Fuzzy vs neural network models for environmental decision support system implementation aiming to standardise the multiparametric decision in a Drinking Water Plant with Electrodialysis Reversal

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Fuzzy vs neural network models for environmental decision support system implementation aiming to standardise the multiparametric decision in a Drinking Water Plant with Electrodialysis Reversal

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Abstract: The development of an environmental decision support system (EDSS) by means of two different aims to support the operators’ decisions in the drinking water treatment plant (DWTP), equipped with the biggest electrodialysis reversal (EDR) in the world has been tested. A fuzzy artificial neural network model (fuzzy) and an artificial neural network (ANN) have been compared for optimizing the decision: how to manage water blending ratios from EDR and conventional treatment of the drinking water plant, evaluating Llobregat River characteristics (inlet DWTP), current operating conditions of DWTP, weather conditions and distribution requirements on-line. This tool has been tested among 4,5 months in the facility, showing better tendencies regarding the fuzzy model in comparison to the ANN model. A further application of the fuzzy and ANN process models, tested and validated, will be integrated into a process-controlled architecture of the EDSS.

Keywords: Fuzzy, neural network, environmental decision support system

1 INTRODUCTION

Drinking water plants (DWP) are one of the key elements in the water supply system to ensure the health standards of inhabitants. With the increasing appearance and discovery of chemicals in the environment, which also triggered stricter drinking water legislation, the treatment schemes of the DWP are becoming more complex: from fairly simple schemes with sand filters and chlorination (few decades ago) to multiple process units such as pre-treatment, flocculation, settling, carbon filtration and different membrane technologies as reverse osmosis or electrodialysis reversal (EDR).

Consequently, the operation of the DWP is becoming more uncertain and also its process automation increases its complexity, particularly, when there is a high potential of trihalomethanes (THM) formation during and after the treatment process (temperature) (Carnicero et al. 1996; Valero and Arbós 2010).

Removal of THMs precursor material before chlorination is carried out in many utilities using enhanced coagulation or adsorption processes. This procedure reduces the levels of THMs despite of not all of the NOM is removed, because neither enhanced coagulation nor granular activated carbon (GAC) adsorption effectively remove bromide, the ratio of bromide to natural organic matter is higher in the treated water and can result in a shift to the formation of more brominated disinfection by-products. There are different treatments in order to reduce some of the precursors of THMs, organic matter, conductivity, but there are other parameters not related with inlet stream that directly affect into the THM formation, like operating conditions and/or distribution requirements (contact time) or only due to the weather conditions (such us temperature) (Valero et al., 2011).
The Llobregat, Northeast Spain, supply water to more than 4.5 million inhabitants residing in the metropolitan area of Barcelona. The total treated flow by Llobregat DWTP is 4.0 m$^3$/s but only 2.4 m$^3$/s can be treated by EDR (Valero et al. 2013).

![Figure 1. Llobregat DWTP Scheme.](image)

Now, after half a decade of operation, the managers of the DWTP wanted to optimize the decision that every day is taken to decide the amount of water to be treated by EDR according the different factors involved in the THMs formation. In this context it has proposed to develop an Environmental Decision Support System (EDSS) aiming to introduce Artificial Intelligence (AI) tools to manage the operation of DWTP and to establish user-friendly tools to be used by plant managers.

2 MATERIALS AND METHODS

The decision to be optimised consists of a process operation and diagnosis to calculate real-time data to manage water blending ratios from EDR and conventional treatment of the drinking water plant, evaluating Llobregat River characteristics (inlet DWTP), current operating conditions of DWTP, weather conditions and distribution requirements (Dixon 2005; Chen and Hou 2006).

This situation makes the fuzzy and ANN modelling approach a rational choice for process modelling and controlling in water treatment. Once reliable fuzzy and ANN process models are developed, it will be able integrated into a process-controlled architecture. Both models has been tested using historial data (2014-2015), and validated using on-line data generated in the facility among 4.5 months.

2. 2 ANN model

Feed-forward neural networks with Bayesian regularized artificial neural networks have been used to develop the ANN model. This mathematical process is more robust than Standard back-propagation nets and can reduce or eliminate the need for lengthy cross-validation. The training method of the artificial neural networks is based on cross-validation, with several repetitions and seeds (Burden & Winkler, 2009).

2. 3 Fuzzy model

It has been necessary to build the fuzzy matrix and the rules for each category, in that sense this systems requires the support and the knowledge from the managers and operators of the plant. For this, it has been build two fuzzyfication matrix to estimate the risk of THMs formation, taking into account the precursors coming from Llobregat River (Table 1) and the formation kinetic of THMs based on the current operating conditions of the DWTP (Table 2).
Table 1. Fuzzification variables from the precursors river water for THM risk

<table>
<thead>
<tr>
<th>Variable</th>
<th>Language Category</th>
<th>TOC (mg C/L)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>Normal</td>
</tr>
<tr>
<td>CONDUCTIVITY (µS/cm²)</td>
<td>Very Low &lt; 1100</td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td>Low 1100-1299</td>
<td>Very</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Normal 1300-1499</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>High 1500-1699</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Very High 1700-1999</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td></td>
<td>Extreme ≥ 2000</td>
<td>Very High</td>
<td>Extreme</td>
</tr>
</tbody>
</table>

Table 2. Fuzzification variables to kinetic risk for THMs formation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Language Category</th>
<th>Temperature (ºC)</th>
<th>[Range]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very Low</td>
<td>Low</td>
</tr>
<tr>
<td>HRT (hours)</td>
<td>Low &lt;18</td>
<td>Minimum</td>
<td>Very</td>
</tr>
<tr>
<td></td>
<td>Normal 18-28</td>
<td>Very</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>High &gt;28</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Both fuzzy matrix give a desirable conductivity to achieve in the treated water (TW). Then, it has been necessary to build a decision tree in order to calculate the ration of water to be treated by EDR (Figure 2).

Figure 2. Decision tree using a fuzzy system
3. RESULTS

Once the models have been adjusted and calibrated with historical data, it has been compared the results obtained for each system. The results evaluation has permitted to obtain good decision in both systems lightly lower accuracy with ANN than with fuzzy, 73% in ANN and 77% in fuzzy. In addition, the flexibility and accessibility of fuzzu facilitates the acceptance of the final users to be implemented.

Figure 3. Evolution of the predicted modules by ANIFS and ANN from 18/10/15 to 29/2/2016

Figure 4. Correlation between the applied modules and the predicted modules by both models.
4 CONCLUSIONS AND RECOMMENDATIONS

This study developed an environmental decision support system (EDSS) comparing two different models capable of supporting the operator to make informed decisions about the best course of action for multiparametric evaluation of the drinking water treatment plant. A fuzzy artificial neural network (ANN) modelling and network-based fuzzy inference system have been compared for optimizing the decision. ANN model presented a lower linear regression than the fuzzy model. Despite the promising results, the validation of both methodologies needs a longer implementation in order to identify the gaps of each model and optimize with the experts the rules and tables generated by the fuzzy model and, therefore, become more robust. In addition, the combination can be the best option to provide the best decision. Once reliable ANN and fuzzy process models are developed, it can be integrated into a process-controlled architecture.

REFERENCES


