An Environmental Decision Support System to Identify the Most Appropriate Wastewater Treatment Process. From Catalonia to Latin America

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Abstract. To define the most appropriate process to treat urban wastewater is not an easy problem to solve. This definition represents a complex problem that requires the participation and the consensus of different agents (social, economic, environmental). In order to confront this problem, the Catalan Water Agency developed an Environmental Decision Support System (EDSS). This EDSS has proved to be a good tool to help in the planning process to select adequate wastewater treatment options. Therefore, we propose the reutilization of the Catalan EDSS in Latin American regions. This paper presents the EDSS developed by the Catalan Water Agency and a preliminary study for the adaptation of this tool in Latin American regions.

1 Introduction

1.1 Urban Wastewater Treatment in Latin America

Latin America is a region rich in water resources: it has almost a third part of the renewable water resources of the world [1]. Although, exist marked differences in the endowment of water and its availability among regions. For instance, Mesoamerica, the Andes or the north-east of Brazil, are regions which suffer lack of water [2].

Many challenges of water in Latin America gather in two basic problems: decrease of the available water and loss of its quality. The decrease of reserves happens because of the impact of deforestation, urban expansion or excessive extraction (stimulated by the population growth and the agricultural and industrial demand). The quality loss is originated in the lack of wastewater treatment, the excessive use of fertilizers and pesticides, and the pollution by industrial, mining and energetic sources. Also, the quality loss is influenced by the undervaluation and ignorance of the need to support "minimum flows" (it is to say, the water necessary for other vital functions of the natural ecosystems) [3].

Nowadays, 21% of the Latin American population does not have access to any type of sanitation, 30% only possesses septic tanks, and 49% has access to sewer, though in the great majority of the cases without treatment of effluent [3]. Moreover, Governments and the private sector in many Latin American countries fail to fully recognize the necessity of wastewater treatment and the importance of water quality to improve the quality of life of existing and future generations [4].

The contamination of natural resources is a major obstacle to achieve the stated objectives of Agenda 21 for environmentally sustainable economic growth and development. Chapter 18 of Agenda 21, the Action Programme of the United Nations Conference on Environment and Development (UNCED, held in Rio de Janeiro, Brazil, in 1992), deals with the utilization of appropriate technologies in water supply and sanitation. Improved access to information on environmentally sound technologies has been identified as a key factor in developing and transferring technologies to and among developing countries. Chapter 34 of Agenda 21 addresses this need by promoting the transfer of environmentally sound technologies, through improved cooperation and building capacity, among developing countries. The primary means of transferring environmentally sound technologies is through improved access to technical information that will enable developing countries to make informed choices that will lead to the adoption of technologies appropriate to their situations [4].

In any way, relatively simple wastewater treatment technologies can be designed to provide low cost sanitation and environmental protection while providing additional benefits from the reuse of water. These technologies use natural aquatic and terrestrial systems and can be classified into three principal types: (a) mechanical: oxidation ditch, extended aeration, sequencing batch reactor and trickling filter; (b) aquatic lagoons: facultative, aerated and HCR (hydrograph controlled release); and (c) terrestrial: slow-rate, overland flow, rapid infiltration and subsurface infiltration [4].

1.2 Urban Wastewater Treatment in Catalonia

Catalonia (the north-east of Spain) is located into the Mediterranean region. This involves a significant aridity during three or more months in summer. Despite spring and autumn can give torrential rains, during summer months the amount of water can be insufficient to attain urban, industrial, agricultural, etc. demand, as well as to guarantee the "minimum flows" in the rivers. Like in Latin America, the lack of water is not the only problem; the water quality is also an important problem. In Catalonia lots of industries, farms, villages and cities are located along the rivers and they spilled their wastewater into the stream, without any treatment.

