1. PROBLEM ANALYSIS

Four operational problems are currently considered in the risk model: filamentous bulking, filamentous foaming, rising sludge and deflocculation. For each operational problem, one knowledge-based flow diagram that only uses available data within the BSM has been developed (Henze *et al.*, 1993; Wanner, 1994; Grady *et al.*, 1999; Jenkins *et al.*, 2003; Comas *et al.*, 2006).

Filamentous bulking. Three main causes of filamentous bulking are evaluated: low DO concentration, nutrient deficiency and low F/M ratio or substrate limiting conditions (Figure 1). Filamentous bulking sludge caused by septic conditions or low pH in the influent cannot be considered within the current benchmark model. The left branch of the tree illustrates that limiting DO conditions in the biological reactors relies on the current F/M ratio (Grady et al., 1999). Encouraging conditions for the growth of low F/M filamentous bacteria can be caused by both readily biodegradable substrate limiting conditions in the bioreactor and by low influent organic loading. If the simulation results indicate that conditions for more than one branch are completely fulfilled, the worst conditions are selected.

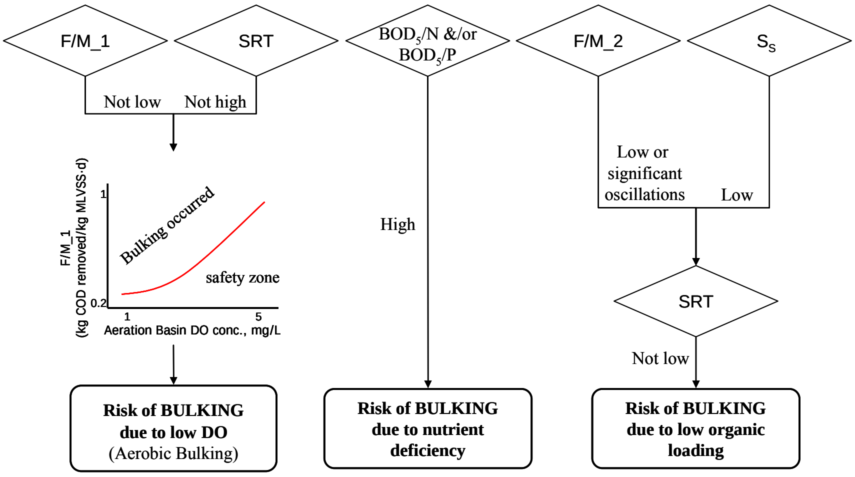

Figure 1. Flow diagram developed to evaluate the risk of filamentous bulking.

Filamentous foaming. The operational conditions enhancing the growth of Nocardioforms and *M.Parvicella* (low F/M, high SRT values and, in the *M.Parvicella* case, also low DO values) and the growth of type 1863 (high fraction of readily biodegradable organic matter in the influent) are investigated (Figure 2).

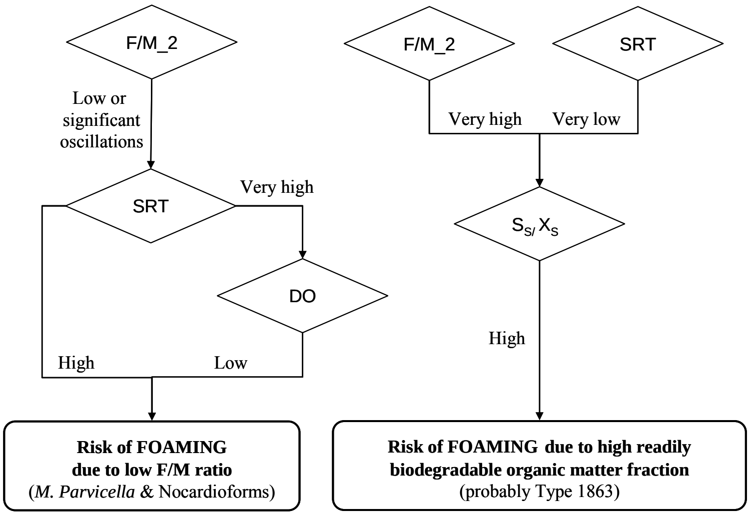

Figure 2. Flow diagram developed to evaluate the risk of foaming.

