Journal of Environmental Management 184 (2016) 409–418

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Validation of a decision support tool for wastewater treatment selection

A. Castillo [a, f, *], J. Porro [a], M. Garrido-Baserba [b], D. Rosso [b], D. Renzi [c], F. Fatone [d], V. Gómez [f], J. Comas [a, e], M. Poch [a]

[a] Laboratory of Chemical and Environmental Engineering (LEQUIA), Universitat de Girona, Faculty of Sciences, Campus Montilivi s/n, 17071, Girona, Spain
[b] University of California, Irvine, Civil & Environmental Engineering Dept., Urban Water Research Center, 844G Engineering Tower, Irvine, CA, 92697-2175, USA
[c] Alto Trevigiano Servizi, Srl, Via Schiavonesca Priula, 86, 31044, Montebelluna, Italy
[d] University of Verona, Department of Biotechnology, Via Le Grazie 15, 37134, Verona, Italy
[e] Catalan Institute for Water Research (ICRA), Emili Grahit 101, Parc Científic i Tecnològic de la UdG, E-17003, Girona, Spain
[f] SUEZ ENVIRONNEMENT, Passeig de Zona Franca 48, 08038, Barcelona, Spain

ARTICLE INFO

Article history:
Received 4 August 2016
Received in revised form
27 September 2016
Accepted 29 September 2016
Available online 11 October 2016

Keywords:
Demonstration
EDSS
Validation
WWTP process selection

ABSTRACT

Wastewater treatment selection is a complex task usually addressed by applying separate tools for the correct assessment of multi-criteria evaluation. Novedar_EDSS integrates technical, environmental, economic and social assessment capabilities in one single platform. The aim of this work is to evaluate and demonstrate the capabilities of this environmental decision support system (EDSS). For that purpose, 4 case studies of real projects were selected to validate the results in the EDSS by comparing them with those from the study of alternatives performed by the decision makers. Moreover, 1 conceptual case study was applied to support the selection of the most properly strategy for plant retrofitting. Results have demonstrated that the EDSS provides key aspects when deciding the retrofitting process to apply and, when compared to real projects, it recommends analogue treatments as those applied in the projects, ranking them in the same order. Therefore, results in the validation process performed show that this tool provides a reliable basis to support decision makers to select properly treatment alternatives in wastewater treatment plant pre-design.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In the context of the rapid pace of urban development across many parts of the world, specifically China, India, and countries in the Middle East, Africa, and Latin America (City Mayors Foundation, 2013), new wastewater treatment plants are needed to meet the public health and ecological standards that are increasingly being enforced. Where growth is not as fast, like in the U.S. and Europe, new wastewater treatment plants (WWTPs) are in less demand; however, there is still need to retrofit existing WWTPs to meet more stringent water quality regulations. Different factors add complexity to the fundamental drivers for installing new/retrofitted treatment facilities: (i) water scarcity, (ii) growing number of leading edge alternatives to conventional wastewater treatment, (iii) growing pressure on balancing technical, environmental, economic and social criteria in water projects.

Thus, decision making inherently becomes highly complex, driving to clear need for decision support tools that can address the complexity of selecting wastewater treatment technologies.

Decision support systems (DSS) are recognized feasible tools to support complex decision making processes (Shim et al., 2002; Poch et al., 2004; Guimãres Pereira et al., 2005). DSS have the capacity to manage huge volumes of data, integrating databases and models under a graphical user interface, at the same time that expert knowledge from different sources can be included, Zhang et al., 2015). Different capabilities within the same platform allows to retrieve large amount of information in a matter of minutes to evaluate different alternatives.

A variety of EDSS to tackle wastewater treatment selection have been developed in recent years. While Gómez-López et al. (2009) developed an EDSS to select promising disinfection technologies,

* Corresponding author. Laboratory of Chemical and Environmental Engineering (LEQUIA), Universitat de Girona, Faculty of Sciences, Campus Montilivi s/n, 17071, Girona, Spain.
E-mail address: acastillo@aquatec.es (A. Castillo).

http://dx.doi.org/10.1016/j.jenvman.2016.09.087
0301-4797/© 2016 Elsevier Ltd. All rights reserved.

Zeng et al. (2007) and Karimi et al. (2011) presented tools to select secondary treatments, among a short list of available treatments. Similarly, plant maintenance also benefit from such decision-making approaches (Kilic and Hamarat, 2010). Even, some tools were developed to optimize decisions in the selection among a pre-selected set of wastewater treatment technologies (Kalbar et al., 2012; Bozkurt et al., 2015; Huang et al., 2015).

Novedar_EDSS overcomes some limitations from the previous approaches, it consists of an EDSS able to consider a huge range of treatment alternatives (more than 150 technologies), and their corresponding combinations within the whole wastewater treatment process (i.e. the whole plant level). The so called Novedar_EDSS supports the analysis of the alternatives through a multi-criteria approach, considering operational, economic and environmental criteria in a user-friendly interface. Moreover, this tool is designed to be flexible and adaptable to knowledge upgrading and allows to explore different solutions in a term of minutes.

A rigorous validation process is essential to widen the potential use of this tool in order to ensure the proper support to decision-makers in the complex process of wastewater treatment selection.

The aim of this work is to evaluate and demonstrate the capabilities of an EDSS tool for the pre-design of wastewater treatment plants (WWTP). This evaluation is performed by comparing a set of four real case studies with the EDSS outcomes obtained when those real cases are applied in the tool. A conceptual case study was also selected to demonstrate the capabilities of the tool when performing retrofitting scenarios. This validation and demonstration process allows to check the correct functioning of the tool, as well as to identify some limitations/gaps which need to be addressed.

Presented herein, two case studies from Italy (conceptual) and USA (real) are performed to demonstrate and validate, correspondingly, the application of the tool for different relevant problems related to retrofitting facilities. After that, three case studies were selected for new facilities from different locations around the world to validate the EDSS response by comparing them with the results in the state-of-the-art approach.

2. Methodology

2.1. How does Novedar_EDSS work?

Novedar_EDSS was developed following the five steps proposed by Poch et al., 2004: (i) analysis of the problem, (ii) data and knowledge acquisition, (iii) cognitive analysis, (iv) model selection and (v) integration.

The architecture of the EDSS is based on a rule-based hierarchical decision approach and uses both quantitative and qualitative information. Hence, heuristics together with the use of reasoning processes (expert judgment) are applied to produce suitable process flow diagrams (PFDs) for any specific scenario. PFDs are then ranked based upon the specific criteria priorities established by the user (Garrido-Baserba et al., 2012a). Two knowledge bases are linked: one about the features of the different technologies, which is called specific knowledge base (Skb-units), and other about the compatibility amongst the different treatments, compatibility knowledge base (Ckb-units). The first step in the methodology consists of defining the scenario (i.e. influent characteristics, effluent discharge requirements and priority setting criteria) (Fig. 1). Once the scenario has been defined, the alternative generation process selects all suitable secondary treatments for the specific scenario, based on parameters as flowrate and Biochemical Oxygen Demand (BOD) concentration (Table 1), with the structural network model. In the next step, based on the Ckb-units, suitable and complete process flow diagrams (based on the among 150 treatment alternatives included in the Skb-units) are generated by means of the hierarchical approach and the decision trees. Finally those feasible solutions satisfying the effluent requirements will be selected and further evaluated by the recursive evaluation. Detailed information about the EDSS structure and functioning can be found in Garrido-Baserba, 2013.

