Chapter 2
Wastewater Treatment and Reuse as a Tool for the Social and Environmental Improvement of Populations Within Protected Environments

A. de Miguel, J.M. Sanz, I. de Bustamante, A. de Tomás, and J.L. Goy

Abstract Downsized conventional water treatment systems as used for small population wastewaters are extremely inefficient. In practice, due to high maintenance and operation costs their use is frequently discontinued in many small municipalities that cannot afford to treat their wastewater, which is finally dumped untreated. Land application systems have been a suitable treatment system, due to their low operation and maintenance costs and their high yield. However, the most recent change in the Spanish legislation (RD 1620/2007) promotes their adaptation into the more socioeconomically beneficial water reuse systems. In this study, a techno financial analysis was used for the establishment of land application systems of water treatment and reuse in 12 municipalities located within the protected environment 'El Rebollar', Salamanca, Spain.

Keywords Water treatment systems • Wastewater treatment • Land application systems • Spain

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2.1 Introduction

2.1.1 Description of the Study Area

The Protected Natural Landscape *El Rebollar* has a 50,040 ha surface. It is located to the SW of *Salamanca* province (Spain) (Fig. 2.1), in the northern slope of the Mountain range *Sierra de Gata*. It was included in the network of Natural Areas of *Castilla* y *León* by rule 8/1991. At the moment, it is in the course of upgrading to the Natural Park level of protection. Its surface covers 11 municipalities. The population of these municipalities is 4,050 inhabitants (INE 2009). It belongs, hydrologically, to the *Águeda* river sub-basin, within the *Duero* river basin.

2.1.2 Land Application Treatment System

Land application system with forest mass (LAS) is a plot of land, determined by the influent to treat, where arboreal vegetation is planted and irrigated with waste water. The wastewater evaporates partially, so the remainder part is used by the tree roots and leaked through the ground. To obey the current legislation on reuse matters, it is necessary to introduce a primary treatment system to eliminate some of the solids in suspension. LASs are beyond a simple wastewater treatment system, as they produce the highly economic valued biomass.

The installation of a LAS, a low cost system, simple, but effective and solid, is recommended in this study area, due to the small size of these populations and their location within a protected environment. This system has to hold the increases in the volume flow experienced during summer time in this area, as well as the minimum costs in the operation and maintenance.

2.1.3 Spanish and European Legislation on LAS

According to norm 91/271 of the European Community legislation, populations with less than 2,000 inhabitants must properly treat its wastewaters before dumping them into the receiving environment. In addition, according to the article 253,1 to the RHPD (regulation of Hydraulic Public Dominion) all the discharges inferior to 250-inhabitants equivalents (i.E.) must ask for a discharge declaration.

On the other hand, RD 1620/2007 on wastewater reuse establishes the quality limits that regenerated water must fulfil its reuse. Understanding LAS as a forestry system in which an indirect charge of the aquifer takes place, the required quality values, before its use in irrigation, are disclosed in Sects. 5.1 and 5.3 in Annex 1.A. (RD 1620/2009).

