THE DEPURANAT PROJECT: SUSTAINABLE MANAGEMENT OF WASTEWATER IN RURAL AREAS

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Abstract

The DEPURANATt project received co-financing from the European Union through its inter-regional cooperation programme, Interreg IIIB Atlantic Arc Programme. This project, coordinated by the Canary Islands Institute of Technology, allowed French, Portuguese and Spanish institutions to work together on sustainable management of wastewater in rural and protected areas.

Within the framework of this project, twelve natural wastewater treatment systems have been built or adapted from pre-existing systems in Portugal, Andalusia and the Canary islands. In these systems, a shared ambitious protocol of physical-chemical and microbiological analyses was established, and several studies carried out with respect to the agronomical quality of the effluents and the physiology of the plants. These analytical campaigns also attempted to promote a positive image of these systems to, and in, the rural areas.

Moreover, it is important for the target publics to value correctly the possibilities created by regenerated wastewater and vegetal biomass, and thus accept the same as integral methods which contribute to sustainable local development. Several studies relating to social integration were focused, to this end, on measuring people’s acceptance of these systems in their areas, whereas the environmental impact of the systems was determined using an adapted life cycle assessment methodology.

The economic analysis of the systems focused on analysing the financial indicators, empirical cost functions, and the potential market for these technologies.

Furthermore, maps of potential areas where natural wastewater treatment systems may be implemented have been created. Finally, a support tool for deciding upon the installation of conventional or natural wastewater treatment systems has been designed with the aim of informing at technicians about the most suitable technology to be applied in each situation.

Keywords: natural wastewater system, sustainable management, potential implementation, evaluation, life cycle assessment.

Introduction

In the rural areas of Spain, Portugal and France, inside, or in the vicinity of, protected natural reserves, the population settlements are usually scarce and disperse, often lacking in sewage and adequate water treatment plants. Environmental values and the need to promote sustainable development based on the protected natural area for the local populations leads, necessarily, to the problems relating to wastewater treatment figuring on the agenda, and in such a way that, rather than being a perceived weakness, these plants can be converted into strength and even an opportunity for socio-economic development.

The centralised wastewater treatment plants and their associated costs, both in terms of investment and maintenance, are not the only possible solution to the problem in rural areas, where there are also limited financial and management resources. The present European policy encourages the implementation of systems of water resources management efficient and totally environmentally integrated. This tendency is specially related with the wastewater treatment systems which allow to protect the large masses of water of pollution and to optimise the financial resources of exploitation. It is within this framework that the DEPURANAT project was born. DEPURANAT was designed 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.

This initiative which was co-financed by the European programme INTERREG III - B "Atlantic Area", depended upon the close collaboration of entities of diverse nature, local authorities, research centres and technological development, together with private companies and associations.

The partners of DEPURANAT decided to call the systems, *Sistemas de Depuración Natural (SDN)*, (Natural Reclamation Systems, NRS). This decision was made given the structure of the systems which did not consist merely in setting up artefacts to treat the water, completely divorced of other environmental considerations. On the contrary, NRS have been conceived as a matter of implementing complex systems of social, environmental and economic integration which would allow for a close-knit fit between the activities generating of wastes, the people of the area, the local environment and the valorisation of by-products generated from each wastewater treatment system.

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. As a result, the development of this type of 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.

Methods

The DEPURANAT project organised the work over four different scientific and technical programmes, plus two further programmes designed to guarantee trans-national cooperation, to give broad publication to the results and to promote training and employment. The methodology applied to develop the scientific and technical programmes can be summed up under the following headings:

Experimentation and demonstration of the technological, social and environmental aspects of the by-products of the system and the way to which they can be made use advantageously.

There were four work packages in this programme:

- Evaluation and design of pilot wastewater treatment plants.
- Construction and adjustment of pilot projects.
- Evaluation and control of pilot wastewater treatment plants and potential by-by-products.
- Development and evaluation of social and environmental integration.

The methodology used was as follows:

- Agreement upon the criteria to be used and the information to be collected for choosing new locations and pre-existent wastewater treatment plants to be included in DEPURANAT project monitoring, within the geographical sphere of the project. The chosen wastewater treatment plants must be based on low-cost energy technology and to allow a proper evaluation of the by-products generated.
- Design of the basic layouts of the wastewater treatment plants and exploitation to be implemented in the new building projects together with proposals for re-adjustment of existing plants plus including a previous training process, designed for collaborating businesses and technicians.
- The establishment of a shared protocol of basic analytic monitoring, to evaluate the performance of the wastewater treatment plant and to supervise the correct operation of all the systems.
- The development of specific protocols for the microbiological analysis of the NRS.
- The development of specific protocols for the agronomical evaluation of the recycled water in each influenced area.
- Analysis and classification of the wood and vegetable biomass generated in the NRS.
- Monitoring of the environmental parameters of the NRS.
- Research, development and application of methods designed at enhancing the social acceptance of the SDN and the participation of local stakeholders in the decision-making processes, operations and benefits of the systems.

Market study, economic and environmental feasibility of the NRS.

The economic analysis was focused to define financial indicators for the overall design of the empirical functions of costs, together with a preliminary evaluation of the potential market for these technologies.

The environmental evaluation, apart from monitoring in situ the environmental parameters, was carried out using the method Life Cycle Analysis (LCV) of different potentially usable technologies, above all the Constructed Wetlands, Green Filters and Activated Sludges. The LCA included the phases of building, operation, maintenanceand dismantling of the systems. The variation in the environmental impact of the different wastewater treatment systems tested was reflected using several different descriptors, e.g. global warming.