The Skb-units (Fig. 1) includes both quantitative (e.g.space requirements) and qualitative parameters (e.g. need of specialized staff). Quantitative parameters are calculated based on different formula (Table 1) while qualitative parameters are evaluated in a range from "very low" to "very high" compared to the other treatment alternatives considered. This information (i.e. formula and qualitative information) is based on bibliographic data and expert knowledge (Garrido-Baserba et al., 2012b).

Most parameters (i.e. investment costs) are considered as criteria (i.e. Capital expenditure (CAPEX)) in the multi-criteria evaluation. However, those parameters included in the influent and effluent sections, (e.g. BOD, Total Phosphorus (TP)) are taken into account to define the feasibility of each treatment line. Since each technology performs well in a range of values for some influent parameters (e.g. flow rate) and implies different performance (e.g. BOD removal), therefore only those treatment lines able to treat the defined influent and to achieve the effluent requirements will be selected.

Qualitative parameters include impacts and operational characteristics. Noise potential considers the potential of the treatment alternative to generate noise, while visual impacts evaluates its integration in the landscape. Operational parameters, as "need of specialized staff", considers skilled staff requirements for a treatment alternative, while "flexibility" measures the process capability to tackle influent disturbances (e.g. changes in the flowrate).

LCA is calculated for each treatment alternative by applying the method developed by the Center of Environmental Science (CML) taking into account the emission factors included in the Ecoinvent database (detailed information about this calculations can be found in Garrido-Baserba et al., 2014).

In the multi-criteria analysis, each treatment alternative is ranked based on the value obtained for each criteria considered. For each criteria, the best mark (i.e. 10) is given to the most properly treatment alternative (i.e. less space requirements), while the worst score (i.e. 0) is given to the least appropriate (i.e. more space requirements). After that, a normalization process is applied to rank the treatment alternatives which are in between the best and the worst alternative. When qualitative criteria are considered, those ranked as "very low" take a "0" and those ranked as "very high" take a "4" (this is for positive criteria, as "flexibility", while for negative criteria, as "visual impact", it is the opposite) and the scores are calculated in the same way as for quantitative criteria.

Finally, the user, based on their preferences, defines the weight for each criteria and the total score for each treatment alternative is calculated by applying Equation (4), where the score for each criteria is multiplied by its appropriate criteria weight. Finally, the weighted scores for all criteria are summed up.

$$V(X) = \sum_{i=1}^{n} W_i \cdot V_i(X_i) \quad (4)$$

2.2. Demonstration and validation process

In order to verify the feasibility of Novedar_EDSS, two different approaches were validated in this work: (1) the first one tackles with **WWTP retrofitting**, which can be partially addressed in the current version of the EDSS and (2) the second one is the **pre-design of new WWTP**, which is the original purpose of the EDSS developed.

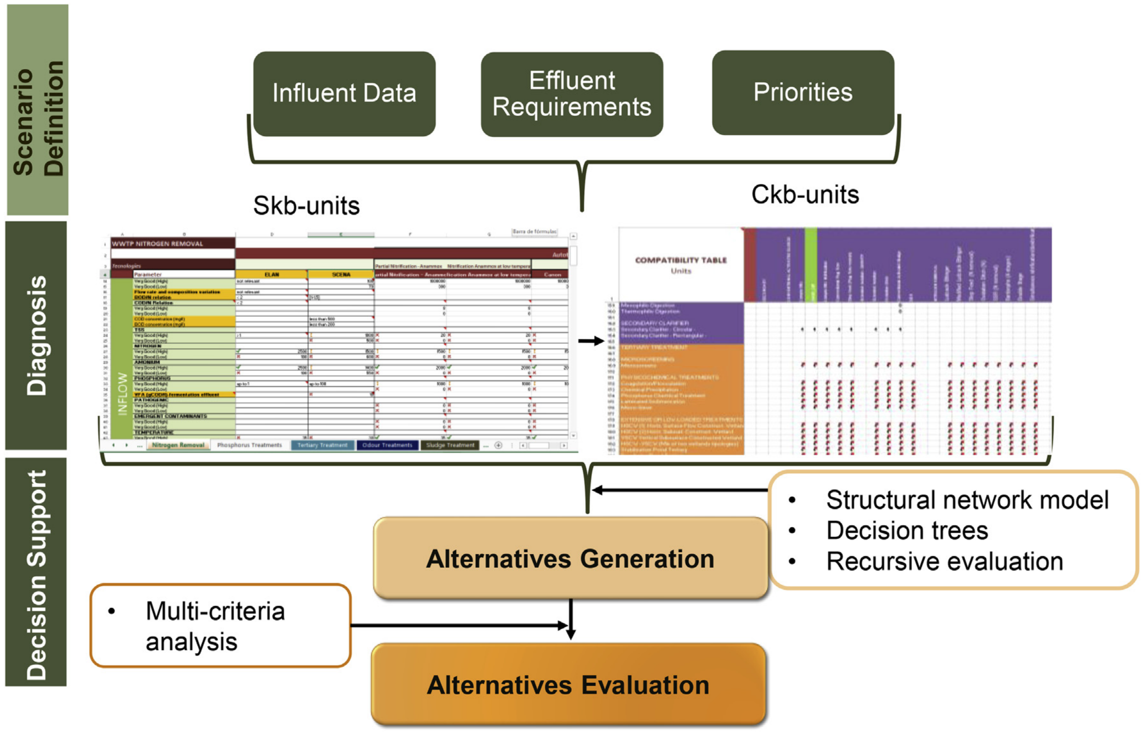

Fig. 1. Scheme about the Novedar_EDSS methodology.

To test Novedar_EDSS outcomes in retrofitting as well as in the pre-design of new WWTP, **five case studies** were selected. The first one is a demonstration case, while the other case studies are applied to evaluate the EDSS results when compared with the study of alternatives performed by decision makers in the real projects. For a better evaluation, same criteria as those applied by the decision-makers in the real projects was applied to perform the multi-criteria analysis in the Novedar_EDSS.

2.3. Case studies

2.3.1. Retrofit WWTP

Two case studies were selected to demonstrate the retrofitting capabilities of the EDSS. A different approach was applied in each

Table 1
Information and formula considered to calculate values for some of the criteria considered in the knowledge base Skb-units (Castillo et al., 2016).