In order to confront this problem and to comply the 19/1991 Law [5] and the 91/271/ECC European Directive [6], the *Generalitat de Catalunya* (Catalan Government) approved, in November 7th 1995, the *Pla de Sanejament* (Sanitation Plan). This plan was divided in 5 programs: (a) Industrial Wastewater Treatment Program, (b) Urban Wastewater Treatment Program, (c) Cattle Wastewater Treatment

Program. (d) Agricultural and Diffuse Wastewater Treatment Program. and (e) Sludge Treatment Program. Our group effort was focused in the Urban Wastewater Treatment Program, the so called *Programa de Sanejament d'Aigües Residuals Urbanes* (PSARU).

The PSARU was divided in two parts. In the first one. the definition of wastewater treatment plants (WWTPs) for communities with more than 2000 inhabitant equivalents was done, and represented an increase up to 300 facilities. According to the European Directive, whenever possible, these WWTPs must be based on biological processes. The main technology used for biological wastewater treatment is the activated sludge system. The design and building of this kind of WWTPs is typically an engineering problem. The flow to treat and the pollutants concentrations of the wastewater are the input data to determine the plant's size. A team of engineers is enough to perform this work [7].

The main objective of the second part of the PSARU. the so called PSARU-2002, was the definition of WWTPs for about 3800 communities with less than 2000 inhabitant equivalents. In this case, the Council Directive [6] only specifies that the level of treatment must be appropriate. This means treatment of urban wastewater by any process and/or disposal system which, after discharge, allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives. This definition makes it necessary to consider new dimensions of analysis which will be able to combine aspects of (a) the small community and landscape, (b) the ecological status of the receiving media and (c) all the available wastewater treatment technologies for small communities (both conventional and non-conventional). Additionally, the real perception of an existing WWTP is different among urban inhabitants, who in most cases are not conscious of it, from rural inhabitants, who are aware and suffer its malfunctioning when it occurs [7]. Integrating all the considerations of these three dimensions leads to a scenario with a multi-disciplinary set of sustainability indicators, since it considers the technical aspects of treatments but also the economical, environmental and social aspects. Therefore, the decision process of selecting the optimal treatment changes significantly as it requires the integration of knowledge of experts from different disciplines [8].

The great number of small communities and the complexity related to the definition of the most appropriate treatment led the Catalan Water Agency (*Agència Catalana de l'Aigua*) to design a tool built upon the concepts and methods of human reasoning. An Environmental Decision Support System (EDSS) based on expert knowledge was chosen as the most suitable tool to support the identification of the adequate wastewater treatment for small communities [8]. An EDSS is a computer system that assists environmental decision makers in choosing between alternative actions by applying knowledge about the decision domain to arrive at recommendations for various options. It incorporates an explicit decision procedure based on a set of theoretical principles that justifies the *rationality* of this procedure [9]. Also, an EDSS can reduce the time in which decisions can be made [10; 11].

The developed EDSS offers plausible proposals to the end-user not only concerning at the level of treatment (primary, secondary, nutrient removal, or nutrient removal plus disinfecting), but also a set of possible treatment options (e.g. extended aeration, tricking filter, rotating biological contactor, sequencing batch reactor, waste stabilization ponds, high-rate pond, constructed wetland, intermittent sand filter, buried sand filter and plant soil treatment). Those alternatives are hierarchically prioritised, taking into account the receiving media impact, the investment, the operation cost, etc.

To develop and implement the EDSS that enables a multi-disciplinary approach to the problem mentioned above, the Catalan Water Agency commissioned four universities from Catalonia and the Spanish Scientific Council (CSIC).

1.3 Proposal

The Latin American Governments and the Catalan Water Agency try to solve the same problem: to choose the most appropriate wastewater treatment system, for communities with scarce resources (both economical and human), in order to improve the streams water quality. In Catalonia, the development and implementation of an EDSS allowed the definition of the most appropriate treatment for communities with less than 2000 inhabitant equivalents. Therefore, we propose the application of the EDSS developed in Catalonia, in the Latin American regions. To perform this application, it will be necessary to make some modifications in the current EDSS.

