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Management of Water Resources in Protected Areas

Springer

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Management of Water Resources in Protected Areas: An Introduction

Biodiversity is one of the most important elements in defining a protected area. However, the protection of these areas requires a holistic understanding, keeping in mind all of the elements of the natural and social environments.

On a global scale, there are more than 100,000 protected land and marine sites. These areas cover almost 19 million square kilometers (nearly 4 % of the global surface). An immense majority of the sites are terrestrial. Among them, 149 are of exceptional natural value in the most varied environmental conditions. The terrestrial aquatic ecosystems only occupy a small area of the planet, but it may consist of the most threatened biomass and habitat by human activities (Dudley 2008).

Natural ecosystems are heavily dependent on water, as it is essential for the development of life. The ecology and landscape play an important role in the quality and availability of water. It is no coincidence that exceptional hydrological phenomena are found in protected areas. Such is the case of the geothermic occurrences (principally, geysers) in US Yellowstone National Park, the oldest park in the world. The Ramsar wetlands (where the ecosystem dependency on water is strongly evident), the Iguazu Falls (on the border of Argentina and Brazil), or the Zapata Swamp (the largest of its kind on the Caribbean islands) further exemplify this point.

The relationship between the protected areas and the conservation of terrestrial waters is complex. Many real and perceived incompatibilities and challenges arise when considering this relationship (Dudley 2008). However, in many cases, the conservation strategies of the hydraulic resources in protected areas are ignored, or simply deprived of the attention they require. There are many types of suitable management strategies for planning and protecting our valuable treasures. Therefore, water resources management in protected areas is an issue not to be separated from the rest of the conservation measures. The relative considerations to terrestrial waters should be integrated in the administration of all the outstanding protected areas that, on the other hand, should be negotiated in function of their bioregional context and of that of their hydrographical basin in the widest sense (Dudley 2008).

The first *Symposium for the Management of Hydraulic Resources in Protected Areas* held in Viñales National Park, western Cuba, was intended to be a framework of communication about experiences with water resources management in protected areas. Advances in research and possible solutions to the problems within these areas were discussed.

Forty papers from Europe and America were accepted in this meeting. They are grouped under six main parts. The first part is dedicated to **Purification and Reuse of Wastewaters in Rural Communities**. Four chapters (10 % of the book) are related to the theoretical aspects of these processes and present several case studies, especially those that refer to extensive methods. These methods comprise multiple environmental compensations as compared with conventional or intensive treatment systems. The most important are low energy consumption, CO_2 absorption, landscape integration, new habitats for flora and fauna, low sludge production, and solid waste reuse (de Armas et al. 2006). These characteristics render these methods suitable for the integration of protected areas. Proposals to integrate these strategies in the normative document and management plan of protected areas and two examples of their application in Spain and Mexico are presented.

The **Impact of Public Use on Water Resources** (8 % of the book) is analyzed in the second part. The first chapter shows a combined strategic environmental assessment and impact characterization procedure to analyze the impact of human activities on water resources in protected areas through an example from Salamanca, Spain. Other two chapters show the effect of human activities in coastal karst aquifers of Cuba by means of hydrogeochemical analysis. One evidences the human influence over the chemical denudation rate, and the second examines it on the acting hydrochemical processes.

For protected areas, groundwater vulnerability maps are highly desired as management tools, because they help in delimiting protection zones, classifies their importance, and thus show where most management attention is required (Williams2008). Several studies (13 %) of **Vulnerability and Risks of Aquifers** are presented in the third part. Research related with vulnerability of groundwater and strategies for defining the protection zones in selected study areas are presented in this part. The part begins with two chapters on the use of geophysical methods in sensitive zones of Cuba and Spain. The next chapter comprises three papers that exemplify the importance of vulnerability mapping and an adequate definition of protection zone in karst terrains. The fourth chapter the results of the application of EPIK and PaPRIKa in tropical karst areas. The part ends with the first approach for the assessment of groundwater resource protection zone at Viñales National Park, western Cuba.