Parameter	Data/Formula/Qualitative information
Influent:	
- Flow rate[a] range (m^3/d)	50–800,000
- Population equivalent[a] range (p.e.)	2400–1000000
Effluent:	
- Nitrogen removal[b] (%)	80–85
Costs	
- Investment costs[c] (for Modified Ludzack-Ettinger (MLE))	$y = 5635.3 \cdot x^{-0.352}$ (1)
- O&M costs[c] (for MLE) (x is p.e.; y is the total cost expressed as eur/p.e.)	$y = 309.44 \cdot x^{-0.389} \cdot x$ (2)
- Cost-Benefit Analysis (CBA) based on the Net Profit Value (NPV) Bi are benefits; Ci are costs; t is time (30 years) and r is discount tax (4%).	$NPV = \sum_{i=0}^{t} \frac{B_i - C_i}{(1+r)^i}$ (3)
Environmental	
- Life cycle analysis (LCA) Emission factors from Ecoinvent database.	Categories considered: - Eutrophication - Global warming
Impacts	
- Noise potential (noise generated in the facility)	High
- Visual Impact (based on the integration in the landscape)	High
Operational	
- Need of specialized staff	High
- Flexibility	Low

[a] CEDEX, 2013.
[b] Moore, 2010.
[c] EDSS-PSARU, 2002.

case: Case study 1 aims to demonstrate how the tool can help in the decision strategy, while in the second case the EDSS response is compared to the process applied in the real facility to select the treatment alternative.

In **case 1** (Table 2), the tool was applied to compare the feasibility of upgrading/retrofitting three decentralized wastewater treatment plants versus the construction of one large centralized plant and decommissioning the existing plants in Italy.

Each existing plant was evaluated individually using the Novedar_EDSS and selecting the configuration best matching the actual planned retrofit. On the other hand, it was defined a new scenario taking into account the total flow rate and loading for the three existing plants, in order to identify the best strategy to treat this influent in one bigger facility, achieving the required quality of effluent. The technical, environmental, and economic results (based on the selected criteria in Table 3) were then aggregated for the three plants and compared to that of the scenario for the one large plant.

As for the **case study 2** (Table 2), it is focused on a retrofit case in the USA. Several strategies were evaluated in order to increase 35% the plant capacity and to meet stringent forthcoming regulatory nutrient limits. The plant performs conventional plug flow activated sludge and consists of two main aeration basins arranged to operate in parallel. Although space limitations were the main constraint, economic criteria were also essential in the selection of the most convenient treatment (Table 3).

There are two options in the EDSS to perform a facility when it consists of two treatment lines (as in case study 2): 1) to generate two different scenarios with half flow rate, then different treatments can be recommended for each of them, depending on the criteria considered; 2) to create only one scenario, which means to apply the same treatment in both lines. In case study 2, both methods were applied in order to determine the best treatment strategy.

2.3.2. New WWTP

The aim in case studies 3, 4 and 5 (Table 4) is to select the most properly treatment to build a new facility. These case studies were applied in the EDSS to validate its capability to create suitable PFD alternatives for new WWTP.

In order to consider a wider range of possibilities, the three case studies selected present different location, size and effluent requirements. The criteria applied to score the feasible treatment alternatives depend on the user needs (Table 5).

Case study 3 is based on the project of Steichecn et al. (2009), the same influent wastewater characteristics and effluent requirements were input into Novedar_EDSS. In this case, a new facility was required to treat domestic wastewater obtaining a high quality effluent for irrigation. Non-economic criteria were considered in the treatment alternative evaluation, such as operational reliability, flexibility, simplicity, environmental impacts and space requirements.

Table 3
Selected criteria in the real project and in the EDSS for case studies 1 and 2.

Category of criteria	Criteria	Case 1	Case 2
Environmental	Space requirements	x	x
	LCA	x	
Operational	Operation simplicity	x	
	Control over the process	x	
Economic	Capital expenditure (CAPEX)	x	x
	Operational expenditure (OPEX)	x	x

Case study 4 corresponds to a new facility which will be located in South America. A high flowrate needs to be treated before being discharged in a river, considered as a sensitive area, therefore some nutrient removal is required. Regarding the criteria applied for the alternative selection, reliability as well as need of specialized staff and economical parameters were prioritized as the most important criteria.

In **case study 5**, the aim was to build a new WWTP, located in Europe, to treat the wastewater from a medium size town. Several treatment alternatives were considered to achieve the effluent requirements to discharge in a river. Environmental, operational and economic criteria were prioritized in the alternative selection process, being space requirements the main constraint.

3. Results and discussion

In this section, results obtained in the EDSS are analyzed and evaluated taking into account the results in the real projects as well as references.

3.1. Retrofit WWTP

3.1.1. Case study 1- retrofitting (Italy)

In this case, Novedar_EDSS is applied to identify the best alternative when three WWTP upgrades were required in the same area. The assigned technicians for the upgrade considered two main options: (i) to retrofit the three WWTPs and (ii) to build a bigger one. Table 6 provides a summary of the results offered by the EDSS when comparing the retrofitting scenario versus the construction of one large centralized plant. In this case, two analysis are performed, the first one based on the economic data for the whole plant level and the second one considering the scores obtained for the secondary treatments. The current version of the EDSS is limited to the scores in the secondary treatment. Therefore, while the scores are exclusively considered when comparing secondary treatment strategies, economic parameters (i.e. total equivalent cost) will be considered during assessment and analysis of the whole plant.

Table 2
Values for the influent and effluent requirements for case studies 1 and 2.

Parameter	Units	Case 1[a]			Case 2[b]
Flowrate (Q)	m^3/d	12,000	120,000	30,000	33,700
Biochemical Oxygen Demand (BOD_5)	mg/l	245	300	240	204
Chemical Oxygen Demand (COD)	mg/l	410	600	450	340
Total Suspended Solids (TSS)	mg/l	250	160	200	250
Total Kjeldahl Nitrogen (TKN)	mg/l	45	70	50	34
Total Phosphorus (TP)	mg/l	5	9	6	25
Effluent requirements	Sensitive area[c]	Sensitive area[d]	Sensitive area[d]	Sensitive area[d]	

[a] Personal Communication.
[b] Howard, 2012.
[c] Sensitive area (when population equivalent (p.e.) <100,000): maximum concentration BOD = 25 mg/l; COD = 125 mg/l; TSS = 35 mg/l; TKN = 15 mg/l; TP = 2 mg/l.
[d] Sensitive area (when p.e.>100,000): maximum concentration BOD = 25 mg/l; COD = 125 mg/l; TSS = 35 mg/l; TKN = 10 mg/l; TP = 1 mg/l.

Table 4
Values for the influent and effluent requirements for case studies 3, 4 and 5.