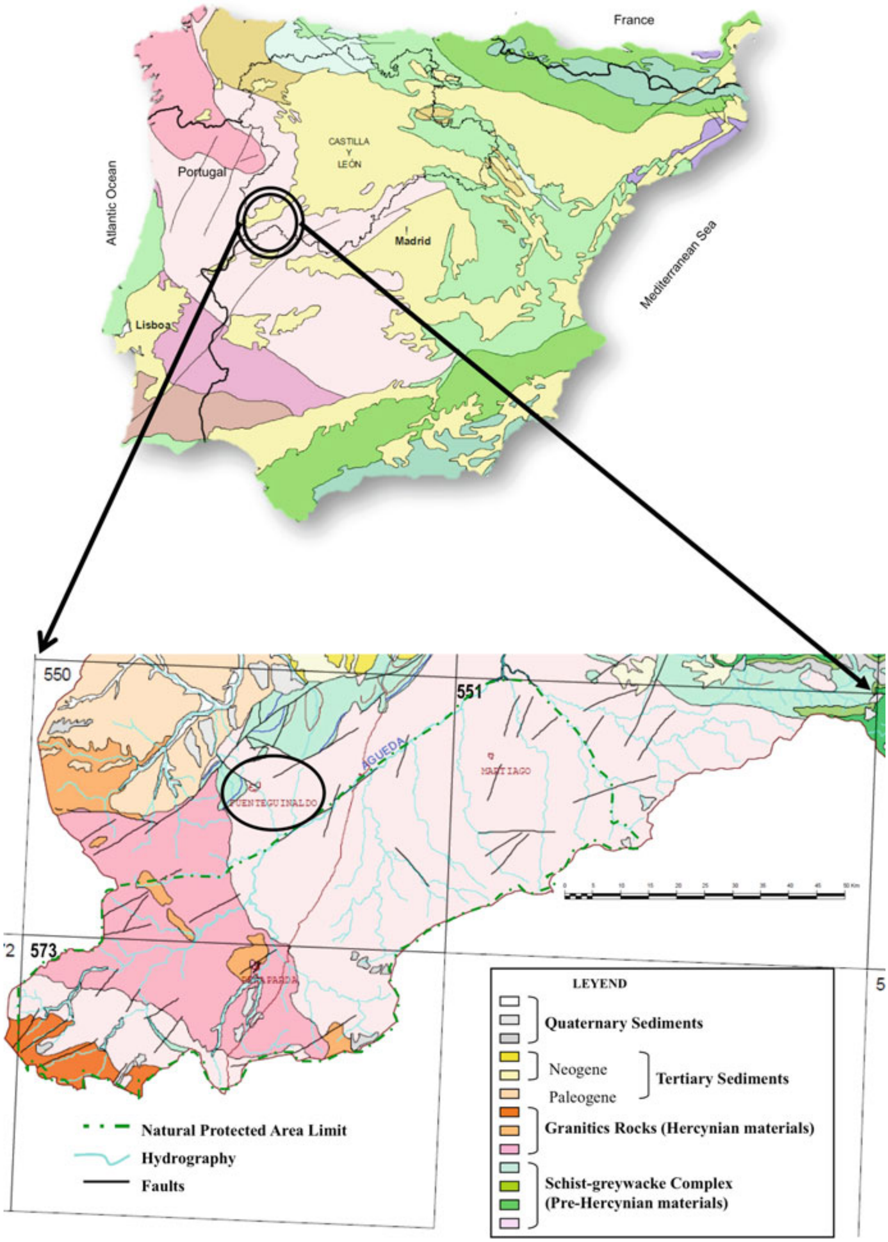

Fig. 2.1 Location map

Table 2.1 Main design variables using the methodology of multi-stage land application systems (De Bustamante et al. 1998, 2001, 2009)

Municipality	Population (inhabitant)	Inflow (m^3)	i.E.	Poplar stage surface (m^2)	Meadow stage surface (m^2)	Total surface (m^2)	Total recharge (m^3/año)
Navasfrías	523	30.692	247	6.000	3.000	9.000	18.519
El Payo	405	33.239	267	7.000	3.500	10.500	22.949
Fuenteguinaldo	803	47.651	383	10.000	5.000	15.000	28.280
Villasruibias	259	15.369	124	3.500	1.500	5.000	8.889
Robleda	521	19.417	156	4.000	2.000	6.000	11.204
Martiago	329	19.523	157	4.000	2.000	6.000	11.669
Serradilla del Llano	182	10.800	87	2.500	1.250	3.750	6.180
Casillas	228	13.530	109	3.000	1.500	4.500	7.872
Alberguería de A.	161	9.554	77	2.000	1.000	3.000	5.675
La Alamedilla	199	11.809	95	2.500	1.250	3.750	6.987
Puebla de Azaba	216	12.818	103	2.700	1.350	4.050	7.597
Ituero de Azaba	239	14.183	114	3.000	1.500	4.500	8.029

2.2 Material and Methods

To analyse the suitability of land application systems as a wastewater treatment and reuse system in small municipalities a methodological framework is proposed based on two points.

