This research developed a modified ASM1 dynamic computer model to better describe the overall removal of organic substrate (quantified as COD or chemical oxygen demand) from A-Stage Activated Sludge Systems. It was determined early in the project that influent soluble COD, which is normally represented by a single state variable in ASM1, had to be subdivided into two state variables (SBs and SBf, or slow and fast fractions) to simulate the performance of A-stage systems. Also, the addition of state variables differentiating colloidal COD from suspended COD was necessary due to short hydraulic residence times in A-stages systems which do not allow for complete enmeshment and bioflocculation of these particles as occurs in conventional Activated Sludge Systems (which have longer solid residence times and hydraulic retention times). It was also necessary to add several processes (both stoichiometry and kinetic equations) to the original ASM1 model including bioflocculation of colloidal solids. How to properly quantify heterotrophic growth on SBs and SBf resulted in two separate approaches with respect to process kinetic equations. In one approach the SBf was metabolized preferentially over SBs which was only utilized when SBf was not available. This is referred to as the Diauxic Model. In the other approach SBf and SBs were metabolized simultaneously, and this is referred to as the Dual Substrate Model. The Dual Substrate Model calibrated slightly better than the Diauxic Model for one of the two available pilot studies data sets (the other set was used for model verification).

The Dual Substrate A-stage model was used to describe the effects of varying specific operating parameters including SRT, DO, influent COD and temperature on the effluent COD:N ratio. The effluent COD:N ratio target was based on its suitability for a downstream nitrite shunt (i.e. nitrification/denitrification) process. In the downstream process the goal is to eliminate nitrite oxidizing bacteria (NOB) from the reactor while selecting for ammonia oxidizing bacteria (AOB). The results showed that a low SRT (<0.25 d) insures high effluent substrates (SB and CB), and elevated COD:N ratios consistent with NOB out-selection downstream, the HRAS model was able to predict the measured higher fraction of CB in the A-stage effluent at lower SRTs and DO concentrations, and to achieve the benefits of operating an A-stage process, while maintaining an effluent COD:N ratio suitable for a downstream nitritation/denitritation process, an A-stage SRT in the range of 0.1 to 0.25 d should be maintained.

This research also included an analysis of A-stage pilot data using stoichiometry to determine the bio-products formed from soluble substrate removed in an A-stage reactor. The results were used to further refine the process components and stoichiometric parameters to be used in the A-stage dynamic computer model, which includes process mechanisms for flocculation and enmeshment of particulate and colloidal substrate, hydrolysis, production of extracellular polymeric substances (EPS) and storage of soluble biodegradable substrate. Analysis of pilot data and simulations with the dynamic computer model implied (indirectly) that storage products were probably significant in A-stage COD removal.

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Approved for distribution by Dr. Andrew A. Randall, Committee Chair, on February 2, 2015.
The public is welcome to attend.