Parameter	Units	Case 3[b]	Case 4[c]	Case 5[d]
Q	m^3/d	45,000	86,400	7776
BOD_5	mg/l	131	208	225
COD	mg/l	218[a]	447	450
TSS	mg/l	129	148	270
TKN	mg/l	32	45	45
TP	mg/l	4	10	8
Effluent requirements		Reclaimed water for irrigation[e]	Sensitive area[f]	River[g]

[a] Assuming ratio BOD/COD = 0.6 to calculate COD concentration in Case 3.
[b] Steichecn et al., 2009.
[c] Personal Communication, 2015.
[d] Personal Communication, 2011.
[e] Reclaimed water for irrigation: maximum concentration BOD = 25 mg/l; COD = 125 mg/l; TSS = 20 mg/l; TKN = 100 mg/l; Nitrate = 100 mg/l; TP = 20 mg/l; Nematodes = 1 egg/10L; Escherichia = 100 egg/10L; Legionella spp = 1000 CFU (colony forming units)/L; Taenia Saginata = 10,000 egg/10L; Taenia Solium = 10,000 egg/10L; Turbidity = 10 NTU (nephelometric turbidity units).
[f] Sensitive area (when p.e.>100,000): maximum concentration BOD = 25 mg/l; COD = 125 mg/l; TSS = 35 mg/l; TKN = 10 mg/l; TP = 1 mg/l.
[g] River: maximum concentration BOD = 25 mg/l; COD = 125 mg/l; TSS = 35 mg/l.

When looking at the **whole plant level** (i.e. "all line"), retrofitting the existing plants is more economical, as seen in Table 6 (Retrofitted: 81.19 Meur; new: 152.88 Meur). This is due to in retrofitted plants some parts can be utilized in the new process, while a new plant requires large capital expenditures for new infrastructure and equipment (Rubino, 1996). However, total OPEX is higher in the three plants than in the bigger one, since personnel costs, as well as energy consumption, can easily optimize when all the influent is treated in one bigger facility. Therefore, if CAPEX was the prioritized criteria, the retrofitting strategy would be selected. However, if decision-makers consider OPEX as the most important, they would prefer to build a new bigger plant.

On the other hand, when looking at the **secondary treatment line**, which is what the EDSS tool scores, the new centralized plant has significant advantages (total score retrofit WWTPs: 4.45; new centralized WWTP: 6.74) in terms of technical, environmental and economic criteria because there is the freedom to select the best theoretical technology, whereas, for the existing plants, you are limited to select the configuration that is the best practical retrofit (Tejero and Larrea, 2008).

Therefore, in this case, the EDSS provides key information to choose between the two options by comparing different strategies. The most properly alternative will depend on the user preferences, which can be easily implemented in the EDSS considering different criteria and weighting them according to their needs.

3.1.2. Case study 2- retrofitting (USA)

The plant under study performed a Biological Nutrient Removal (BNR) treatment with a plug flow configuration and works in two parallel lines. Several alternatives were evaluated as strategies to meet both stringent forthcoming regulatory nutrient limits (resulting from a recent legislative approval of the Jordan Lake Nutrient Reduction Rules) and flowrate increase due to the deployment of new complex of industrial warehouses that would be connected at the sewage system. The parallel lines can be isolated from each other allowing to evaluate combinations of two different treatments.

As part of this evaluation, one of the main alternatives being considered was the implementation of an integrated fixed film activated sludge (IFAS), as it could help to increase the influent flowrate but avoiding the construction of a new reactor tank. The evaluation considered the following alternatives: (i) two lines (100%) with IFAS process (Alternative 1); (ii) one line (50%) with IFAS + one line (50%) with BNR (Alternative 2); (iii) two lines (100%) BNR (Alternative 3) and (iv) one line (50%) with BNR + one line (50%) with Step Feed (SF) (Alternative 4). Every alternative was evaluated embracing economic criteria (*capital and operation costs*) and physical constraints (***space requirements***). The four alternatives considered were also evaluated using the Novedar_EDSS. Results and comparison between real case estimations and EDSS projections obtained for each alternative treatment are presented in Table 7.

Table 7 shows the option BNR (100%) (Alternative 3) as the best-positioned alternative in the real project for this specific scenario. BNR presents one of the lowest *CAPEX* (11.6 M$) as it can be seen in Fig. 2, this alternative would be scored as the best candidate if space constraints criteria had a criteria weight prioritization of only 33%. However, if ***space constraints*** criteria is considered as an exclusive parameter (i.e. weigh prioritization of 100%), BNR and BNR+SF would be discarded, as they could no longer absorb the increase in influent flowrate without any treatment extension.

Although *space requirements* projections carried out by the real case were not available, the EDSS estimated that in the case BNR (100%) was chosen the current plant layout (1280 m^2) would require an approximate increase in treatment surface of 28% (up to 350 m^2) to assimilate the new influent flowrate, while close to 15% (up to 190 m^2) in the case of the BNR+SF option. Hence, when *space requirements* is the prioritized criteria, the isolation of the treatment lines in two different processes IFAS 50%-BNR 50% (Alternative 2) or a whole new process maximizing the treatment capacity IFAS 100% (Alternative 1) could provide a more convenient solution.

IFAS has been proven to be a suitable technology for retrofitting as a venue to increase tank capacity (Rosso et al., 2011), and in some cases, it even permits to use existing secondary settlers as reactors (Zalakain et al., 2008). The required modifications will focus on the

Table 5
Selected criteria in the real project and in the EDSS for case studies 3, 4 and 5.

Category of criteria	Criteria	Case 3	Case 4	Case 5
Environmental	Visual Impacts	x		
	Odor potential	x		
	Noise potential	x		
	Space requirements	x		x
Operational	Operation simplicity	x		
	Flexibility	x		
	Reliability	x	x	
	Control over the process			x
	Performance			x[a]
	Need of specialized staff		x	
Economic	CAPEX		x	x
	OPEX		x	x

[a] Performance is one of the criteria considered in the real project although it is not yet available in Novedar_EDSS.

Table 6
Results case study 1- Score in the EDSS considering to retrofit 3 WWTP and to build a new WWTP.

Parameter	Criteria	Units	Retrofit WWTPs 1-3		New unified plant	
			All line	Secondary	All line	Secondary
Costs	OPEX	Meur/year	5.15	0.66	2.96	0.47
	CAPEX	Meur	28.69	17.99	58.59	13.39
	Total equivalent costs	Meur	81.19	29.41	152.88	22.01
	Reactants	Meur/year	4.93	0	2.79	0
Scores	Total		N/A	4.45	N/A	6.74
	Economic		N/A	1.43	N/A	1.53
	Environmental		N/A	1.27	N/A	2.58
	Operational		N/A	1.75	N/A	2.62
Cost Benefit Analysis	Total equivalent cost	Meur	81.19	N/A	152.88	N/A
	Accumulate benefit	Meur	0.97	N/A	22.70	N/A
	Net Profit Value	Meur	−83.27		−130.18	

Table 7
Results case study 2 - Score real project versus Novedar_EDSS. The final simplified score for every criteria in the left corresponds to the real project and in the right to the Novedar_EDSS (in bold).