2.2.1 Technical Analysis and Main Design Variables

The main design variable is used to determine the applicable hydraulic load. As the volume is a fixed variable, only the filter surface was used. If it is considered that this type of facility is based on a forest system subjected to hydric conditioners, the surface will be estimated with a hydric balance of the system. The hydric balance consists of the total water to apply to the land (the sum of the precipitation and the wastewater) and the one that returns to the atmosphere by evapotranspiration. Therefore, it is possible to evaluate the amount of wastewater that can be used without surpluses getting flood or deficit producing hydric stress. In this study, the multi-stage land application methodology was used (De Bustamante et al. 1998, 2001, 2009).

To estimate the evapotranspiration the methodology proposal by Blaney and Cridle (1950) was used. The weather data come from AEMET (Spanish Agency of Meteorology) and the estimation of the volume of wastewater from the drinkable water consumption of each municipality. As there are no data from all the municipalities in the protected environment, some bordering municipalities have been included (Table 2.1).

2.2.2 Financial Analysis

The objective of the financial analysis is to determine the proposed system's financial viability, comparing costs with other possible proposals. An NPV (Net Present Value) methodology, widespread in studies on construction of water purifying stations viability, was used (Brealey and Myers 2006).

$$NPV = \sum_{i=0}^{t} \frac{B_i - C_i}{(1+t)^t} \tag{2.1}$$

Where B_i is the benefits, C_i is the costs, t is the time, and r is the discount rate.

In this analysis, the costs of construction of a new installation were included without considering any subvention. On the other hand, only the benefits of the biomass production in a long cycle (harvested every 15 years) were included, regardless of the annual pruning or other different timber managements. This analysis has not assessed the environmental externalities.

2.3 Results

2.3.1 Technical Analysis and Main Design Variables

Table 2.1 displays the main design variables needed in the implementation of a LAS. The largest surface corresponds to Fuenteguinaldo (383 inhabitants), a total of 15,000 m^2, divided in two different areas: one area of arboreal vegetation (poplar forest) of 10,000 m^2 and one area of 5,000 m^2 of meadow. The smallest municipality is Alberguería de Argañán (77 inhabitants) with a surface of 3,000 m^2 (2,000 and 1,000 m^2, respectively, in each area). The authors propose the use of the system in the two areas (multi-stage); therefore, when higher evapotranspiration, the arboreal area will be used (summer); whereas when evapotranspiration is reduced, the treatment surface to the grass area will be extended. The recharge is around 140,000 m^3 per year for all the villages.

Although in summer there is an influent increase (due to the population increase), the evapotranspiration rise is bigger. This season determines the forested area of the LAS, because it is necessary to provide the water needs of trees to prevent drying.

The proposed system follows this scheme: influent undergoes grinding and sieving to eliminate the thickness, afterwards it will come through desanding and degreasing to eradicate part of the total solid suspended (TSS) and floating oil. The resulting water will go by an Imhoff tank where the partial digestion of the organic matter and the elimination of a high percentage of the TSS take place. In order to fulfil the requirements of RD 1620/2007, a final filtration of the influent will be necessary, before its distribution in the LAS (Fig 2.2).

