IMPROVING AERATION EFFICIENCY

Ian Ho, Harrison Grierson
Ash Deshpande, Harrison Grierson

ABSTRACT

Aeration is critical to the efficiency of any activated sludge treatment process. The right amount of air at the right time and to the right organisms ensures proper pollutant degradation. In a typical treatment plant, aeration accounts for about 60% of the total power costs of the plant. Hence, failing to optimise aeration is not only detrimental to plant performance but also incurs unnecessary costs.

This paper outlines how savings can be achieved in operating costs by smarter use of aeration in typical activated sludge process. Various principles and techniques of aeration control are discussed in this paper. The main techniques being feed forward control based on influent and air on/air off method. In the latter, two classes of nitrifying organisms are made to work sequentially thus optimising the utilisation of supplied oxygen. Furthermore, real time oxygen uptake rates of the mixed liquor can be measured, which further assists in process optimisation and control.

A desktop benchmarking process was conducted to compare a number of simple aeration control regimes. It was found that approximately 15 to 20% aeration power saving can be achieved. Despite the desktop benchmarking exercise demonstrates 20% aeration saving, it has been reported that aeration saving could be around 25 to 40% at field conditions. This corresponds to a significant reduction of power consumption, greenhouse gas emission (from the power plant) and lower operational and maintenance cost.

A co-ordinated effort between the operational and maintenance staff and the equipment suppliers is vital to deliver the aeration power reduction and cost saving.

KEYWORDS

Wastewater Treatment, Optimisation

1.0 INTRODUCTION

Activated sludge is the predominant biological wastewater treatment process and process aeration is by far the most critical element in terms of achieving the required treatment performance such as organic degradation and ammonia removal as well as maintaining biomass health. Without providing the correct amount of aeration, the treatment processes are at risk of failing to comply its performance standards and/or discharge limits.

Moreover, process aeration is energy intensive and could represent around 60% of the energy cost for activated sludge processes. This has motivated the treatment plant operational staff to explore various ways to optimise aeration either through better (often more sophisticated) aeration control or more efficient aeration equipment such as replacing coarse bubble diffusers with fine bubble diffusers.

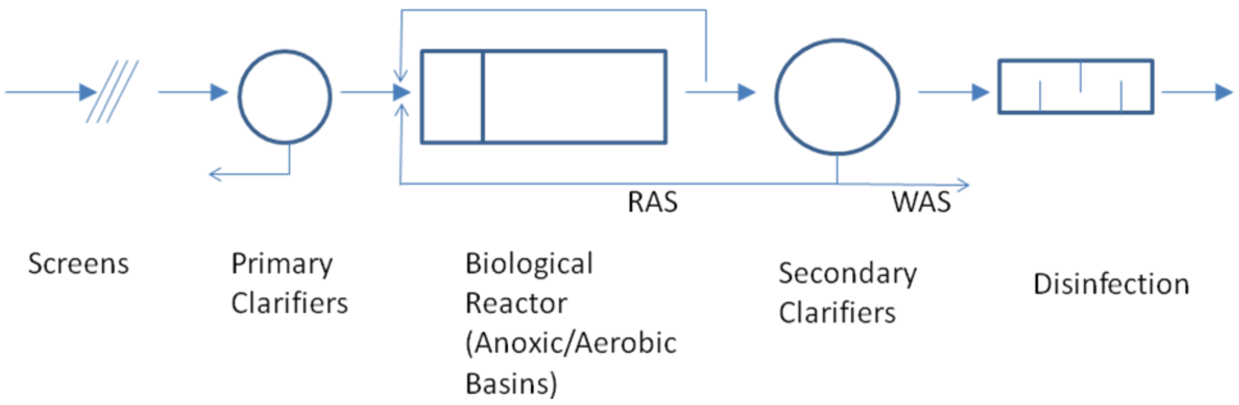
Numerous researches have been conducted to identify the most optimum means to control the aeration (L Amand et al 2011), and a range of improvement efficiencies have been reported. However, these publications often have different baselines to each other, this in turn causes difficulties for the readers to compare the potential gains for these improvement options.

This paper is a review of various aeration control techniques and a few of these were simulated in BioWin for comparison.

2.0 AERATION CONTROL BASICS

As shown in the Figure below, a typical wastewater treatment plant with activated sludge process normally consists of inlet works (Screens and grit removal), Primary Clarification, Activated Sludge Reactor Basins, Secondary Clarification and Disinfection (UV or chlorination).