Criteria	Weight (%)	Alternative1[a] Project/EDSS	Alternative2[b] Project/EDSS	Alternative3[c] Project/EDSS	Alternative4[d] Project/EDSS
Total score	100	4.9/**3.3**	5.9/**4.5**	7.5/**6.6**	6.6/**6.6**
Space requirements	33	10.0/**10.0**	7.5/**5.2**	5.0/**0.0**	2.5/**0.0**
CAPEX	33	2.5/**0.0**	5.0/**4.5**	10.0/**10.0**	7.5/**10.0**
OPEX	33	2.5/**0.0**	5.0/**4.0**	7.5/**10.0**	10.0/**10.0**

[a] IFAS (100%).
[b] IFAS (50%)+BNR (50%).
[c] BNR (100%).
[d] BNR (50%)+SF (50%).

implementation of three different compartments: the aerobic zone filled with biofilm carrier media (30–40%) for nitrification, an anoxic zone (40%) for denitrification, and the anaerobic (15–25%) for phosphorous removal (Rutt et al., 2006; Albizuri et al., 2010). Therefore, both IFAS alternatives (50% and 100%) would avoid associated investment costs due to the construction or expansion of existing tanks. However, the hydraulic load and the oxygen demand applied to the IFAS process will be approximately twice that of an extension of the current BNR process, with almost also twice the *OPEX* (aprox. 35–45%) (Fig. 3). Note that IFAS is characterized by elevated air flux due to mixing requirements specified by the process manufacturer, with associated lower oxygen transfer efficiency, due to the use of coarse bubble instead of fine-pore diffusers (Rosso et al., 2011). However, although the deployment of the IFAS-related alternatives for both the EDSS and real projections pointed out in the increase of CAPEX close to 70% and 35% due to carrier installation and reconfiguration (Real: 15.8 M$ and 12.0 M$; EDSS: 14.6 M$ and 12.4 M$, respectively) (Fig. 2), and OPEX increase of 25% and 40% due to the new air requirements (Real: 1.5 M$/year and 0.9 M$/year; EDSS: 1.1 M$/year, 0.7 M$/year, respectively) (Fig. 3), the total cost-benefit analysis over the period favorited these retrofitting options. Similarly, in the real case the total projections costs for these expansions were estimated to exceed the theoretical CAPEX and OPEX costs of the IFAS-related alternatives, which have not construction costs implied.

It can be seen as both, the approach followed by the decision-makers and the EDSS, conclude that in this scenario the most competitive cost alternatives, conventional BNR (Alternative 3) and

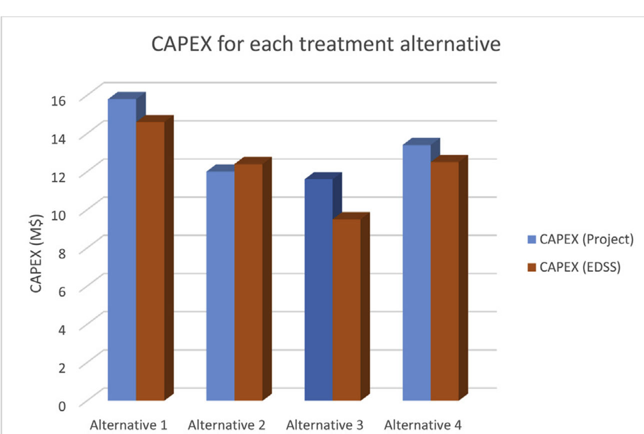

Fig. 2. CAPEX for each treatment alternative in the real project and in the EDSS. Alternative 1 corresponds to IFAS (100%), Alternative 2 to IFAS (50%)+BNR (50%), Alternative 3 to BNR (100%) and Alternative 4 to BNR (50%)+SF (50%).

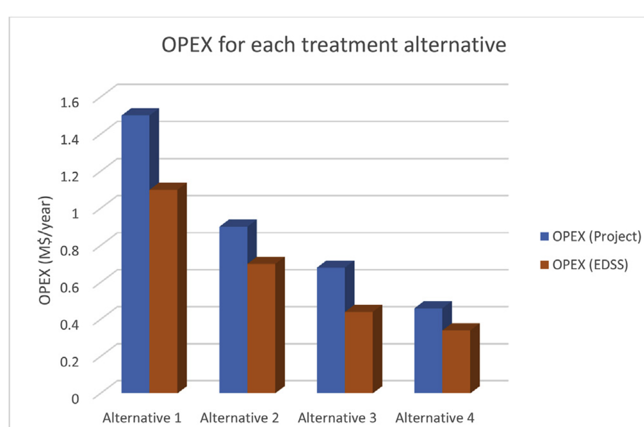

Fig. 3. OPEX for each treatment alternative in the real project and in the EDSS. Alternative 1 corresponds to IFAS (100%), Alternative 2 to IFAS (50%)+BNR (50%), Alternative 3 to BNR (100%) and Alternative 4 to BNR (50%)+SF (50%).

Table 8
Results case study 3 - Score state-of-the Art approach versus Novedar_EDSS. The score for every criteria in the left corresponds to the real project and in the right to the Novedar_EDSS (in bold).

Criteria	Weight (%)	MBR Project/EDSS	MBBR Project/EDSS	MLE Project/EDSS
Total score	100	5.9/**6.3**	5.8/**5.9**	5.5/**5.5**
Impacts	75	3.5/**5.0**	3.0/**4.4**	2.0/**3.6**
Operation simplicity	12.5	1.3/**0.3**	1.5/**0.6**	1.7/**0.6**
Reliability	12.5	1.1/**0.9**	1.3/**0.9**	1.8/**1.3**

BNR+SF (Alternative 4) with their corresponding CAPEX (Real: 11.6 M$ and 13.4 M$; EDSS: 9.5 M$ and 12.5 M$, respectively) (Fig. 2) and OPEX (Real: 0.68 M$/year and 0.46 M$/year; EDSS: 0.44 M$/year and 0.34 M$/year) (Fig. 3), are hindered as the ***space constraints*** are key factors in the decision making.

3.2. New WWTP

3.2.1. Case study 3 - new WWTP (USA)

In case study 3 a study of alternatives is performed in order to select a treatment for a new WWTP. In that sense, a broad range of alternatives were considered and subsequently discussed in this section. Taking into account user needs, non-economic factors (i.e. *impacts*, *operation simplicity* and *reliability*) were considered to evaluate the feasible treatment technologies.

Table 8 shows the results of the treatment technology evaluations conducted. Novedar_EDSS includes the same technologies as those in the shortlist of technologies developed by Steichecn et al. (2009): Membrane Bioreactor (MBR), Moving Bed Biofilm Reactor (MBBR) and Modified Ludzack-Ettinger (MLE). It can be seen as these alternatives are ranked essentially in the same order in the EDSS and through the state-of-the-art approach, based upon the criteria and weights established for the project.

