Activated Sludge Basins Get on Track

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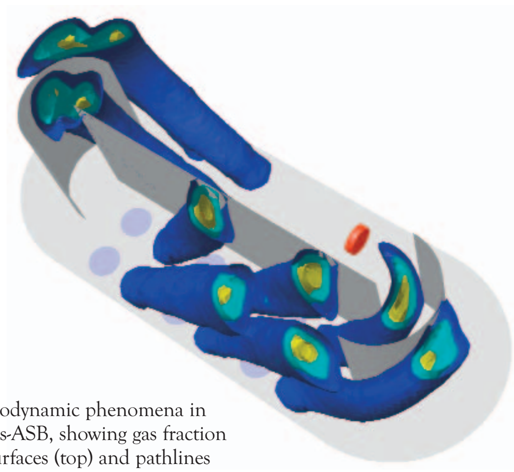
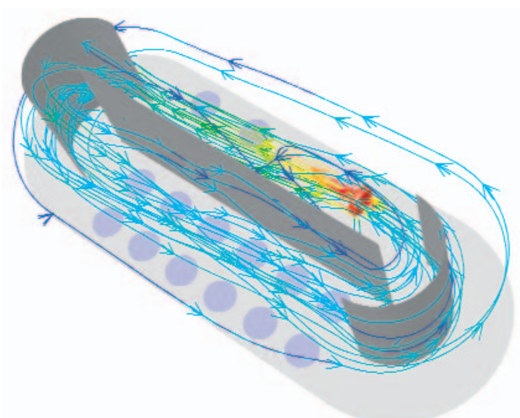
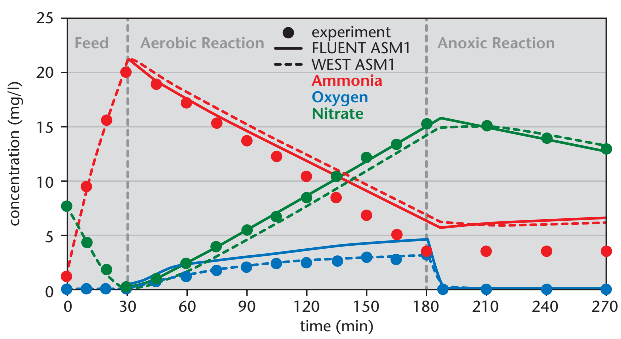




Hydrodynamic phenomena in the ps-ASB, showing gas fraction iso-surfaces (top) and pathlines of liquid velocity (bottom)



Profile plots of the reaction phenomena in the ps-ASB

ACTIVATED SLUDGE BASINS (ASBs) are a key step in the treatment of municipal wastewater. ASBs are used to degrade biochemically reactive pollutants from water that is discharged into the natural environment. The bacteria found in the sludge consume and assimilate nutrients such as carbon, nitrogen, and phosphorous under several environmental conditions. The design of ASBs is difficult, however, due to factors including:

- the treatment aims (pollutants to be degraded)
- the influent wastewater composition (time and location dependent)
- the application of liquid agitation and aeration (brushes, disks, membrane aerators, impellers, turbines and venturi tube mixers)
- the location and spatial requirements (local weather, above or below ground, sparsely or densely populated regions)
- the daily treatment loading (from a few hundred liters to thousands of cubic meters)

Each one of these factors influences the size, form, and mode of operation (continuous or sequenced batch treatment) that is used when designing an ASB. Variation in some of the factors, such as daily changes in the temperature and in the influent composition and flow rate, can impact the efficacy of the treatment process. Thus, for the design of any ASB, an appropriate selection of agitators and aerators is essential to provide optimal environmental conditions for the treatment of wastewater.

A study that was co-funded by Anjou Recherche, the R&D arm of Veolia Water, and the European Union was recently performed to develop a computational strategy for modeling ASBs. The primary focus of the study was to examine the effect of the local hydrodynamics on the biochemical reactions observed in ASBs for both pilot and real scale processes. The results provided an improved understanding of the hydrodynamic impact on the environmental conditions experienced by the bacteria.