The applications of Geographic Information Systems (GIS), remote sensing, mathematical models, and hydrochemical studies are presented as tools for the **Design and Management of Water Resources in Protected Areas** of Cuba, Ecuador, and Spain, exemplified in seven chapters. In this part (18 %), the use of GIS and remote sensing is presented in three chapters, one of which determines flood risk assessment in a river basin at the southwest of Salamanca, Spain. Other two chapters show the application of a distributed water balance method model for assessment water excess in the high and medium basins in Ecuador and other, the use of GIS as a platform for integrate diverse database and as results, a 3D geomodel design in a detrital aquifer located in

Madrid, Spain, are presented. An application example of a simulation model based on system dynamics in a protected area and its urban surrounding area in Cuba is presented. Two studies in wetlands are also discussed: one, related to hydrogeochemical studies, is used to define the relationship between surface water and groundwater in an important coastal wetland of Almería, Spain, and the second deals with the analytical framework for the study, planning, and management in an important Ramsar site in Ecuador. The management techniques applied to small watersheds in the mountain karst of the Humid Tropics are exemplified in the case of the Santo Tomas Cave hydrologic system, highlighting the most hydrological features controlling surface and underground runoff and the related biogeochemical hydrodynamics.

Forty-three percent of the book is dedicated to exemplifying the importance of **Research and Monitoring of Water Resources in Protected Areas**. A great diversity of studies on protected areas of America and Europe are presented. The importance of fundamental and applied research in these areas and the design and operation of bio- and hydrochemical monitoring networks are expressed in the chapters presented. Major and minor changes in biodiversity and in the physical framework sustaining the local environment could not be detected without efficient operation of properly designed monitoring networks (Molerio and Parise 2009). Adequate research on the environmental and particularly on the ecohydrological variables is still needed in protected areas. In the particular case of the tropics, the transport of nutrients remains one of the most important tasks to be achieved.

This part begins with a preliminary hydrogeological characterization in a protected area of the Dominican Republic, followed by a chapter about underground water of deep circulation in karst terrains of western Cuba and a study of the capacity of recharge in a protected area of Mexico. Two chapters on rainfall-runoff relationships in Spain and Cuba and nine related to studies of chemical and microbiological composition of water showed interesting examples of contamination by bacteriological and emergent contaminants. A study of seawater intrusion by means of hydrochemical models and geophysical methods in coastal karst aquifers show the importance of multidisciplinary studies. The part concludes whit a study about the seasonal behavior of the vegetation at the complex lagoons.

The last part is dedicated to **Information, Popularization, and Training**, occupying 10 % of the book. Four chapters are included, one of which is related to the strategies used in Cuba for effective management of water. The second one is dedicated to exemplifying the use of geodiversity and hydrological heritage as a tool for educational itineraries that help promoting their conservation through knowledge. In the third chapter, recent observations on the geology of the Cuban occident as well as the most important aquifers and the geomorphology of their basins are exposed. The last chapter is a revision of the importance of Alexander von Humboldt's work in Cuba that is integrated nowadays in the National System of Protected Areas in Cuba.

The diversity of topics discussed in this book makes it a valuable consulting document for the personnel that work directly or indirectly in the field of water research, especially in protected areas. Thus, they deal with common interests identified in protected areas and underline the importance of knowing properly the qualitative and quantitative characteristics of water resources, in order to establish efficient measures for management and conservation of natural resources in protected areas.

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The first symposium on Management of Water Resources in Protected Areas, Viñales 2010, was organized by the Viñales National Park (ECOVIDA), the National Center of Protected Areas of Cuba and the Madrid Institute of Advanced Studies in Water Technologies (IMDEA water) of Spain, as part of the agreement for collaboration among these institutions. We thank equally those people and institutions that supported the organization of the event and the realization of the book.

This book is a contribution to the improvement of the Management Plans of Protected Areas, offering a more holistic focus to the study of those natural ecosystems that come under the diverse handling categories defined by the UICN.

Contents

Part I
Purification and Reuse of Wastewaters in Rural Communities

Chapter 1
Wastewater Problems in Rural Communities, Their Influence on Sustainable Management in Protected Areas

J.L. Corvea, Y. Martínez, A. Blanco, I. de Bustamante Gutiérrez, and J.M. Sanz

Abstract Managing wastewater treatment is a valuable alternative for water resource depuration and reuse in small rural communities. This is actually a common practice and is being implemented in territorial planning, based on sustainable use of the diverse systems. Despite the advantages and positive experiences obtained by the use of these techniques in small human settlements, its influence as criteria to evaluate the effectiveness of the natural spaces management can be understood by the administration and management team as a healthy indicator of the ecosystems coming from "secondary effects and reactions". This paper presents methodological bases for the union of wastewater management as a key factor for standard procedures for protected areas, taking into account the phases of diagnostic, normative, programmatic and cartography.

