By Malcolm E. Fabiyi

α understanding the Alpha Factor

Applying the alpha factor and pure oxygen to reduce aeration power demand

The use of membrane bioreactors (MBRs) is rapidly growing, driven largely by the significant advantages such as smaller footprint, lower sludge yield, good effluent quality and enhanced nutrient removal that their deployment brings to wastewater treatment operations.

Although these systems can theoretically be operated at solids concentrations up to 30 to 40 gal/L mixed liquor suspended solids (MLSS), in practice they are operated at solids concentrations of about 8 to 12 gal/L. The major limiting constraint to running MBR systems at high concentrations has largely been due to the increase in power consumption that arises as a consequence of the characteristic exponential degradation of the alpha factor observed as the solids concentration in the MLSS increases. The increase in fouling at high solids concentrations is also a factor.

The Alpha Factor Effect

The effect of high solids concentrations on the mass transfer properties of diffuse air systems has been well studied; there are no comprehensive studies that have systematically examined other aeration approaches in which oxygen transfer mechanisms differ substantially from the diffuser approach. There has been a tacit assumption that most aeration systems would have similar solids concentration-mediated mass transfer performance features to those observed for diffuser systems.

This focus on diffuser systems is somewhat justified given the fact that they tend to be the most commonly utilized aeration devices in MBR systems. Fine bubble diffusers are generally used for oxygen delivery on the aeration side, and coarse bubble-type systems are used for scouring. However, the relatively high oxygen demand, or oxygen utilization rates (OURs), associated with MBR systems and the increasing footprint limitations that result for diffuser placement make it imperative for other classes of aeration systems to be investigated.

Several studies have confirmed the exponential decline in the alpha factor as the solids concentration increases in diffuser-type aeration systems. The validity of extending this degradation profile to other aeration systems, however, can be problematic given the variation in alpha observed even within diffuser-based aeration systems. Various aeration equipments, especially of the mechanically aided (impeller-driven) mixing kind, are known to occasionally report alpha values that exceed 1.0.

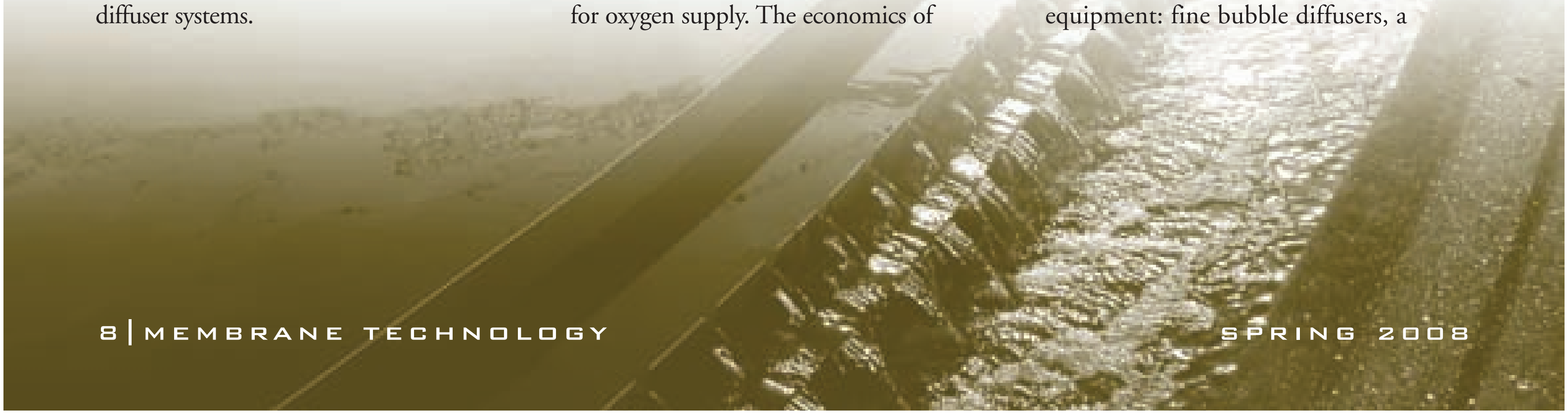
The importance of understanding with a greater degree of clarity the causal underpinnings of the alpha-factor phenomenon cannot be overemphasized. Günder (2001) indicates that an increase from 5 gal/L to 30 gal/L MLSS has a negligible impact on the specific energy requirements for membrane filtration but leads to a 300% increase in the specific energy requirement for oxygen supply. The economics of high-solids MBR operations are therefore largely predicated on a thorough understanding of the alpha-factor effect.

Testing

My colleagues and I have carried out comprehensive studies aimed at understanding the causal mechanisms underlying the alpha-factor phenomenon. Previous studies have established that significant changes in viscosity occur when the mixed liquor concentration changes. We replicated these findings in our tests.