As it can be seen in Table 8, when a *multi-criteria analysis* is applied (i.e. impacts, operation simplicity and reliability), MBR is the best scored treatment alternative (score SOA: 5.9; score EDSS: 6.3), followed by MBBR (score SOA: 5.8; score EDSS: 5.9).

The score obtained when prioritizing each criteria can be analyzed individually, to obtain a more detailed evaluation. As for ***impacts***, MBR seems to be the technology producing less impact (score Real: 3.5; score EDSS: 5.0) because it consists in a compact technology (Yang et al., 2006) with a small footprint (Chen et al., 2012). On the other hand, MLE obtains the lowest score in both, the real approach (score: 2.0) and the EDSS results (score: 3.6), because it requires bigger reactor volumes and secondary settler. MBBR is in between both (score Real: 3.0; score EDSS: 4.4) because, compared to MLE, it requires lower reactor volumes, since it includes both suspended and fixed-filmed sludge, which allows high biomass concentrations. The EDSS, similarly to the state-of-the-art approach, would recommend MLE and MBBR if *operation simplicity* was the main criteria considered, since MBR is a more complex system where additional parameters as membrane cleaning and fouling should be considered.

Finally, both methodologies (state of the art and the EDSS) consider MLE as the most *reliable* alternative in this case, compared to MBBR and MBR systems. This could be due to the fact that MLE is a well-established technology which has been successfully worldwide applied.

Therefore, it can be stated that the EDSS recommends and score the alternatives for this case study similarly than the state-of-the art approach. This means that results obtained when applying one integrated platform (i.e. EDSS) are comparable to those from a conventional approach. Thus, similar results while decreasing effort and time requirements.

3.2.2. Case study 4- new WWTP (South America)

In this case, four treatment alternatives were considered by the engineers in order to treat the influent before being discharged in a river: MLE, Extended aeration (EA) Trickling Filters (TF) and Sequential Batch Reactor (SBR).

TF involves a three-phase based system with fixed biofilm. In this case, this technology allows to achieve the required effluent quality with less energy consumption than activated sludge (Daigger and Boltz, 2011).

MLE, EA and SBR consist on different activated sludge configurations with higher effluent quality than TF (Jing et al., 2015), although they imply higher energy consumption. In fact, EA achieves not only the properly effluent quality but also generates stabilized sludge, avoiding the need to install a digester in the sludge

Table 9
Results case study 4 - Score state-of-the Art approach versus Novedar_EDSS. The score for every criteria in the left corresponds to the real project and in the right to the Novedar_EDSS (in bold).

Criteria	Weight (%)	MLE Project/EDSS	EA Project/EDSS	TF Project/EDSS	SBR Project/EDSS
Total score	100	8.3/**8.7**	7.5/**5.5**	5.9/N/A[a]	7.7/**5.7**
Reliability	50	5.0/**5.0**	5.0/**2.5**	1.7/N/A	4.8/**1.3**
Need of skilled staff	25	1.7/**1.9**	1.7/**1.9**	2.5/N/A	1.3/**1.9**
CAPEX	12.5	0.8/**1.1**	0.4/**1.1**	1.25/N/A	1.0/**1.3**
OPEX	12.5	0.8/**0.7**	0.4/**0.0**	1.25/N/A	0.6/**1.3**

[a] N/A: Not Available.

Table 10
Results case study 5 - Score state-of-the Art approach versus Novedar_EDSS. The score for every criteria in the left corresponds to the real project and in the right to the Novedar_EDSS (in bold).

Criteria	Weight (%)	MBR Project/EDSS	MBBR Project/EDSS	BF Project/EDSS
Total score	100	6.6/**7.1**	4.6/**6.1**	6.1/**7.6**
Space requirements	50	3.3/**4.8**	1.7/**3.8**	3.3/**4.3**
Performance	N/A	1.25/N/A	0.4/N/A	0.8/N/A
Control over the process	25	0.8/**1.3**	0.9/**1.3**	0.8/**1.3**
CAPEX	12.5	0.4/**0.0**	0.8/**1.0**	0.4/**0.7**
OPEX	12.5	0.8/**1.0**	0.8/**0.0**	0.8/**1.3**

line. However, it requires more energy than the other considered alternatives (Leslie et al., 1999).

When this case study was defined in the EDSS, the short-list of treatments generated included: MLE, EA and SBR. However, TF was not in the list, since the EDSS considers it performs better in smaller facilities (according to CEDEX, 2013). This is consistent with the main reason for the engineers to finally discard trickling filters in the real project, since their effectiveness has not been demonstrated in large WWTP.

In this case, ***reliability*** of the treatment was the most important criteria to meet. Since the reliability of activated sludge treatments has been demonstrated by many applications around the world (Guo et al., 2013; Wei et al., 2003), decision makers decided to finally focus on this kind of treatment (i. e. MLE, EA or SBR) instead of on a fixed biofilm (i.e. TF).

Table 9 presents the score obtained in each case when applying both approaches: the project and the EDSS.

Results in the project shows that when *economic criteria* (i.e. *CAPEX* and *OPEX*) were prioritized, TF obtained the best score. Followed by SBR (TF score: 1.25; SBR score: 1.0), in agreement with Singh and Srivastava, 2010. Since TF was not considered as a feasible treatment alternative in the EDSS, SBR is the best ranked alternative when both CAPEX and OPEX were prioritized.

Regarding ***reliability***, which was the prioritized criteria in this project, the most promising alternatives in the EDSS were MLE followed by EA (MLE score: 5.0; EA score: 2.5), which are the best ranked alternatives by decision-makers when prioritizing this criteria (MLE score: 5.0; EA score: 5.0).

TF is the less *skilled staff* demanding, based on the project approach, being SBR the treatment which need more specialized staff. However, in the EDSS a similar level of knowledge seems to be required in all the treatment alternatives considered.

Lastly, a *multi-criteria analysis* was performed, in order to rank the different treatment alternatives considering different weights for the different criteria, based on the customer's needs (i.e. reliability: 50% weight; need of skilled staff: 25%; CAPEX: 12.5%; OPEX: 12.5%). Since reliability was the most important criteria considered in this case, MLE was benefited, being the best scored treatment alternative in both, the EDSS and the project (score in EDSS: 8.7; score in project: 8.3).

Therefore, although some slightly differences have been identified when ranking the alternatives (i.e. skilled staff), most criteria as well as the overall analysis obtains a really similar response in both approaches (i.e. the real project and the EDSS). Thus, it can be seen as the EDSS allows to tackle the complex process of wastewater treatment selection considering both quantitative (e.g. CAPEX) and qualitative criteria (e.g. reliability).

3.2.3. Case study 5- new WWTP (Europe)

Three treatment alternatives were considered in the study of alternatives of the project to be applied in the new WWTP under study: MBR, MBBR and Biofiltration (BF).

When this case study was defined in the EDSS, these treatment alternatives were in the list generated with the feasible alternatives. The same criteria were applied to rank these alternatives in the study of alternatives and in the EDSS. Based on that, a comparison between the punctuation obtained in the real project and in the EDSS is performed as well as a reasoning process to validate the selection of these alternatives in the selection process. Results in the scores for every criteria obtained in the EDSS and in the study of alternatives in the project are presented in Table 10.