Keywords Ecosystems • Wastewater treatment management • Natural depuration systems • Spain

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1.1 Introduction

Water as a natural resource is an element of major importance for the physical environment as well as for the individuals who live in it. Water controls a majority of the processes that occur in nature, shapes the landscape, is essential for the survival of living beings, regulates the natural cycle of ecosystems, and interacts with a majority of abiotic elements that intervene in the conservation of protected spaces. As a management element, wastewater generated from any source where human activity exists may produce severe damage to natural systems. Therefore, measures have to be taken to avoid environmental problems. A sound water management procedure allows for the preservation of natural ecosystems in optimal conditions for which natural depuration techniques are of great value.

The proposition presented by this paper does not pretend to modify the actual standard methods, but attempts to complement it by adding new procedures to the process of decision making regarding wastewater management.

1.2 Environmental Advantages of Natural Depuration Systems (NDS) Over the Conventional Techniques of Waste Water Treatment

Natural Depuration Systems (NDS) comprise multiple environmental benefits compared to conventional or intensive treatment systems, especially those used for wastewater treatment in rural communities that are closer to naturally protected territories. Among those benefits, the most important are (de Armas et al. 2006):

- Low energy consumption
- CO_2 absorption
- Landscape integration
- New habitats for flora and fauna
- Low sludge production
- Capacity of use products and by-products of the depuration processes like wood, ornamental or livestock feeding species for their later sale (Salas et al. 2006)
- Some other advantages are considered such as the potentiality for environmental education. These facilities are often supported by many people due to the environmental services associated with its function.

According to Zavala (2006), water resources, soils, geology and geomorphology are features that were not incorporated into the guidelines to select sites for conservation, nor integrated into the Management Programmes of the Protected Areas. Therefore, it is necessary to include the abiotic elements as key factors for the management of protected spaces. The use of soils and water should be regulated to avoid negative effects on the biodiversity of the zone.

Wastewaters are usually the cause of severe sanitation problems in rural communities due to the economic constraints that limit the application of appropriate measures (Nogueira et al. 2006). NDS also encompass environmental disadvantages, such as the eutrophication of water reservoirs, producing a spectacular bloom of aquatic vegetation, when the design for the NDS is not appropriated or the terms of operation are violated. Usually excess water discharged into the system and the overload in terms of pollutant concentration is the limiting factors that cause system breakdowns. Another problem regarding the use of NDS is the land extension needed to implement the project.

Assuming Salas et al.'s (2006) statements, it can be summarized that NDS is an appropriate technique that can be extended to protected areas due to its economical, environmental and social benefits. From the environmental point of view, this wastewater treatment technique provides, along with water quality improvement, habitat conservation and perfect integration with the local environment. Regarding economic terms, it reduces costs of implementation and management. Socially speaking, the fact that constitutes a source of local employment and the facility may be of importance as a centre for environmental education for local inhabitants.

1.3 NDS Integration with the Management of Protected Spaces

As appointed by Salas et al. (2006), NDS provide services for decentralized management of wastewater, which are possible sources of other resources for the rural environment if included in the production cycle as an alternative for agricultural activities by turning wastes into agro fertilizers and other purposes.

Most of the protected spaces, no matter its management category, include certain regulations that lead to the conservation of the main natural resource. Those spaces with more strict regulations, such as public use, the presence of human settlements and the existence of economic and social activities, are almost absent. Some others include recreational possibilities as well as the development of activities related to the sustainable management on the local environment; nevertheless, it is less probable that both spaces are not affected by the negative impacts of wastewater flowing out to the neighboring communities.

Yet NDS, as an alternative for wastewater treatment, offers interesting environmental services; the management of the existing capacities in rural settlements associated with protected areas is usually a local or state government or a competition of private agencies.

Although there is proper operation of these technologies, only in fewer occasions the administrations in charge of protected ecosystems make use of them in their management plans. In this sense, the water resource should be evaluated not only

Table 1.1 Proposal for the diagnostic stage

Methodology for the management plan compilation (Cuba)	Proposal for NDS use
I. Diagnostic stage	
1. Description of natural conditions	
Brief description of the territorial context	Identification of water and waste water problems. Types of treatments. Operation conditions. Plans for new facilities for waste water treatment
2. Natural resources	
Geology	Description of the main tectonic features that may influence water dynamic
Climate	Bioclimatic features
Hydrology and oceanography	Hydrogeological features. Rock properties, types and distribution of the aquifer, water recharge and discharge, irrigation and flooding areas, pollution vulnerability
Soils	Hydrological properties of soils permeability, porosity, water retention coefficient and soil depth
Biodiversity	Aquatic flora. Water and water dependent fauna
Landscape variety	Description of aquatic habitats and there conservation
3. Socio-economic features of the area and surrounding	
Description of the economical bases	Water supply system dedicated to industry, agriculture, livestock and other services. Waste water discharge
4. Selection of conservation target	
Significance	Characteristics of water resource directly related to conservation objectives
Peculiarity	Characteristics of water resource as unique conservation object
Threat level	Evaluation of the threats affecting the quality of water resource
Conservation characteristics	Water significance as object of conservation
5. Water problems identification	
Environmental problems	Water related problems
Management capacity of the area	Identification of management capacity of the area
Economic and social issues	Water related problems: quality, supply, treatment
Analysis of research needs to support planning and management	Determine needs for information regarding water, water treatment and reuse
Synthesis of the problem	Description of current water problems as a key element of conservation