A pilot-scale ASB (ps-ASB) was used to establish a database of hydrodynamic data (circulation velocity and mean bubble sizes) and interphase mass transfer data under different operating conditions. The ps-ASB was then used to study the impact of the normal and abnormal operating conditions on the biochemical reaction phenomena by monitoring the change in concentration of key wastewater constituents, such as ammonia, organic carbon, nitrates, organic nitrogen, and particulate matter.

The ps-ASB applied different environmental conditions in a programmed sequence. The different conditions were affected by contacting the mixed liquor, a mixture of wastewater and activated sludge, with air in the form of fine bubbles, and applying a circulation velocity with a marine-type impeller. This condition enabled the aerobic oxidation of both organic carbon and nitrogen (in the form of ammonia) to carbon dioxide and nitrate, respectively. A second condition only agitated the biomass in the mixed liquor to reduce the overall nitrogen content of the wastewater. Under these conditions a different type of biomass (anoxic bacteria) consumes the nitrate producing nitrogen, which then evolves as a gas.

The operational data was used to create a hydrodynamic and biochemical reaction model of the ps-ASB. The first step was to model the biochemical reactions assuming perfectly mixed reactor conditions with the wastewater modeling tool WEST® [1], which uses the Activated Sludge Model No. 1 (ASM1) protocol [2].

The mixed liquor composition and the calibrated kinetic and stoichiometric parameters derived from this global model were then applied to a converged local hydrodynamic solution constructed in FLUENT. The Eulerian multiphase model was employed with the dispersed phase form of the k-ε turbulence model to resolve the gas-liquid motion under steady flow conditions.

The application of the ASM1 protocol to FLUENT was validated by analysis of the component profiles during the aerobic and anoxic reaction phases. The rates under the different operating conditions were accurate to within 10% of the experimentally measured reaction rates, where the accepted error was 10 to 15%.

Liquid velocity pathlines and volume fraction contours of the ps-ASB were used to illustrate the hydrodynamics of the basin. The distribution of dissolved oxygen after one hour of aeration was also examined. The difference between the cold and warm iso-surfaces was found to be 0.4 mg/l over the range from 2.9 to 3.4 mg/l. At this point in the simulation, the oxygen concentration gradient does not influence which biochemical reaction processes are predominant. However, at a mean concentration of less than 0.5 mg/l different treatment regimes could be found in the reactor (informal aerobic and anoxic zones).

The aeration and agitation regimes applied to the ps-ASB were considered to be perfectly mixed and at a comparatively small scale for treatment processes. Thus, the effects observed with the ps-ASB may be different from those of real scale Activated Sludge Basins (rs-ASBs) where volumes of up to 10,000m^3 are widely used. At the larger scale, perfectly mixed reactor or plug flow regimes are not guaranteed, and the potential influence of the mixing regimes is far greater and more difficult to categorize. Thus, incorrect operating conditions will cause mixing regimes that would hinder the ability of the ASB to meet the treatment objectives.

To test this possibility, two rs-ASBs with different geometries and hydrodynamic regimes were simulated. The basin rs1-ASB is a carrousel type ASB, whereas rs2-ASB is a race-track type ASB. The information derived from these simulations (circulation velocity and oxygen mass transfer characteristics) indicated how well each ASB could meet its objectives.

The pathlines for rs1-ASB indicate that the conditions are near optimal, while pathlines in rs2-ASB showed that the process was not close to optimal conditions. The flow field in rs2-ASB was characterized by low horizontal liquid velocities and large recirculation zones and short-circuiting upstream of the bubble plumes. The liquid circulation patterns were disrupted by the bubble plumes, causing them to degrade. In general, poor liquid circulation reduces the oxygen mass transfer rates and the dispersion of oxygen throughout the ASB. The ability of the biomass in this particular basin to aerobically treat the wastewater could therefore be limited by the operating conditions applied.