This paper details, in section 2, the development of the EDSS, as well as its application in Catalonia in section 3. Also, in section 4, we reason about the necessary modifications to export the EDSS from Catalonia to Latin America and give some conclusions.

2 EDSS Development

How a particular EDSS is constructed will vary depending on the type of environmental problem is being investigated and the knowledge that can be acquired [12]. The EDSS which recommends the most appropriate wastewater treatment alternative was developed following a standard methodology proposed by Poch *et al.* in [13]. This methodology involves the following steps (Fig. 1): (i) environmental problem analysis, (ii) collecting data and knowledge acquisition, (iii) model selection, (iv) model implementation and (v) validation.

2.1 Environmental Problem Analysis

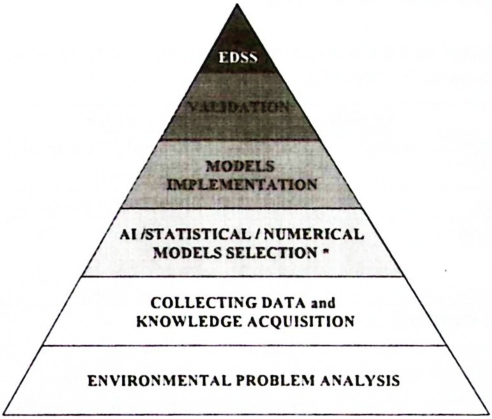
The first step in the development of an EDSS must include the environmental problem definition and a review of available information and knowledge related to this problem [14].

In Catalonia there are 200000 inhabitants (currently censed) distributed among 3800 agglomerations with less than 2000 inhabitant equivalents. The main characteristics of these small communities are:

- The main part of these communities is located in rural areas and almost 75 % have less than 200 inhabitants.

- There exists a relevant contribution of seasonal population with respect to the permanent (more than 50 % in some cases).
- The proportion of industrial wastewater in some villages can be around 25 % or more.
- Different climatic conditions are encountered among communities located at different altitudes and latitudes.

Therefore, Catalonia has a great number of small communities which present many different situations (e.g. different influent properties, climatic conditions, characteristics of the receiving media, etc.). These diverse conditions are described by lots of data, many of them qualitative, which must be processed to select suitable wastewater treatments, making this task a complex problem.



* (rule-based / case-based / model-based / evolutionary reasoning / constraint satisfaction / neural networks / simulation models / lineal models)

Fig. 1. Flow diagram for the development of an EDSS

2.2 Collecting Data and Knowledge Acquisition

Once the environmental problem analysis is finished, data collection and knowledge acquisition begin. This stage involves electing, analysing and interpreting data and knowledge that allow proposing a problem solution [14].

Data collection and knowledge acquisition. In order to build reliable knowledge-bases, the methodology proposes the use of different sources of knowledge [14]. In this case the following sources were used [7]:

- Interviews with experts in water management and wastewater treatment, as well as experts in the ecological state of the receiving environment.
- Experience gained by means of conversations with stakeholders from other neighbouring regions where the treatment of small communities has already been implemented (e.g. France and Portugal).

- Reviews from scientific and technical literature.
- A detailed data survey, sent out to each one of the municipalities, asking the characteristics of their communities, their corresponding receiving media, the wastewater generated and the possible localization to build the treatment plant (Table 1).
- Analysis of the historical data of temporary and permanent streams (the receiving environment).

As a result of the data collection and knowledge acquisition, empirical, theoretical and historical information and knowledge are included in the knowledge-bases. In the same way, the consultation of different sources facilitate the integration of the plurality of views and perspectives, as well as the goals, of each discipline involved in the environmental problem solution [14].