because of its natural value, but also to keep it from contamination to maintain ecological integrity.

Table 1.2 Proposal for the normative stage

Methodology for the management plan compilation (Cuba)	Proposal for NDS use
II. Normative stage	
Limits and category of the protected areas	Physical and socio-economical issues related to water problems
Objectives of the management plan	Set objectives with the aim of water resource management
Zoning and regulations for the use of the area	Zoning and regulating water resource
Conservation zone	No intervention on water resources admitted
Public zone	Obligation of using natural depuration systems compatible with the management category
Cultural and historical zone	Enhancement and promotion of the traditional usages of water resources
Zone for genetic resources	Prohibition of human intervention
Restoration zone	Regulation of water pollutants
Administrative zone	Meet the water standards
Socio-economic zone	Regulate the use of chemical and organic substances
Buffer zone	Keep close control on pollution sources
Marine zone	Meet the water standards

1.4 Proposal to Incorporate NDS to the Management Plans for Protected Spaces

Based on the methodology to compile the Management Plans for Protected Areas in Cuba (Gerhartz et al. 2008), and considering the priority attention to water resource conservation, some methodological bases are proposed to include wastewater management as a key element for the protected areas' official documentation.

These bases are not meant to replace any normative document that actually regulates the management of protected spaces. The intention is to include at every step of the current methodology the wastewater issue and the existing variety of techniques for wastewater treatment, without modifying the content and formality of the current procedures.

1.4.1 Some Proposals to Establish the Methodological Bases

- DIAGNOSTIC STAGE: Normally, during this phase the water resource is taken into consideration as a specific section: Hydrology and Oceanography, although it is possible to integrate a group of elements that simplify a detailed description about natural water and wastewater characteristics, attention must be paid to

Table 1.3 Proposal for the programmatic stage

Methodology for the management plan compilation (Cuba)	Proposal for NDS use
III. Management plans	
1. Protection programmes	
Surveillance and protection programme	Set surveillance systems for water resource control and installed depuration systems
Fire protection programme	Protection of water supply sources
Plans against disasters	Control over zones with potential risks, danger and vulnerability to water related disasters
2. Resource management programmes	
Forest management plan	Identify actions for water resource conservation
Management plan for species, habitats and ecosystems	Identify vegetal species compatible with NDS
3. Public use programmes	
Tourism programme	Integrate NDS wastewater stations into visits
Programmes for information, education and interpretation	Introduce activities related to water conservation, use, depuration and reuse
4. Programmes for scientific research and monitoring	
Research programme	Carry out research about water quality, ecosystem conservation and vulnerability
Monitoring programme	Set monitoring network
5. Administration programmes	
Administration programme	Create infrastructural, personal and resource capacities
Programme for compilation and actualization of management plans	Water issues have to be permanent and high-priority
Signalization programme	Introduce signals along natural water bodies, water springs and NDS facilities
Training programme	Include water subjects at every training activity
Public relation programme	Set partnerships on water management
Maintenance programme	Define actions for infrastructure maintenance
Investment programme	Declare explicitly the investments to be carried out in relation with water management

their natural values and socio-economic and cultural features of the sites. Using all this information, a varied description of the current water situation in the area is made, including its potential use and the environmental problems concerning water management (Table 1.1).

- NORMATIVE STAGE: It is important at this stage, to integrate all possible aspects to fulfill current regulations in the country, especially those related to protected spaces, as wastewater is a key element for the management of protected areas. Regulation for the use and actions regarding water resources must be specifically addressed to provide a safe and stable water resource. A sound area zoning must be performed to include any harmful factors (Table 1.2).