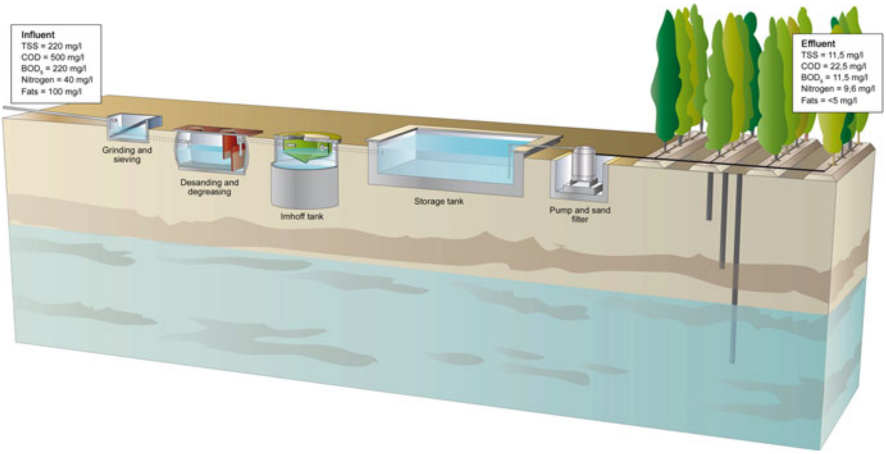

Fig. 2.2 Water flow within the system (Data from Tchobanoglous et al. 1985; De Bustamante et al. 1998, 2001)

The selected forest species is the white poplar (*Populus euroamericana*), specifically the I-214 clone. The authors proposed the use of a plantation frame of 5 × 5 m, with a density of 350 foot/ha (Fernández and Henanz 2004). The land plot will be divided in 50 m long × 5 m wide streets to facilitate use and operability. Pegs will be implanted on terraces. The irrigation system will consist of a grooved hose, so dripping irrigation systems are not necessary. In the meadow area, the same system of division and irrigation will be used. The used species are those that grow spontaneously. Maintenance cares will never consist of the total disposal of the grass.

2.3.2 Financial Analysis

The major costs of investment and maintenance correspond to the municipality with a greater population, *Fuenteguinaldo*, with an initial investment of 77,690 € and annual maintenance costs of 3,750 € as could be anticipated. *Alberguería de Argañan*, on the other side, represents an investment of 28,171 € and annual costs of 1,615 €. These costs include the necessary facilities for the construction, operation and maintenance of the proposed system (Table 2.2). The initial investment, the primary treatment, corresponds to 41 %, the implantation of the LAS and the irrigation systems to 39 % and the needed land to 10 % of the investment costs. The last costs could be reduced, if the proposed land belonged to the municipality.

The price of the water that would make the NPV to zero, in other words, the price neighbours had to pay to finance completely the installation and maintenance of the purifying plant was also calculated. It is estimated considering three life

Table 2.2 Summary of financial analysis. Data of *biomass incomes* from Esteban et al. (2005). Data of cost are from several companies

	Navasfrías	El Payo	Fuenteguinaldo	Villasrubias	Robleda	Martiago	Serradilla del Llano	Casillas	Alberguería de A.	La Alamedilla	Puebla de Azaba	Ituero de Azaba
Initial investment (€)												
Primary treat	30.706	30.706	36.623	15.898	18.516	15.898	12.365	15.898	12.365	12.877	12.877	15.898
LAS	23.777	25.201	32.464	15.092	16.019	16.019	13.837	14.568	13.102	13.837	14.130	14.568
Land prices	5.653	6.391	8.603	3.687	4.179	4.179	3.073	3.441	2.704	3.073	3.220	3.441
Invest. cost	60.137	62.298	77.690	34.677	38.714	36.096	29.275	33.907	28.171	29.786	30.226	33.907
Operating cost (€/año)												
Personnel	1.974	2.023	2.169	1.123	1.156	1.156	1.082	1.107	1.058	1.082	1.092	1.107
Energetic	503	545	782	252	318	320	177	222	157	194	210	233
Consumables	800	800	800	400	400	400	400	400	400	400	400	400
Annual cost	3.277	3.368	3.751	1.775	1.874	1.876	1.659	1.729	1.615	1.676	1.702	1.739
Incomes, cycles every 15 year (€)												
Biomass value	16.880	19.694	28.134	9.378	11.254	11.254	7.034	8.440	5.627	7.034	7.596	8.440
Price that equates the NPV to 0 (€/m^3) in relation with the plant life												
15 years	0.235	0.222	0.182	0.265	0.228	0.216	0.335	0.296	0.371	0.311	0.290	0.283
30 years	0.134	0.126	0.102	0.151	0.129	0.122	0.193	0.169	0.215	0.179	0.167	0.162
45 years	0.086	0.080	0.064	0.096	0.082	0.078	0.124	0.108	0.138	0.115	0.106	0.103