Table 1. Data collected with the survey to municipalities, concerning to the agglomeration and the receiving media (modified from [7])

Agglomeration characterization	
Inhabitant equivalent	° Urban / Industrial / Residential ° Permanent / Seasonal
Industry	° Low / High pollution potential
Sanitation	° % collecting pipes ° Discharging points ° Amount of septic tanks
WWTP location	° Area ° Slope ° Distance from urban area ° Distance from receiving media ° Distance from electricity ° Distance from water supply ° References of the owner
Environment typification	
	° Receiving waters uses (swim / fish / reservoir) ° Drinking water supply (wells / river / reservoir) ° Wind direction ° Rainfall information ° Temperature in colder months
Receiving waters	° Flow (if measured) ° Months with water running ° Months with water pools ° Months with dried stream bed ° Reuse area near the discharge point ° Pictures upstream / downstream / soil

Data and cognitive analysis. Data collected and knowledge acquired from various sources are analysed. Different analytical techniques can be used: statistical analysis, data mining or machine learning, etc. The results of these analyses allow to build models of the processes or to identify relevant data and knowledge [15; 16; 17].

The analysis allowed the identification of the relevant data and knowledge. Also, in order to make knowledge-bases as comprehensive and accurate as possible the data and knowledge acquired was structured and codified into three different types of knowledge [13]:

- Knowledge about the different treatment alternatives for small communities, with information about removal efficiencies, space requirements, climatic constraints, geological and hydrographical features (e.g. altitude, slope, presence of aquifers, etc.), investment and operating costs, social aspects and any advantage and disadvantage that must be considered to be implemented.
- Knowledge about the features that characterise each community and discharge point (e.g. number of inhabitants, surface available, climatic, geological and hydrological conditions, future prospects, benefits and impacts of the new WWTP, etc. and other economic, social and environmental aspects) obtained through the survey of municipalities. The answers to the survey could be subjective and hence qualitative and vague; however it is a valuable tool since it provides information about the territory and environment that can be obtained only from local knowledge. Moreover, the views of local officers often differ from those of experts and should be also included in the decision making process.
- Knowledge that allows the quantitative assessment of the characteristics and state of the receiving environment (e.g. quantity of water, presence of aquifers, sensible zones, groundwater nitrate pollution vulnerability, protected areas, etc.), which enable to set the minimum treatment level for each case consistent with the current ecological state of the receiving environment (e.g. primary, carbon removal, carbon removal and nitrification, carbon removal and nitrification/denitrification, carbon removal and nutrient removal or carbon removal, nutrient removal and disinfection).

2.3 Model Selection

After the analysis of the available information and knowledge, a set of tools can be selected (Fig.1). This applies not only to numerical models, but also Artificial Intelligence (AI) methodologies, such as knowledge management tools. The use of AI tools and models provides direct access to expertise, and their flexibility makes them capable of supporting learning and decision making processes [12]. Rule-Based Systems (RBS) is one of the sub-disciplines of AI that is used and applied more than any other AI technology [18]. RBS are usually used when the expert knowledge is general. When this knowledge is more specific, Case-Based Systems (CBS) become more used. CBS reuses some results and experience from previous particular situations that have affected the process performance [19].

Among the diverse AI, statistical and numerical models (Fig.1), we chose the RBS because it provides the best representation of the knowledge acquired in the second step. A RBS is a computer program that can mimic many human decision-making processes to deal with a specific problem. Its structure presents two main independent modules: the knowledge base and the inference engine. While the knowledge base contains the overall knowledge of the process, usually codified by means of heuristic rules, the inference engine is the software that controls the reasoning operations of the RBS.

2.4 Model Implementation

The model implementation step entails the representation of the information and knowledge acquired, according to the selected model. This information and knowledge can be represented in decision trees, matrices, mathematical equations (algebraic or differential), etc. In some cases, like in neural networks, the representation needs to include the definition of the input and output layers as well as the type of function [14].