- PROGRAMMATIC STAGE: Once this stage is concluded, the ending point of the management plan, it is important to consider the potentialities of each programme in order to integrate activities and actions towards a sound water resource management, whether it is for conservation purposes as a natural element or for later reuse as is shown in the next table (Table 1.3).
- CARTOGRAPHY STAGE: It is recommended at this stage to draw maps representing the diversity of elements related to water resource, such as Slopes, Geomorphological units, Hydrogeology, Aquifer vulnerability, Water pollution sources, Pollution risks, NDS location, and Groundwater protection zones.

1.5 Conclusions

The methodology proposed in this paper might constitute a useful tool for decision makers for the integration of Natural Depuration Systems (NDS), within the Management Plans. Wastewaters are the possible cause of the collapse at any average ecosystem, especially those in rural and conservation areas.

Although NDS are managed by foreign institutions, private or public, data of the results derived from its operations must be part of the management and planning in protected areas.

This proposition will be more complex in those places where a karstic component of the substrate occurs, due to the complexity of the surface and groundwater karst systems.

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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 Gutiérrez, 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).

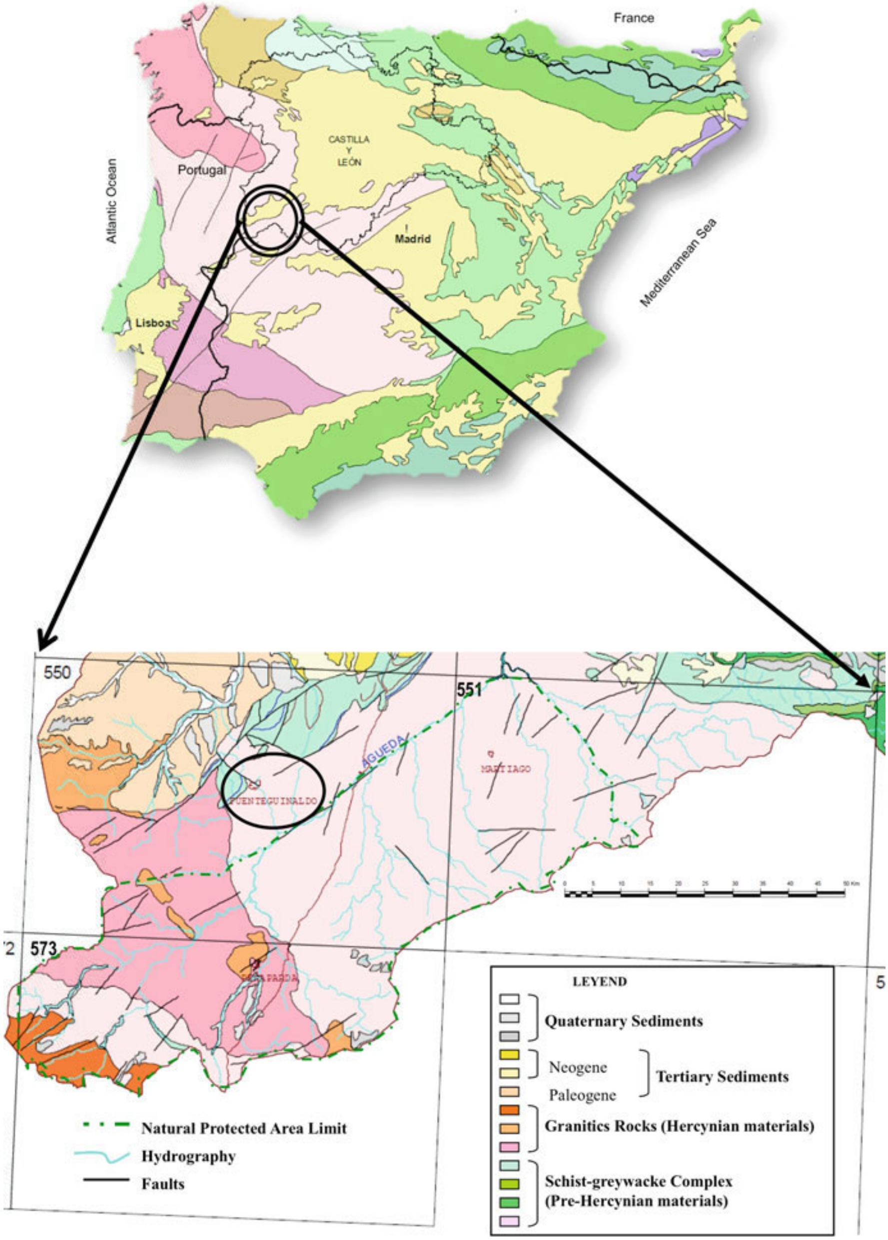

Fig. 2.1 Location map

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).