Although ***space requirements*** is the main constraint, a *multi-criteria* analysis has been also applied in order to analyze an integrated approach. When all criteria are considered (Table 10) (taking into account the weight in brackets), MBR is the best scored alternative in the real project (score: 6.6). However, the EDSS scores Biofiltration (score: 7.6) as the best alternative, followed by MBR (score: 7.1). This difference between the project and the EDSS is due to the fact that performance is not included as a criteria in the EDSS, since it is considered as a requirement (based on the effluent quality defined in the legislative framework). However, MBR presents higher performance than other secondary treatments while BF performs worse than conventional activated sludge (Jing et al., 2015). Therefore, if performance was considered as a criteria in the EDSS, MBR would obtain higher score than BF, similarly as in the real project.

When *economic criteria* are prioritized, the best scored treatment is MBBR (*CAPEX* project: 8.6 Meur; EDSS: 7.5 Meur) followed by BF. As for *OPEX*, MBBR obtains the lowest score because oxygen consumption is doubled in this case (Rosso et al., 2011), which implies higher operational costs.

The evaluation of the criteria *control over the process* gives similar results for all the treatment alternatives considered when using both approaches: the conventional study of alternatives in the real project and the EDSS, being MBBR the best scored treatment alternative.

As for *space requirements*, the alternative treatments considered are ranked similarly in both the real project and the EDSS. MBR (score project: 3.3; score EDSS: 4.8) and BF (score project: 3.3; score EDSS: 4.3) are better scored than MBBR (score project: 1.7; score EDSS: 3.8), this can be explained because they need less area since no secondary settler is required (Mohammadi et al., 2012; Gabarrón et al., 2014).

Hence, it can be seen as the EDSS recommends the same treatment alternatives as those considered in the real project and ranks them similarly, which allows to use this tool to support decision-makers when selecting wastewater treatment. These results allow also to identify new features to improve the EDSS applications (i.e. performance as a criteria in the multi-criteria analysis).

3.3. Future perspectives

Future work will consider to adapt the multi-criteria analysis to the decision-makers' needs. In that sense, some new criteria (as treatment performance) will be included in the multi-criteria analysis. Hence, it will be possible to rank the treatments based on this criteria, giving higher score to those treatment alternatives which achieve better effluent quality, thus it will allow to approximate the analysis to the technicians' considerations.

As for the features to face retrofitting utilities, the applicability of the EDSS tool will be increased by including in the methodology some functionalities required to fix the current facility treatment train. Based on that, the new requirements will be defined (e.g. higher flow rate, higher quality in the effluent) and the EDSS will recommend to combine the existing treatment with other technologies or even to change the whole treatment, depending on the criteria prioritized.

Therefore, the tool is expected to increase the help provided to decision-makers in both situations: the pre-design of a new WWTP and the retrofitting of an existing plant.

4. Conclusions

In this study, the capabilities of Novedar_EDSS have been evaluated and illustrated. For that propose, 4 real case studies (1 for plant retrofitting and 3 for new plants) have been implemented in the EDSS in order to compare the tool's response with the results obtained when applying the state-of-the art approach (i.e. the study of alternatives performed in each real project). A multi-criteria analysis was performed to score the different treatment alternatives in the EDSS, based on the criteria applied by the decision makers in the real projects.

Based on the results from this evaluation, it can be stated that considering the same input (i.e. influent and effluent data and criteria), Novedar_EDSS recommends similar treatments as those applied in the real projects, ranking them in the same order. Therefore, this tool can be used in the study of alternatives to support decision-makers to select properly treatment alternatives to be applied in wastewater facilities.

On the other hand, a conceptual case study was applied to support the selection of the most properly strategy for plant retrofitting. Results have demonstrated that the EDSS provides key aspects when deciding the retrofitting process to apply.

Future work will be focussed on increasing the range of scenarios where the EDSS can be applied to support decision-makers. This will be achieved by adapting functionalities to the user's needs as well as by including a new methodology in the EDSS to perform retrofitting scenarios.

Acknowledgements

This work was partially supported by Doctorat Industrial 2013-DI-038 (AGAUR and SUEZ) and by the Spanish Ministry of Economy and Competitiveness (CTQ2014-53718-R). The authors would like to thank EU-Cost Action Water2020 (ECOST-STSMES1202-110614-044095). LEQUIA and ICRA were recognized as consolidated research groups by the Catalan Government with codes 2014-SGR-1168 and 2014-SGR-291, respectively.

