ECO2 Eco Oxygen Technologies Technical Bulletin

COMPARING AERATION AND OXYGENATION

INTRODUCTION

In many situations, high purity oxygen (HPO - 90 to 99% O_2), can be generated and dissolved into water for about half as much electricity consumption and comparable total cost compared to that required to dissolve the same amount of oxygen from "free" air. (For purposes of this paper, aeration will be the term used to describe transfer of oxygen into water from air, while oxygenation will be the term used to describe transfer of oxygen into water using HPO.)

It is no surprise that electricity costs have risen dramatically in the last several decades. The underlying assumption that gave rise to the almost universal use of aeration for oxygen transfer in water quality management was that the high-energy consumption by the process was offset by low electricity costs. Since relatively low electricity rates are now a thing of the past, this occasions an opportunity to re-examine the economical advantage of aeration vs. oxygenation. Furthermore technology for generation of HPO on-site having total costs of approximately $70/ton has come into common usage.

This changing scene favoring oxygenation opens up unique opportunities to solve water quality problems that were not possible using conventional aeration. Off-gas stripping is reduced by about 2 orders of magnitude in oxygenation vs. aeration. This has great significance in odor generation and activated sludge treatment of industrial wastewaters containing volatile and/or hazardous air pollutants (HAP), as found in the pharmaceutical as well as pulp and paper industries. Because the D.O. can economically and efficiently be increased to 50 to 100 mg/L, oxygenation also makes possible a completely different approach to odor elimination in force mains and primary clarifiers.

Higher environmental standards, increased energy costs, improved oxygen dissolution techniques, ready availability of commercial oxygen, implementation of better safety measures for commercial oxygen use, and the critical need for strict odor and other noxious gas containment all dramatically affect the wastewater treatment choice of today's water quality management professionals.

LIMITS OF AERATION

Under field conditions today many aeration systems–-composed of coarse bubble diffusers and mechanical aerators–transfer only 1 to 2 lbs. O_2/ kwhr. This low rate translates into1000 to 2000 kwhr/ton of oxygen absorbed. Several decades ago when electricity was only $0.02/kwhr, operating costs totaled only $20 to $40/ton O_2 dissolved. Now that electricity costs in many parts of the Northeast and California exceed $0.12/kwhr, this price hike translates into $120 to $240 /ton O_2 dissolved just for the electricity costs. Furthermore, it is economically disadvantageous to maintain D.O. concentrations above 2 to 4 mg/L..

DISSOLVED NITROGEN GAS STRIPPING

An unfortunate oversight in the development of past technology to dissolve HPO into water was the fact that N_2, already dissolved in the water was significantly stripped into the gas phase. This was especially pronounced when the oxygen transfer took place at ambient pressure – which was often the case. The bottom line of the impact of dissolved nitrogen stripping is firstly to increase the unit energy consumption to dissolve a ton of oxygen, because the D.O. deficit is markedly reduced. Secondly it severely limits the maximum D.O. concentration that can be added to a side stream. A proper oxygenation system must minimize nitrogen gas stripping.

OFF-GAS STRIPPING

Unfortunately conventional methods of dissolving oxygen into water utilizing air as the oxygen source are quite inefficient – achieving only 5 to 10 % oxygen absorption efficiency. This means that for every 100 ft^3 of air bubbled through the water, only 1 to 2 ft^3 of oxygen is dissolved at 5 - 10% absorption efficiency. This results in 98 to 99 ft^3 of off-gas per 100 ft^3 of air injected. The same would also be true of surface aeration, which is even more effective at air stripping volatiles from the water.

COSTS FOR AERATION vs. OXYGENATION

The total cost of dissolving 1 ton of oxygen per day from air as compared to that using HPO is shown in the following table:

Aeration (1.5 lb O_2/kwhr)	Oxygenation	
Capital Cost - $40,000	Capital Cost of PSA oxygen generator + Air compressor	$70,000
Operational Cost – 1300 kwhr/ton O_2	Electricity Consumed	
	Produce O_2	400 kwhr/ton
	Dissolution & Mixing	400 kwhr/ton
	Total	800 kwhr/ton

Amortization at 8% over 10 years (0.15/yr)

	Aeration			Oxygenation		
Electricity ($/kwhr)	0.06	0.09	0.12	0.06	0.09	0.12
Operating ($/ton)	78	117	156	48	72	96
Amort. ($/ton)	16	16	16	27*	27*	27*
Total ($/ton)	94	133	172	75	99	123

* Amortization only of PSA and its air compressor

LIFE CYCLE COST OF OXYGEN NOT ABSORBED

The life cycle cost of electricity to operate a pump dwarfs the initial cost of the pump and therefore dictates that the pump is selected to operate at high efficiency. So also the life cycle cost of oxygen dwarfs the initial cost of an oxygenation system and therefore dictates that high oxygen absorption efficiency be realized in a proper oxygenation system design. At $100/ton for oxygen, the life cycle cost for 1 ton/day oxygen absorbed comes to $449,000 plus $135,000 for the oxygen NOT absorbed at 70% oxygen absorption efficiency.

MIXING AND CO_2 STRIPPING

In wastewater treatment applications involving activated sludge and aerated lagoons, mixing to maintain the bacteria in suspension and CO_2 stripping are often accomplished simultaneously with oxygen transfer by the same device. The system is then sized in horsepower by whichever function predominates, resulting in the system being oversized for the non-controlling functions. Mixing and CO_2 stripping do not have to be accomplished together with oxygen transfer by the same piece of equipment. These objectives can and are separated to advantage.

Although such a traditional practice may be an appropriate solution in some cases, in the majority of cases it may be more energy and cost efficient to uncouple the mixing from the oxygen transfer function. Mixing is much more efficiently achieved with large diameter low speed impellers. Many such mixing systems are presently in operation. Likewise, CO_2 stripping can economically be achieved with a small surface splasher because the dissolved CO_2 deficit is so high e.g. 100 mg/L CO_2 for approximately 200 mg/L BOD_5 removed. For weak BOD_5 wastewater having alkalinity >150 mg/L, no CO_2 stripping is required for pH control. Dissolved CO_2 stripping assumes greater significance for pH control with strong wastewaters.

The CO_2 that results from microbial metabolism is quite soluble in water. For the high BOD concentrations found in some industrial wastewaters, there will be correspondingly high CO_2 generation. Removal of this CO_2 to a concentration commensurate with the alkalinity is required. For example with an alkalinity of 500 mg/L as $CaCO_3$, an ionic strength of 0.2 and 5% CO_2 in the gas phase (100 mg/L CO_2 in aqueous phase) will result in a pH of 7.0. Under this condition it requires only about 1/14 as much HP-hr to strip one pound of CO_2 at 100 mg/L as it does to dissolve one pound of oxygen at 2 mg/L D.O. e.g. D.O. deficit of 7 mg/L. With 1000 mg/L of alkalinity, the CO_2 concentration could be twice as high to maintain a pH of 7.0 and the stripping would require only 1/28 as much energy. Therefore CO_2 is easily stripped with low energy consumption by a small surface aerator.

For assistance with your specific needs in this application, please contact your Eco Oxygen Technologies systems engineer.