4. KNOWLEDGE BASES

4.1 Membership functions

Table 3 summarizes the number of (triangular and trapezoidal in the extremes) membership functions for each variable considered in the bulking, foaming and rising problems of the risk assessment model (deflocculation is missing) and the default limit values corresponding to 100% of certainty for each membership function (see as an example Figure 13).

Table 3. Membership functions, and their values corresponding to 100% certainty, for each variable considered in the risk assessment model.

Variable \ Modality	Very low	Low	Normal	High	Very high
F/M_1	-	0.25	0.5	0.75	1
F/M_2	-	0.25	0.5	075	1
DO at reactor 3	0	1	2	3.5	5
SRT	1	3	6	9	12
BOD_5/N at the influent	-	10	20	33.3	-
BOD_5/P at the influent	-	60	80	100	-
S_S at reactor 1	-	4	20	40	-
S_S/X_S at the influent	-	0.1	0.25	0.45	-
S_{NO} at reactor 5	-	2	5	8	-
Time for nitrogen gas production	-	0.046*	0.056*	0.066*	-
Risk of filamentous bulking	-	0	0.5	1	-
Risk of foaming	-	0	0.5	1	-
Risk of rising sludge	-	0	0.5	1	-

*These values work for BSM1 control strategies with a constant sludge recycle flow rate of 18446 $m^3 \cdot d$

Food-to-microorganism ratio is calculated in two different ways within this risk model even though the membership functions are the same. While F/M_1 is calculated based on the daily mass flow rate of COD removed on the whole plant per unit of biomass, F/M_2 aims at detecting low organic loading (daily mass flow rate of supplied BOD per unit of biomass).

The dissolved oxygen level is evaluated in reactor 3, the nitrate concentration (S_{NO}) in reactor 5, the readily biodegradable organic matter (S_S) concentration in reactor 1 and BOD_5/N, BOD_5/P and the ratio between S_S and slowly biodegradable organic matter (X_S) are calculated for the influent. The sludge residence time (SRT) is calculated as the total mass of heterotrophic ($X_{B,H}$) and autotrophic ($X_{B,A}$) biomass within the five reactors divided by the daily mass of $X_{B,H}$ and $X_{B,A}$ removed from the plant via the waste sludge and the effluent.

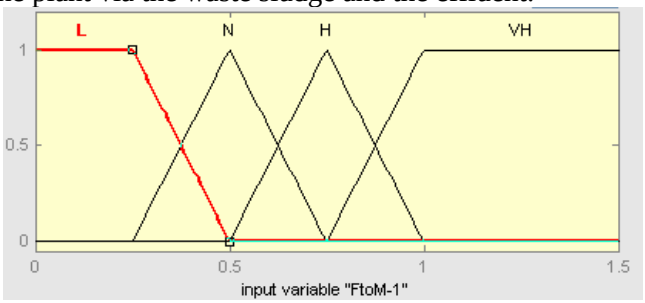

Figure 13. Example of membership function for F/M_1.

4.2 Decision matrices (Rule bases)

4.2.1 Decision matrix for Bulking due to N deficiency (middle branch of Figure 1).

The following table summarizes the set of rules to infer potential bulking problems caused by N deficiency as a function of the BOD5/N ratio.

		Risk
BOD5toN	**L**	Low
	N	Low
	H	High

In total there will be 3x1 (=3) rules.

4.2.2 Decision matrix for Bulking due to low DO (left branch of Figure 1).

The following table summarizes the set of rules that describe the relationship between F/M_1 and DO to infer potential bulking problems.

		F/M_1 (kg COD removed·kg MLVSS^{-1}·d^{-1})			
		L	**N**	**H**	**VH**
DO (mg/L)	**VL**	Low	High	High	High
	L	Low	Moderate	High	High
	N	Low	Low	Moderate	High
	H	Low	Low	Low	Moderate
	VH	Low	Low	Low	Low

It gives a total of 5x4 (=20) rules.

4.2.3 Decision matrices for Bulking due to low F/M ratio (right branch of Figure 1).

2 ways of calculation:
The following table summarizes the set of rules that describe the relationship between F/M_2 and SRT to infer potential bulking problems.

		F/M_2 (kg BOD supplied·kg MLVSS^{-1}·d^{-1})			
		L	**N**	**H**	**VH**
SRT (d)	**VL**	Low	Low	Low	Low
	L	Low	Low	Low	Low
	N	High	Low	Low	Low
	H	High	Moderate	Low	Low
	VH	High	Moderate	Low	Low

The following table summarizes the set of rules that describe the relationship between S_S and SRT to infer potential bulking problems.

SRT (d)	S_S		
	L	**N**	**H**
VL	Low	Low	Low
L	Low	Low	Low
N	Moderate	Low	Low
H	High	Low	Low
VH	High	Low	Low

Then the final value for the risk of Bulking due to low F/M simply consists in taking the maximum value of the two risks (calculated in the 2 different ways) at every time step.

4.2.4 Decision matrix for Foaming due to low F/M ratio (left branch of Figure 2)

The following table summarizes the set of rules that describe the relationship between F/M_2 and SRT to infer potential foaming problems caused by Nocardioforms and *M. Parvicella.*

SRT (d)	F/M_2 (kg BOD supplied·kg MLVSS^{-1}·d^{-1})			
	L	**N**	**H**	**VH**
VL	Low	Low	Low	Low
L	Low	Low	Low	Low
N	Moderate	Low	Low	Low
H	High	Moderate	Low	Low
VH	High	Moderate	Low	Low

A rule is obtained for each ‘combination’ of SRT and F/M_2, e.g.:

IF F/M_2 is *low* & SRT is *normal* THEN Risk of foaming is *moderate*.

4.2.5 Decision matrices for Foaming due to high readily biodegradable organicmatter (Ss/Xs) fraction (right branch of Figure 2)

2 ways of calculation:

The following table summarizes the set of rules that describe the relationship between F/M_2 and S_S/X_S fraction to infer potential bulking problems.

S_S/X_S	F/M_2 (kg BOD supplied·kg MLVSS^{-1}·d^{-1})			
	L	**N**	**H**	**VH**
L	Low	Low	Low	Low
N	Low	Low	Moderate	Low
H	Low	Low	Moderate	High

The following table summarizes the set of rules that describe the relationship between SRT and S_S/X_S to infer potential bulking problems.

S_S/X_S	SRT (d)				
	VL	**L**	**N**	**H**	**VH**
L	Low	Low	Low	Low	Low
N	Moderate	Low	Low	Low	Low
H	High	Moderate	Low	Low	Low

Then the final value for the risk of Foaming due to high S_S/X_S simply consists in taking the maximum value of the two risks (calculated in the 2 different ways) at every time step.

4.2.6 Decision matrix for Rising

The following table summarizes the set of rules that describe the relationship between NO3 and the 'Nitrogen gas production time' to infer potential rising problems.

NO_3	Nitrogen gas proudction time		
	L	**N**	**H**
L	Low	Low	Low
N	Moderate	Low	Low
H	High	Moderate	Low

4.2.7 Decision matrix for Deflocculation

The rules presented about deflocculation problems are summarized in the present decision matrix:

DO ($mg \cdot l^{-1}$)	SRT (d)				
	VL	**L**	**N**	**H**	**VH**
VL	Low	Low	Low	Low	High
L	Low	Low	Low	Moderate	High
N	Low	Low	Low	Low	Moderate
H	Moderate	Low	High	High	High
VH	Moderate	Low	High	High	High