In this stage the knowledge about the receiving environment was organized and documented in the form of decision trees as a prior step to develop a knowledge-based system for the selection of the level of treatment as a function of the receiving environment [13]. The decision trees can then be simply converted to production rules by traversing each branch from the root to the leaf. The collection of IF-THEN rules extracted from the decision trees were codified into an object-oriented programming shell, which already includes an inference engine, the computational mechanism that chains the knowledge, and allows for the development of a user-friendly front end [8].

In addition, the knowledge acquired about the treatment alternatives allowed us to build two useful matrices. One allows the qualitative comparison of the different treatments based on economic, environmental, technological, and other criteria. The other matrix associates the level of treatment established for the receiving environment with the optimal treatment system for each case. These two matrices were combined to form the basis for a *hierarchical discriminant table*, which, once codified also as production rules, became the core of the knowledge-based system to support the specific type of treatment [13].

The function of this table is to assess the value of four key variables (inhabitant equivalents, level of treatment required, water flow of the receiving media and available surface of the site to build the WWTP) for the selection of treatment and to propose one or more alternatives for wastewater treatment for each of the communities. In addition to these four key variables, we organised the remaining considerations for each type of treatment as a series of so-called *safety* rules [13]:

- *Discarding rules* include criteria for discarding a particular treatment proposed as a possible alternative.
- *Favouring rules* evaluate criteria for favouring certain treatments.
- *Disadvantaging rules* evaluate criteria that lower the value of certain treatments when they are accomplished.

The EDSS is linked with geographical information (GIS) and a numerical model, for economical estimations of each alternative. In addition, the EDSS developed provides easy connectivity with external applications, including database operations. Finally, a menu-based interface provides a simple and transparent way to communicate with end-users [8].

2.5 Validation

The main objective of the validation process is to guarantee the correct performance of the EDSS, while checking for compliance with user requirement specifications [14]. The methodology to validate the system must be carried out through a two-stage validation procedure:

Experts. During the EDSS development, results of real situations were tested by experts with different origins (e.g. Catalan Water Agency, university, consultants). This process was repeated for a wide diversity of scenarios and river basins: agglomerations near the sea, at mountains, different surface available for locating the WWTP, with large or small population, etc. The EDSS proposals were evaluated until the experts clearly agree with the alternative proposed and accepted its reasoning [7].

Stakeholders. The EDSS results for a single river basin were presented to various stakeholders (citizen groups and leaders in ecological issues) to perceive their judgement. They were quite pleased because the use of natural technologies was considered. Despite their global agreement with the wastewater treatment alternatives considered in the project, they differ in some of them (e.g. those that require alluvial sand or those planted with *Phragmites australis*) [7].

3 EDSS Application

Once validated, the EDSS was applied to each small community included in the PSARU-2002. As a result [20]:

- Around 1500 communities need onsite systems because they have less than 25 inhabitant equivalents.
- Some of the communities (378) must be connected to others and treated jointly by 132 new planned treatment facilities.
- The sewage of some small communities (762) must be collected and conveyed to already existing plants.
- The rest of communities (1237) must treat and dispose their wastewater individually.

For each solved system (whether it is a community (1237) or a set of neighbouring communities (132)), the EDSS produces a report containing the following results [13]:

- Characteristics of the community used in the reasoning process of the EDSS.
- List of selected treatment alternatives marking which have been discarded, favoured or disadvantaged.
- Environmental technical justification for the selected treatments and the reasons for discarding, favouring or disadvantaging it.
- Economic evaluation of each alternative.

Also, the EDSS illustrates interfaces to show the results to the end-user. Figure 3 shows one of these interfaces (in Catalan). In this case, seven possible wastewater treatments are proposed. Some of these alternatives are favoured (√), some are disadvantaged (!) and two are discarded (X). For instance:

- Waste stabilization pond (*llacunatge* in Catalan) is favoured because the Parlavà community belongs to a region with suitable climatic conditions for optimal performance of ponds.
- SBR and activated sludge (*fangs actius* in Catalan) are disadvantaged due to the community size. Parlavà has 520 inhabitant equivalents, and SBR or activated sludge systems are not recommended for populations with less than 700 inhabitant equivalents.
- Plant soil treatment (*filtre verd* in Catalan), is discarded because the Parlavà community is located in a nitrate vulnerable area.