periods of the installation (15, 30 and 45 years), corresponding to the periods of collection of the biomass. A return rate of 4 % has been defined, the same used by the Spanish Ministry of Environment in viability WWTP (wastewater treatment plant) studies. Prices decrease based on the working life of the plant (a 43 % between first and the second cycle and a 36 % between the second and the third one), varying between 0.27 €/m^3 for the first cycle, 0.15 €/m^3 for the second and 0.10 €/m^3 for the third cycle (Table 2.2). A price variation takes place within municipalities, depending mainly on the size of the population. Therefore, *Fuenteguinaldo* would have the cheapest prices while *Alberguería de Argañán* the most expensive ones.

The cost will be less than 210 € per inhabitant (average), 293 € in case of Serradilla del Llano (the most expensive) and 121 € in Robleda (the cheapest one).

2.4 Conclusions

The proposed system adapts easily to the characteristics of the studied municipalities because it requires a small surface, less than 1 ha per 350 inhabitants, in some cases even 450 inhabitants per hectare (Fuenteguinaldo). It is a strong system, but low maintenance is necessary, which could even be done by non-qualified workers. In addition, it is able to hold the increases in the volume flow experienced during summer time.

This system allows the reusability of wastewater for the highly economic value biomass production, as well as refilling the aquifers with quality water (more than 145,000 m^3 per year among all the municipalities).

The financial analysis shows that it does not suppose a strong investment that could be recovered by the collection of a purification canon, below 0.15 €/m^3. Considering the average price of the quota of sanitation in Spain in 2008 was 0.14 €/m^3 and in *Castilla y León* was 0.08 €/m^3, the costs of the proposed treatment system are highly competitive INE (2008). It is important to establish that the wastewater treatment costs are influenced by the Scale Economy; therefore, in small municipalities these costs will be affected by the initial investment. However, in this study, possible sources of financing the system construction, a very habitual practice in small municipalities have not been included.

In addition, a number of environmental benefits have not been taken into account in the economic evaluation: the long-term woody vegetation (periods of 15 years) aid in the capture of CO_2. It does not cause impact on the landscape, and may be a haven for nesting birds.

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References

Blaney HF, Cridle WD (1950) Determining water requirements in irrigated areas from climatological and irrigation data, vol 96. U.S.S.C. Service, Washington, DC

Brealey RA, Myers SC (2006) Principios de Finanzas Corporativas. McGraw-Hill, Madrid

De Bustamante I, Dorado M, Vera S, Oliveros C (1998) Filtros verdes. Un sistema para la depuración y reutilización de aguas residuales. Tecnoambiente 79:73–75

De Bustamante I, Alpuente J, Sanz García JM, López Espí P, Dorado Valiño M, López Ferreras F, Roquero E (2001) Nueva metodología de diseño, control y gestión de filtros verdes. Aplicación a sistemas en funcionamiento. Hidrogeología y Recursos Hidráulico XXIV:585–594

De Bustamante I, Lillo J, García E, De Miguel A, Martínez F, Sanz García JM, Corvea JL (2009) A comparison of different methodologies for land application systems: application to Redueña's WWTP. Desalination Water Treat 4:98–102

Esteban V, Díaz L, Casquet E (2005) Optimun financial time to introduce the tax in the analysis. Application to the Castilla y León poplar. Investigaciones agrarias: sistemas y recursos forestales 14:122–136

Fernández A, Henanz G (2004) El chopo: manual de gestión forestal sostenible. Junta de Castilla y León, Valladolid

INE (2008) Encuesta sobre Suministro y Tratamiento de Aguas, National Statistical Institute of Spain

INE (2009) Censo municipal. National Statistical Institute, Spain

Tchobanoglous G, Burton FL, Stenser HD (1985) In: Metcalf & Eddy (eds) Wastewater engineering: treatment and reuse. McGraw-Hill College, New York

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