscape and environmental integration with presence of birds and insects, absence of odours, etc.. These aspects and the promotion of public participation in the making-decision process contribute to achieve social integration of NRS in small communities.

The investment costs are similar for the different types of NRS and the costs of equipment, in general, constitute a very small fraction of the investment costs. The variation in the investment and operational costs tend to diminish as the supplied population increases. In all the studied NRS, the operational costs were lower than for conventional wastewater treatment systems. The price of water is a decisive factor for the economic feasibility of the NRS which are generating of reclaimed wastewater as additional resource.

In consequence, DEPURANAT project has demonstrated that the local exploitation of the reclaimed wastewater for irrigation, flowers for selling or the vegetal biomass for agricultural or artisan activities, etc, can contribute to support the local economy.

The results show a high potential for implementation of low-cost energy wastewater treatment plants in rural word of the European Atlantic Area. Moreover, it is foreseeable potential receptiveness of management companies of wastewater systems given the economic advantages and the low environmental impact of these systems.

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