Rising sludge. Rising sludge is primarily a problem if the nitrate concentration in the secondary clarifier influent is higher than 8 mg N-NO3•L-1 (critical nitrate concentration according to Henze et al., 1993). In this situation, favourable conditions for rising sludge are identified by comparing the nitrogen gas production time with the sludge residence time in the secondary clarifier (Figure 3). If the nitrogen gas production time is lower than the sludge residence time in the secondary settler, then rising sludge due to denitrification in the secondary settler is probable. The sludge residence time in the settler is computed as the volume of settling sludge divided by the RAS flow rate. Fast DO consumption is assumed in the settler and therefore the denitrification rate is always computed assuming no oxygen inhibition (DO = 0 mg O_2•L-1).

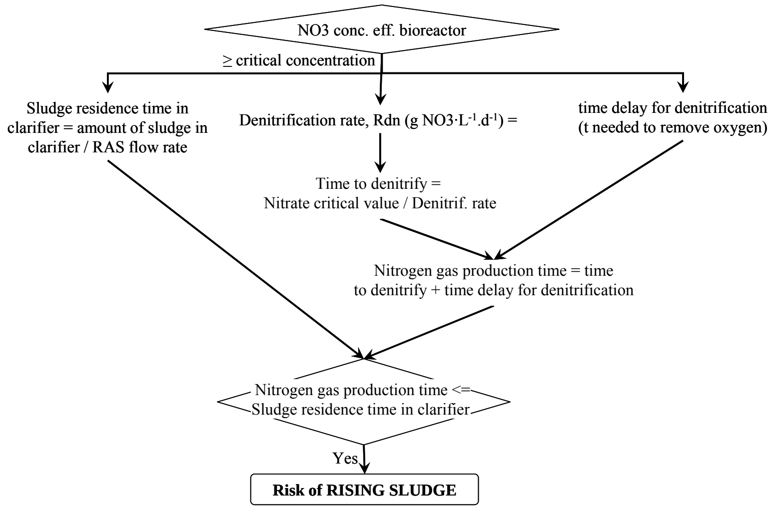

Figure 3. Flow diagram developed to evaluate the risk of rising sludge.

Deflocculation. To the correct diagnosis of the deflocculation problems it is usually necessary to evaluate the activity of the microorganisms in the activated sludge under the microscope. Obviously, this cannot be done in the BSM. To quantify the risk of deflocculation, the main operational causes according to the existing literature have been taken into account. Dissolved oxygen (DO) is the most important variable involved in this diagnosis. Very low DO is insufficient and causes an old sludge (Wilén B and Balmér P., 1999), and too much aeration can broke the floc (Comas *et al., 2003*). The sludge age also influences, if it is too low can cause deflocculation if the Food to Mass ratio (FtoM) is low enough (Barbusiński K. and Kościelniak H., 1995)

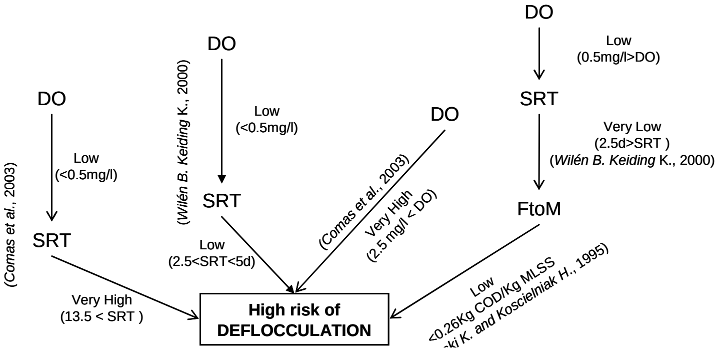

Figure 4. Flow diagram developed to evaluate the risk of deflocculation.

As suggested in the BSM TG meeting #1, these knowledge-based flow diagrams, core of the risk model, have been evaluated by a panel of WWTP experts.