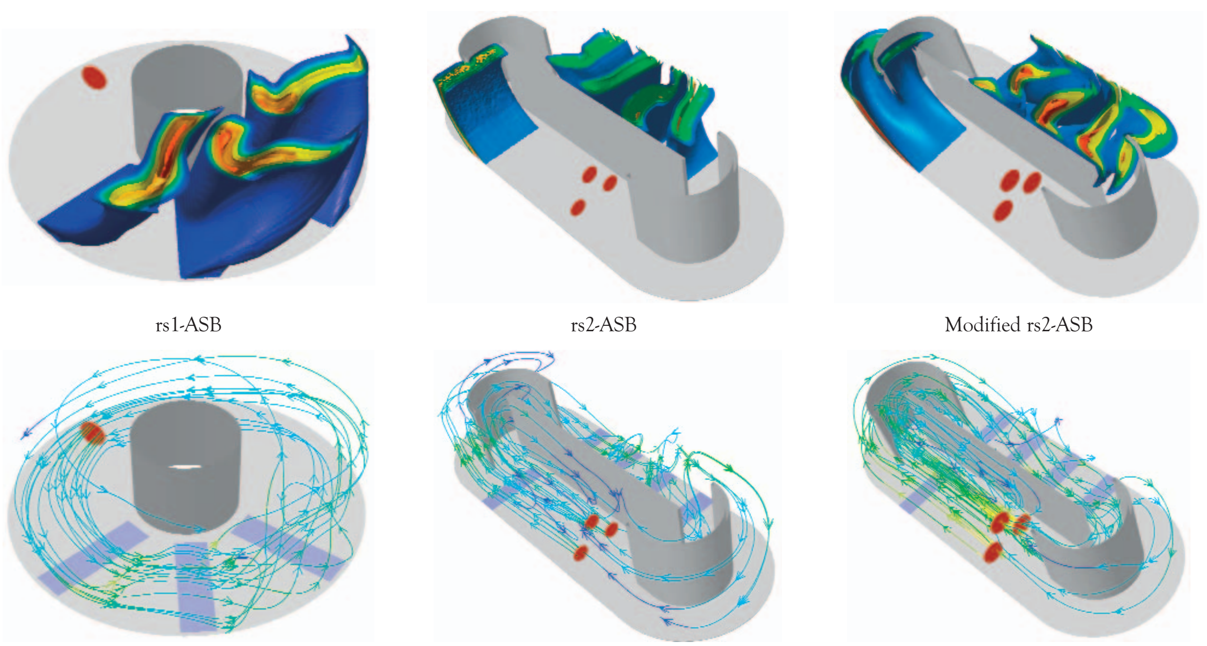
Further simulations were performed to improve the aeration strategy by analyzing the effect that different aerator and agitator configurations had on these two design parameters. The simulations examined the positions of the aerators and agitators as well as the agitation rate and size of the impellers, with the single goal of improving the mass transfer characteristics of rs2-ASB. The hydrodynamics of the modified design showed improved liquid circulation with less disruption of the flow by the bubble plumes, resulting in a 250% increase of the circulation velocity.

The computational strategies developed during the course of this study have enabled Veolia Water to obtain a numerical tool that can aide decisions made in selecting aeration and agitation configurations for Activated Sludge Basins, for the design of new technologies and retrofitting of existing installations. ■

References:

1 Hemmis, N.V., WEST®, Hemmis N.V., Kortrijk, Belgium, 2003.

2 Henze, M., Gujer, W., Mino, T., and van Loosdrecht, M.: Scientific and Technical Report No. 9. IWA Publishing, London, UK, 2000.



Hydrodynamic phenomena in the rs-ASB, showing gas fraction iso-surfaces (top) and pathlines of liquid velocity (bottom)