References

Albizuri, J., Santamaria, A., Larrea, L., 2010. IFAS process for nitrogen removal with an HRT of 4 hours. In: Proceedings WEF/IWA Biofilm Reactor Technology Conference. Portland (Oregon, USA).
Bozkurt, H., Quaglia, A., Gernaey, K.V., Sin, G., 2015. A mathematical programming framework for early stage design of wastewater treatment plants. Environ. Model. Softw. 64, 164–176.
Castillo, a., Cheali, P., Gómez, V., Comas, J., Poch, M., Sin, G., 2016. An integrated knowledge-based and optimization tool for the sustainable selection of wastewater treatment process concepts. Environ. Model. Softw. 84, 177–192.
CEDEX, 2013. XXX Curso sobre tratamiento de aguas residuales y explotación de estaciones depuradoras. Madrid.
Chen, W., Liu, J., Xie, F., 2012. Identification of the moderate SRT for reliable operation in MBR. Desalination 286, 263–267.
City Mayors Foundation, 2013. The World's Fastest Growing Cities and Urban Areas from 2006 to 2020. http://www.citymayors.com/statistics/urban_growth1.html (last acceded August 2015).
Daigger, G.T., Boltz, J.P., 2011. Trickling filter and trickling filter suspended growth process design and operation: a state-of-the-art review. Water Environ. Res. 83, 388–404.
EDSS-PSARU, 2002. Development and Implementation of a Decision Support System for the Selection of Wastewater Treatment Systems for Communities with Less than 2000 Equivalent People in Catalonia. Universities involved: UdG, CSIC, UB, UAB and UPC.
Gabarrón, S., Ferrero, G., Dalmau, M., Comas, J., Rodriguez-Roda, I., 2014. Assessment of energy-saving strategies and operational costs in full-scale membrane bioreactors. J. Environ. Manag. 134, 8–14.
Garrido-Baserba, M., Reif, R., Rodríguez-Roda, I., Poch, M., 2012a. A knowledge management methodology for the integrated assessment of WWTP configurations during conceptual design. Water Sci. Technol. 66 (1), 165–172.
Garrido-Baserba, M., Reif, R., Hernández, F., Poch, M., 2012b. Implementation of a knowledge-based methodology in a decision support system for the design of suitable wastewater treatment process flow diagrams. J. Environ. Manag. 112, 384–391.
Garrido-Baserba, M., 2013. Development of an Environmental Decision Support System for the Selection and Integrated Assessment of Process Flow Diagrams in Wastewater Treatment (Ph.D. thesis). University of Girona.
Garrido-Baserba, M., Hospido, a., Reif, R., Molinos-Senante, M., Comas, J., Poch, M., 2014. Including the environmental criteria when selecting a wastewater treatment plant. Environ. Model. Softw. 56, 74–82.
Gómez-López, M.D., Bayo, J., García-Cascales, M.S., Angosto, J.M., 2009. Decision support in disinfection technologies for treated wastewater reuse. J. Clean. Prod. 17, 1504–1511.
Guimãres Pereira, Ângela, Corral Quintana, S., Funtowicz, S., 2005. GOUVERNe: new trends in decision support for groundwater governance issues. Environ. Model. Softw. 20, 111–118. http://dx.doi.org/10.1016/j.envsoft.2003.12.015.
Guo, W.Q., Yang, S.S., Xiang, W.S., Wang, X.J., Ren, N.Q., 2013. Minimization of excess sludge production by in-situ activated sludge treatment processes - a comprehensive review. Biotechnol. Adv. 31, 1386–1396.
Howard, D., 2012. Aeration technology decisions using off gas testing information-sustainable aeration practice. In: Weftec Conference, 2012–W102.
Huang, Y., Dong, X., Zeng, S., Chen, J., 2015. An integrated model for structure optimization and technology screening of urban wastewater systems. Front. Environ. Sci. Eng. 9, 1036–1048.
Jing, Z., He, R., Hu, Y., Niu, Q., Cao, S., Li, Y.Y., 2015. Practice of integrated system of biofilter and constructed wetland in highly polluted surface water treatment. Ecol. Eng. 75, 462–469.
Kalbar, P.P., Karmakar, S., Asolekar, S.R., 2012. Selection of an appropriate wastewater treatment technology: a scenario-based multiple-attribute decision-making approach. J. Environ. Manag. 113, 158–169.
Karimi, A.R., Mehrdadi, N., Hashemian, S.J., Nabi Bidhendi, G.R., Tavakkoli Moghaddam, R., 2011. Archive of SID Selection of wastewater treatment process based on the analytical hierarchy process and fuzzy analytical hierarchy process methods. Int. J. Environ. Sci. Technol. 8, 267–280.
Kilic, K., Hamarat, C., 2010. A decision support system framework for innovation management. Components 2007, 765–770.
Leslie, C.P., Grady, J., Daigger, G.T., Lim, H.C., 1999. Biological Wastewater. Treatment, 2nd. Marcel Dekker, Inc, pp. 381–382.
Mohammadi, H., Sabzali, A., Gholami, M., Dehghanifard, E., Mirzaei, R., 2012. Comparative study of SMBR and extended aeration activated sludge processes in the treatment of high-strength wastewaters. Desalination 287, 109–115.
Moore, G.T., 2010. Nutrient Control Design Manual. Environmental Protection Agency (EPA), Ohio.
Personal Communication, 2011.
Personal Communication, 2015.
Poch, M., Comas, J., Rodríguez-Roda, I., Sànchez-Marrè, M., Cortés, U., 2004. Designing and building real environmental decision support systems. Environ. Model. Softw. 19, 857–873.
Rosso, D., Lothman, S.E., Jeung, M.K., Pitt, P., Gellner, W.J., Stone, A.L., Howard, D., 2011. Oxygen transfer and uptake, nutrient removal, and energy footprint of parallel full-scale IFAS and activated sludge processes. Water Res. 45 (18), 5987–5996.
Rubino, V., 1996. Caught in the crossfire: wastewater plant retrofit. Pollut. Eng. 28, 6.
Rutt, K., Seda, J., Johnson, C.H., 2006. Two year case study of integrated fixed film activated sludge (IFAS) at Broomfield. In: CO WWTP. Proc. Weftec Conference. 2006.
Shim, J.P., Warkentin, M., Courtney, J.F., Power, D.J., Sharda, R., Carlsson, C., 2002. Past, present, and future of decision support technology. Decis. Support Syst. 33, 111–126.
Singh, M., Srivastava, R.K., 2010. Sequencing batch reactor technology for biological wastewater treatment: a review. Asia-Pacific J. Chem. Eng. 1–11.
Steichecn, M., Kadava, A., Shaw, A., Martin, M., Kazemi, S., October 2009. A new paradigm: carbon footprint and sustainability assessment for process selection. In: Proceedings: WEFTEC09, Orland, FL, USA, pp. 10–14.
Tejero, I., Larrea, L., 2008. Biological Treatment. Tecnologías y estrategias para el rediseño de EDAR. NOVEDAR_Consolider, pp. 12–51.
Wei, Y., Van Houten, R.T., Borger, A.R., Eikelboom, D.H., Fan, Y., 2003. Minimization of excess sludge production for biological wastewater treatment. Water Res. 37, 4453–4467.
Yang, W., Cicek, N., Ilg, J., 2006. State-of-the-art of membrane bioreactors: worldwide research and commercial applications in North America. J. Memb. Sci. 270, 201–211.
Zalakain, G., de la Sota, A., Larrea, A., Malfeito, J.J., Albizuri, J., Larrea, L., 2008. Proceso híbrido aplicado a la remodelación de EDAR para la eliminación de nitrógeno y fósforo. Tecnol. Agua 295, 60–69.
Zeng, G., Jiang, R., Huang, G., Xu, M., Li, J., 2007. Optimization of wastewater treatment alternative selection by hierarchy grey relational analysis. J. Environ. Manag. 82, 250–259.
Zhang, S., Li, Y., Zhang, T., Peng, Y., 2015. An integrated environmental decision support system for water pollution control based on TMDL – a case study in the Beiyun River watershed. J. Environ. Manag. 156, 31–40.

Nomenclature

BF: Biofiltration
BNR: Biological Nutrient Removal
BOD: Biochemical Oxygen Demand
CAPEX: Capital expenditure
CBA: Cost-Benefit Analysis
CFU: Colony forming units
Ckb-units: Compatibility knowledge base
CML: Center of Environmental Science
COD: Chemical Oxygen Demand
EA: Extended aeration
EDSS: Environmental decision support system
IFAS: integrated fixed film activated sludge
LCA: Life cycle analysis

MBBR: Moving Bed Biofilm Reactor
MBR: Membrane Bioreactor
MLE: Modified Ludzack-Ettinger
NPV: Net Profit Value
NTU: Nephelometric turbidity units
OPEX: Operational expenditure
p.e.: Population equivalent
PFD: Process flow diagrams
Q: Flowrate
SBR: Sequential Batch Reactor
SF: Step Feed
Skb-units: Specific knowledge base
TF: Trickling Filters
TKN: Total Kjeldahl Nitrogen
TP: Total Phosphorus
TSS: Total Suspended Solids
WWTP: Wastewater treatment plant