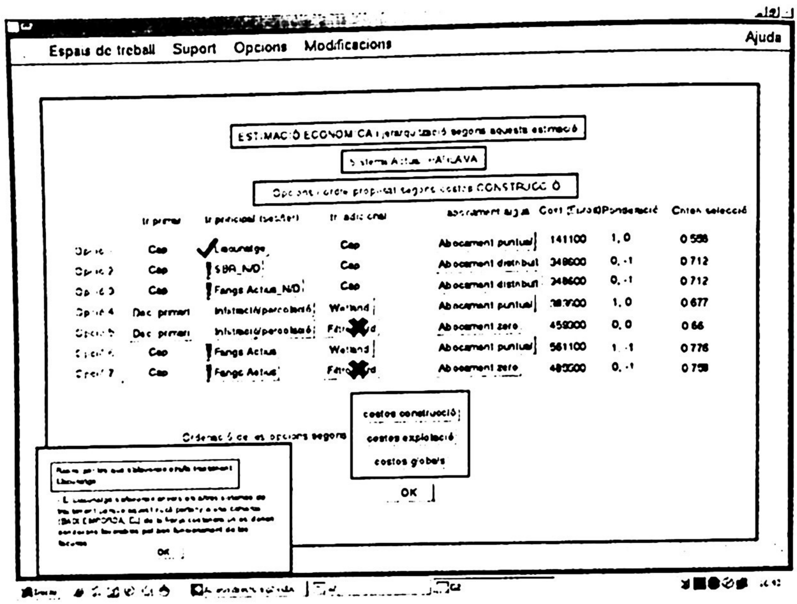


Fig. 2. User-interface showing the results of the EDSS proposal for the *Parlavà* community

4 EDSS from Catalonia to Latin America

As it has been pointed out in the introduction, the Latin American Governments and the Catalan Water Agency try both to choose the most appropriate wastewater treatment system, for communities with scarce resources (both economical and human), in order to improve the streams water quality. In Catalonia, the Catalan Water Agency solved this complex problem developing and applying an EDSS which supports the identification of the most adequate alternative for a given community. At this point the question is: Could it be possible to reuse the EDSS developed by the Catalan Water Agency in the Latin America's regions?

In a previous paper [14], we proposed a simple methodology to study the possible reuse of the knowledge and *know-how* acquired in the development of an EDSS. The proposed method has the aim to define the problem, to know its complexity degree and the knowledge required to solve it. Thus this methodology involves two steps: (1) problem description and (2) problem solution necessities. The first step involves the definition of the problem and the identification of possible EDSS that can be reused. The second step involves the definition of the *elements* needed to solve the environmental problem. Results from both steps allow studying the possible knowledge and *know-how* reutilization. If we applied this simple method in our case study the results would be the following:

4.1 Problem Description

Governments and the private sector in many Latin American countries fail to fully recognize the necessity of build WWTPs. Equally important is the fact that these facilities must be relatively simple wastewater treatment technologies, designed to provide low sanitation costs and environmental protection, while providing additional benefits from the reuse of water. Moreover, it is necessary to keep in mind that only 49 per cent of the population has access to sewer systems, although in the great majority of the cases they do not possess treatment of effluent.

Obviously, the EDSS that can be reused is the EDSS developed by the Catalan Water Agency.

4.2 Problem Solution Necessities

To solve the Latin American sanitation problem we need information related to:

(a) The communities, to characterize the influent, the climatology, the area available to build the facilities, etc.
(b) The ecological status of the receiving media in order to define the required treatment level.
(c) The available wastewater treatment technologies, which comply the three requirements: simple technology, low sanitation cost, and environmental protection.