Given the demonstrated impact of solids concentration on viscosity, we hypothesized that there would be a profound effect of solids concentration on the bubble size distribution. The effect of viscosity on bubble formation, bubble coalescence and mass transfer is generally well known. We elected to model the viscosity effect of sludge on bubble formation (hence mass transfer and alpha factor) using a transparent medium to facilitate visual tracking of the viscosity on bubble behavior. Carboxyl methyl cellulose (CMC), which in solution forms a clear non-Newtonian material with similar rheological properties to mixed liquor, was used for viscosity adjustment. Our team developed a mapping methodology that enabled us to relate the viscosities of the CMC system to the equivalent mixed liquor concentrations.

We tested four types of aeration equipment: fine bubble diffusers, a



dissolved-air flotation (DAF) pump, an injection-type jet aerator and a mechanically agitated contactor (MAC). The MAC system used is a scaled version of Praxair's proprietary oxygen delivery system (In-Situ Oxygenator, I-SO). All mass transfer tests were carried out using the ASCE methodology.

From the mass transfer results obtained at varying solids concentrations, we determined the corresponding alpha-factor values. Figure 1 summarizes the results obtained for the analysis of the impact of different aeration systems on the alpha-factor degradation profile.

We observed a very profound effect of increasing viscosity (solids concentration) on the bubble size. As viscosity increased, average bubble sizes increased for the bubble-driven mixing systems. The mass transfer behavior of two side stream pumping systems—a DAF pump and a jet aerator system—were investigated. It was observed for both these systems that the bubble size generally increased as the solids concentration and viscosity increased. The alpha-factor profile also followed a general exponential decline. However, the decline in the alpha factor was more steep for the DAF system than it was for the jet aerator-type system.

Three main observations were made during the tests carried out with the MAC system: 1) an initial diminishing in bubble size as viscosity increased; 2) an increase in the bubble retention time as viscosity increased; and 3) a subsequent increase in bubble diameter at high solids loading. The alpha-factor profile for this oxygen delivery system exhibited an evolution that was distinct to that of the other devices studied. Alpha initially increased from its base value of 1.0 to reach approximately 1.2 at an equivalent MLSS concentration of about 12 gal/L. The alpha factor dropped subsequently with increasing solids concentration. Figure 1 summarizes the alpha-factor effect for the various aeration systems studied.

Figure 1: Alpha-factor profiles for various mixing and oxygen delivery devices.

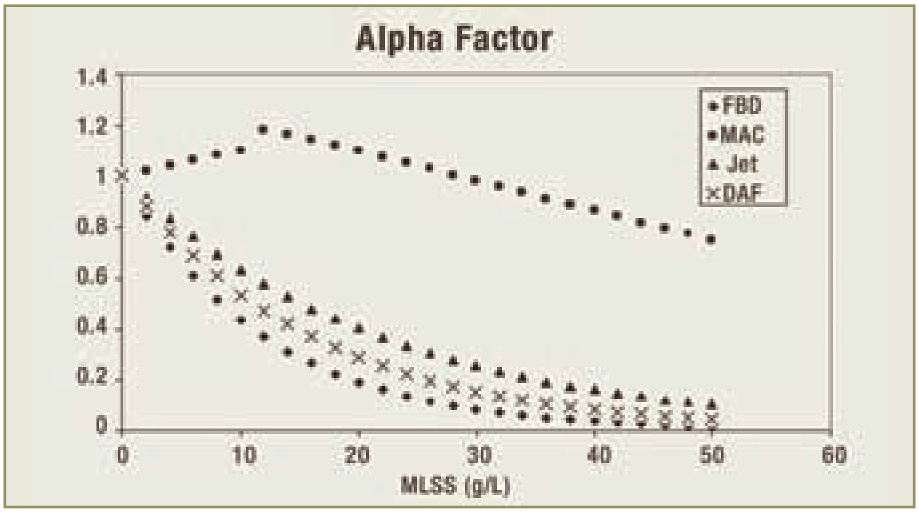


Table 1: Operating costs for aeration in pure oxygen vs. conventional air MBR systems.

Oxygen cost	100	$/ton	
OUE	90%		
POwer cost	0.1	$/kWh	
MLSS	10,000	mg/L	
	Air	**Pure O_2**	
SAE Air	1.5	4.5	kg/kWh
Alpha	0.4	1	
AE	0.6	4.5	kg/kWh
O_2 demand	3,500	3,500	Kgs/day
Power required	243.06	32.41 kW	
	Operating Cost		
Power cost	590.00	80.00	$/day
Oxygen cost	0	390	$/day
Total	**590.00**	**470.00**	**$/day**

Final Analysis

A major conclusion that can be drawn from our work is that the use of a MAC system such as Praxair's I-SO can be used to mitigate the high power costs associated with the operation of MBR systems. These systems offer significant aeration cost reductions compared to conventional aeration approaches. Power demand is typically a fraction of that associated with conventional aeration systems, and this has been confirmed in numerous full-scale systems.

Table 1 shows the operating costs associated with the use of a pure oxygen-based I-SO system versus a conventional air-based diffuser system for meeting the aeration demand in an MBR application. Our findings indicate that with the use of suitable oxygenation and aeration devices that can overcome the alpha-factor degradation observed in conventional air systems, MBR processes can be operated at solids concentrations up to 25 to 30 gal/L in an optimal and economically feasible manner. MT

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