Development of a methodology to study the potential of the application of the NRS in any given territory. Applications, by way of demonstration, in complex island environments.

Several tools were designed to allow for the drawing up of maps of potential implementation, based on Geographic Information Systems (GIS), which took into account the peculiarities and specific nature of the rural environments, whilst analysing the potential demand for implementation of NRS in rural areas. These maps allow us to locate areas of high potential for the implementation of NRS which, moreover, are respectful of the characteristics of the territory and are adapted to the wastewater characteristics. 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 of note, such as the climatic conditions, the altitude, the slopes of the land , the types or uses of the land, are factored in these maps.

Development of support tools for decision-making

It was looked at the possibility of developing software which would integrate some of these experiences implemented in the project with the knowledge collected from the existing literature, about low energy cost and extensive wastewater reclamation technologies. This software can help at professionals who are responsible for taking decisions to do so efficiently in all of the cases, tackling all the problems associated to small-scale wastewater treatment.

Results and Discussion

Experimentation and demonstration

12 pilot projects of wastewater treatment were, either, adapted and submitted to constant monitoring or built, as way of demonstration:

- A green filter in VilaVerde, a municipality in the North of Portugal, in order to value the reclaimed wastewater by a Sequential Batch Reactor designed for 120 population equivalent (P.E.).
- 2 parrallel functioning green filters in the Planta Experimental de Carrión de Los Céspedes (PECC) in Sevilla (Spain), designed for some 40 P.E. in winter and 120 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 P.E., respectively, located the Rural Park of Teno, 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 on the islands of Gran Canaria Island and the third one, on Tenerife Island (Spain). These installations were designed for 30 and 70 P.E., respectively.
- 4 pilot installations with various combinations of wetlands (horizontal and/or vertical flow), inert substrates and mono-specific cultures of aquatic macrophytes, in the PECC, in Seville,

and in three locations on Gran Canaria Island. Two systems were designed for 100 P.E. and the other two, for 15 and 25 P.E., respectively.

In general, it has been obtained optimum removal efficiencies in most of the systems tested, higher than 90% for organic and solid matter in suspension. The concentrations in the effluents over the period of study were in accordance with the required levels of European Directive 91/271, for wastewater treatment plants for over 2,000 P.E.

From the point of view of microbiological quality, an exhaustive monitoring programme of indicators of faecal contamination, bacterial indicators, parasite protozoa, helminth eggs and enteric viruses was carried out in several pilot projects. The average reductions were between 97 and 99.9%, that is, between 3 or 4 $\log_{10}$ units for wastewater comparable to domestic sewage. By way of reference, nematode eggs were no detected or any other type of parasite helminth, except at the entrance to one of the pilot project which received effluents from the milking dairy. However, at the exit of this installation, only an average of 0.02 eggs per litre was isolated.

In the absence of a European or any regional guidelines for the evaluation of the agronomical quality of reclaimed wastewater for re-use, it has been used the concepts of Short-Term Limit Concentration (LCC) and Long-Term Concentration (LTC) as established by ANZECC, 2000 and USEPA, 2004 together with the blueprint for the Spanish Royal Decree for Wastewater Reuse, as references.. The main parameters which are taken into account for these references are BOD_5, Suspended Solids, turbidity and coliforms (USEPA, 2004) together with the EC, N, P, K, B and SAR. According to our results, the options for reuse irrigation, in line with USEPA references, could be for crops of indirect human consumption, recreational uses not involving human contact, environmental uses and recovering of natural wetlands. With respect to the 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).

With respect to the work carried out on the social integration of the systems, we should highlight, as the most tangible result, the organisation of various technical seminars with public participation. These seminars have allowed 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, a method of analysis and specific recommendations has been formulated to improve social integration of the pilot projects. These recommendations draw attention to the need to establish optimum parameters of maintenance and management using protocols and promoting the direct participation of the local people.

The Economic Study

An exhaustive and complete inventory of the twelve pilot projects allowed defining investment and operational costs of the treatment plants and developing functions of cost analysis, which show the following aspects:

- The investment costs are similar over the different types of pilot projects. The costs of equipment, in general, constitute a very small fraction of the investment costs. The variation in the cost of investment (€ per P.E.) and the operational costs (€ per P.E.) tend to diminish as the population increases.

- 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 who carry out other tasks in the place, for example, the management of a hostel, the guards of a natural area or as well if the local population understand the advantages of managing the system.
- 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 potable water (desalination of seawater or exploitation of aquifers). This is a decisive factor for the economic feasibility of the pilot projects as generating of reclaimed wastewater for reuse.

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 the production of steel, used in the aeration system.
- 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) is responsible for the environmental impact in the phase of operation and maintenance in the treatment by Activated Sludges, whereas in the case of the Green Filter, 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, above all those based on Green Filter 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 Sludges aggravates climate change.
- The general 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. 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.
- It is needed to control rodents and various invasive plant species.
- In general, there has been no detected modification of the surrounding ecosystem, nor propagation of the vegetable species used in the NRS.
- 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 aspect by all who visit the pilot plants.

Market studies and territorial potential

In general, in the European Atlantic Area, the situation is identical, with a high concentration of population nuclei under 2,000 inhabitants. In Spain, there are six thousand of the eight thousand existing municipalities with 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 need for 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 areas of the Canary 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 of worrying. These wastes are usually decentralised and possess 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.

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 of natural reclamation processes 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 European Atlantic Area.

The results show the potential of the European Atlantic Area for implementation of low-cost energy wastewater treatment plants. 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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