4.3 Is the Knowledge and *Know-how* Reutilization Possible?

The definition of the Latin American WWTPs requires the integration of different kinds of data and knowledge. Also, the plurality of views and perspectives, as well as the goals, of each discipline must be considered together. In other words, both Governments (from Latin America and Catalonia) try to solve environmental problems with a similar complexity degree. Therefore, the Latin American sanitation problem could be solved using an EDSS tool. Moreover, to develop this EDSS the knowledge and *know-how* acquired in the Catalan EDSS could be reused.

4.4 Knowledge and *Know-how* Reutilization study

Despite the knowledge and *know-how* acquired in the EDSS developed by the Catalan Water Agency can be reused, some points must be reviewed.

Community characteristics. The first point to take into account is the population size. In Catalonia, the EDSS was applied at communities with less than 2000 inhabitant equivalents. For bigger agglomerations, a team of engineers designed a biological WWTP, normally an activated sludge system. In front of this divergence two possible solutions appear:

(a) Modify the rules and adapt the EDSS from small communities to communities with more than 2000 inhabitant equivalents.

(b) Apply the European criteria: for small communities define the appropriate treatment and for big agglomerations design a biological WWTP.

To collect the data from the municipalities we propose to do surveys like those carried out in Catalonia. These surveys comprise information and data necessary to characterize the agglomeration, its wastewater and the environment (Table 1).

State of the receiving environment. Data collected from the survey and an analysis of the historical data of temporary and permanent streams were considered to define the state of the receiving media, and the minimum treatment level. At this point, it is necessary to check if the defined correlation among environmental data and environmental sensitivity; and environmental sensitivity and treatment level, are the same in both places. If not, the decision trees that allow the definition of the environmental sensitivity must be reformulated and updated.

Wastewater treatment technologies. The EDSS from the PSARU-2002 proposes 3 possible primary treatments and 10 secondary treatments (Table 2). The EDSS combines the primary treatments with all the secondary treatments and, in addition, allows the combination of different secondary treatments. Also, the EDSS proposes modified secondary treatments to attain the nutrient removal (see Fig. 2). Some of these wastewater treatment technologies not comply with the three requirements mentioned above in the *Problem solution necessities*. For instance, the conventional systems are not simple technologies and, for small communities, have a considerable exploitation cost.

We propose that Latin American Environmental Agencies build their wastewater treatment systems list. This list must include, for each technology: a brief description, most common configurations, efficiencies, advantages and disadvantages, operation and maintenance requirements, problems and nuisances, and other relevant information for design, construction and exploiting. From this information, a new *hierarchical discriminant table* must be constructed. The four main variables of this table (inhabitant equivalents, level of treatment required, water flow of the receiving media and available surface of the site to build the WWTP) could change. For instance, in Catalonia, surfaces available to build the facilities are scarce (reason why this variable was included in the *hierarchical discriminant table*). Have Latin American regions the same problem?

Table 2. Different primary and secondary treatments considered in the EDSS developed by the Catalan Water Agency

Primary treatments	Secondary treatments	
	Conventional systems	Natural systems
		Waste stabilization ponds
Septic tank	Extended aeration	High-rate pond
Imhoff tank	Trickling filter	Constructed wetlands
Primary settler	Rotating biological contactor	Intermittent sand filter
	Sequencing batch reactor	Buried sand filter
		Plant soil treatment

Sanitation cost (construction and exploitation). The EDSS from PSARU-2002 provides an economic evaluation which includes the construction cost and the exploitation cost (for the first year and the following fifteen). These costs are estimated considering the salaries, materials and energetic costs from Catalonia. Thus, we recommend the reformulation of the equations that allow costs estimations, taking into account the Latin American costs.

