

Evaluation of the Wastewater Evaporation Using Fuzzy Logic Models

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Introduction

For the high salinity organic wastewater, evaporation becomes one feasible treatment to reduce the wastewater disposal amount; and the separated condensate could be recycled as water resource. Mechanical vapor recompression (MVR) is one of the evaporation techniques which is used for wastewater desalination. It has a high energy efficiency and belongs to energy saving evaporation process for saline wastewater treatments as it uses less electricity to recover the latent heat of the vapors. However, its proper application depends on many conditions of wastewater properties, evaporation characteristics and condensate properties.

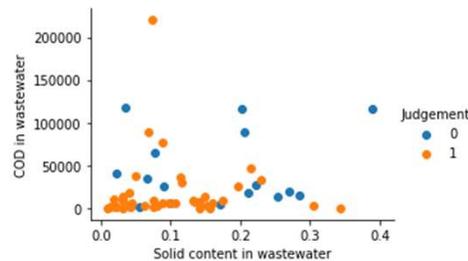
Data description

The conditions include pH, chemical oxygen demand (COD), and solid content of wastewater, pH, COD and electrical conductivity of condensate, initial boiling point, evaporation fraction, and elevated or final boiling point in the experiment.

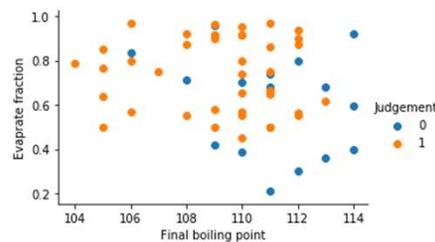
There were totally 57 wastewater samples, and the above parameters were generated for each sample through the evaporation experiments. Finally, 41 samples could be evaporated directly by mechanical vapor recompression (Judgement is '1') and the other 16 samples were not fitted directly or needing pretreatments before evaporation (Judgement is '0'). Some results were shown in Figure 1, 2 & 3.

Some rules were clearly indicated from Figure 1 to 3. For example, when electrical conductivity $\geq 2,000$, the judgement was '0', and when COD in condensate $\geq 10,000$, the judgement was '0'. when $FBP \geq 114^\circ\text{C}$, the judgement was '0', and when $FBP \leq 105^\circ\text{C}$, the judgement was '1'. Some cases were easily classified. However more data were mingled; therefore, they could not be easily distinguished. It was still difficult and time-consuming to determine if the wastewater was directly suitable for the MVR process manually.

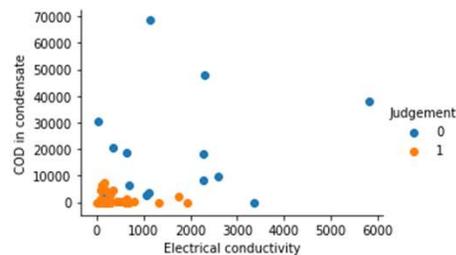
Figures



• Figure 1 The COD and solid content in wastewater



• Figure 2 The evaporate fraction and final boiling point



• Figure 3 COD in condensate and electrical conductivity

Fuzzy Model for Classification

Fuzzy model was developed to study the properties and determine if the samples were directly suitable for mechanical vapor recompression. The five most important parameters among the nine were considered. Between the min level and max level of each parameter, the values would be linearly distributed between 0 and 1.

Table 1 The fuzzy model variables

	COD in wastewater	Evaporation fraction	Final boiling point	COD in condensate	Electrical conductivity
Min level	44	0.2	104	30	15.9
Fuzzy below min	1	0	1	1	1
Max level	100,000	0.97	114	30,000	4,000
Fuzzy over max	0	1	0	0	0

Finally, in the de-fuzzy process, if the average of the values > 0.6 , it would be recognized as '1', and if it ≤ 0.6 , it would be recognized as '0'.

The test results were shown in confusion matrix in Table 2.

Table 2 The confusion matrix of fuzzy logic model

Confusion Matrix		Predict	
		0	1
Real	0	12	4
	1	0	41

There are totally four mistakes among the total 57 observations.

Kappa Coefficient

The kappa coefficient was calculated:

$$NP_e = \frac{16}{57} \cdot (12+0) + \frac{41}{57} \cdot (41+4) = 35.74$$

$$K = \frac{12+41-35.74}{57-35.74} = 81.2\%$$

The kappa coefficient was 81.2%, which characterized values is between 0.81 and 1 as indicating near perfect agreement. So fuzzy model could be used to evaluate and classify the wastewater evaporation.

Conclusions

- The relationship between the six properties and the judgement were analyzed. Some rules were clearly indicated in the figures.
- As the kappa coefficient of the fuzzy logic model results was 81.2%, it indicates it evaluates and classifies the wastewater evaporation with near perfect agreement.