Prioritised list of treatments. The EDSS proposes a non-ordered list of possible treatments with their favouring, disadvantaging and discarding reasons, the justifications for the proposed treatments and their investment and operating costs. To order the alternatives a mathematical algorithm named SelCrit-OE, from Selection Criteria – Ecological & Economical, was employed (*Criteri de Selecció* in Catalan, see Fig.2). The SelCrit-OE integrates and normalizes two independent terms to estimate the economical and ecological impact of each possible alternative treatment. This numerical algorithm enables the EDSS to prioritise one type of treatment and disposal system (the one with the lowest value) from all the possible alternatives proposed for each possible wastewater management solution [20].

If the Latin American Governments ordered the treatment alternatives estimating the economical and ecological impacts, the mathematical algorithm can be reused. If not, a new prioritised methodology will be necessary.

Connection criteria. Sometimes two or more communities are located closely, and then the EDSS has to decide whether to implement separate or combined treatment systems for this group of communities or connect them to an already existing or planned WWTP, leading to multiple solutions or scenarios (Fig. 3). For example, if one small community has another community relatively close by, there are several possibilities. One solution would be to treat the wastewater from both neighbouring communities separately. A second solution would be to join their sewers and plan only one new WWTP. A third solution would be to connect one or both of them to an already existing WWTP. If there are three or more nearby or related small communities, the problem becomes even more complex since the number of possible solutions increases exponentially [20].

This second disjunctive was solved by a mathematical algorithm. This algorithm takes into account three normalized and independent terms. These terms are the economical, the ecological, and the detrimental impact of each cluster system on the receiving environment (SelCrit_OED). The purpose of this second SelCrit estimation is to enable the EDSS to *accept* one of the multiple treatment solutions, while the remaining with higher impact are rejected.

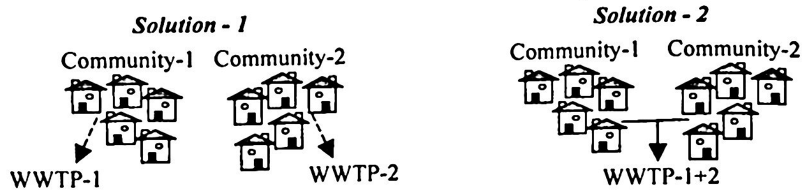


Fig. 3. Connection alternatives for two communities relatively close by

The Latin American Governments must decide whether to solve this disjunction similar to the Catalan experience. In this case, the mathematical algorithm can be reused. If not, a new methodology will be necessary.

Laws and directives. The EDSS from PSARU-2002 was developed within the Catalan and European legal frame (e.g. 19/1991 Catalan Law, 91/271/EEC European Directive, 2000/60/EC European Directive, 74/467/EEC European Directive, etc.). These laws and directives involve some restrictions or obligations in the definition of the most appropriate treatment. Therefore, we propose that each of the Latin American Governments should define own legal frame, in order to fulfil their restrictions and obligations and if it exist identify the appropriate laws and directives.

5 Conclusions

The definition of the most appropriate WWTPs represents a complex problem. It requires the participation and the consensus of different agents (social, economic, ecological) to reach an optimal solution. The Catalan Water Agency developed an EDSS in order to confront this problem. An EDSS is a computer system which is able to integrate and manage knowledge from different sources and to provide a solution reaching a consensus.

The EDSS developed has proved to be a good tool to help in the planning process to select adequate WWTPs for small communities. It considers the environmental conditions and the ecological state of the receiving media before setting appropriate treatments. Moreover, social, economical and environmental situations may discard, favour or disadvantage some adequate treatments proposed.

The Latin American Governments are trying to solve a similar problem. Therefore, we propose the reutilization of the EDSS developed by the Catalan Water Agency in the Latin American regions. The results from a preliminary study indicate that the reutilization of the knowledge and *know-how* acquired in the EDSS development is possible. Despite that, some modifications will be necessary. Future research should extend the analysis of the Latin America situation to identify those aspects of the Catalan EDSS that must be modified or improved.

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