Figure 1: *Typical Activated Sludge Treatment Plant*



Process aeration is usually provided by one of the three following means:

1. Surface aerators – this can be in the form of caged aerators, vertical shaft aerators (high speed or low speed). Oxygenation occurs through mechanical beating of agitators and mixed liquor.

2. Diffused aerators – this form of aeration requires air blowers to supply air to submerged aeration diffusers installed inside the activated sludge basins. Oxygenation occurs through dissolution of air in the mixed liquor.

3. Aspiring aerators – submersible pumps with telescopic suction pipes are often employed. Oxygenation occurs as air is drawn into the submersible pumps along with mixed liquor.

3.0 COMMON MEANS OF AERATION CONTROL

3.1 Timer Control

This aeration control strategy is found in smaller wastewater treatment plants. Control is often time associated with diurnal peaks as well as weekend/holiday peaks.

The advantage of this control strategy is that it is simple to set-up and easy to adjust. However, there could be risks of under or over aeration, which in turns affects the plant performance.

3.2 Dissolved Oxygen Control

This aeration control strategy is by far the most common means of controlling aeration. Dissolved oxygen probes are installed in the activated sludge reactors to measure the instantaneous dissolved oxygen concentration as a controlled variable for optimising air flow or number of surface aerators (manipulated variable).

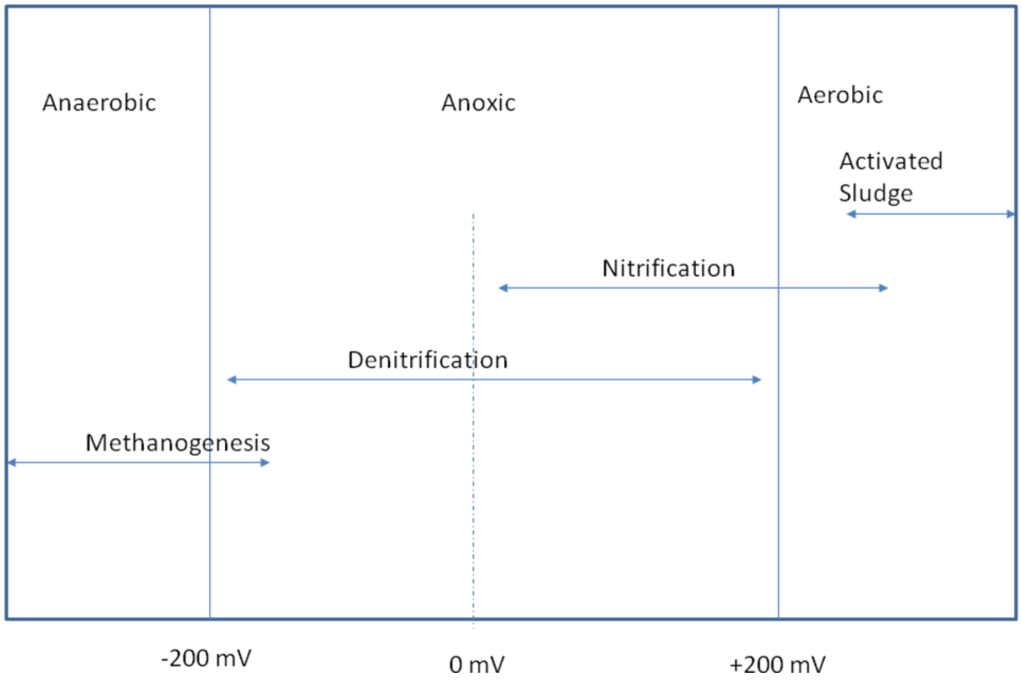
Typically DO setpoint in activated sludge process is usually set between 1.5 to 3.5mg/L, typically around 2mg/L to ensure complete nitrification.

The advantage of this aeration control is that a minimum dissolved oxygen level is always maintained in the aeration basin. However, it also carries a risk of aerating when not required.

3.3 Oxidation Reduction Potential (ORP) Control

Oxidation Reduction Potential (ORP) was developed as an alternative means of aeration control. ORP is a measure of the strength of oxidisers and reducers in terms of the concentration. This in turn is used to detect the actual process conditions in terms of aerobic (oxic), anoxic and anaerobic. An ORP probe is installed in the aeration and facultative zones under this method.

Figure 2: *Typical ORP Aeration Control (note: ORP values are site specific)*



There are mixed results on efficiency gains for this type of aeration control.

3.4 Ammonia-Nitrate Aeration Control

Ammonia oxidation is one of the critical biological processes in aeration tank, hence an alternative aeration control strategy was developed to use online ammonia-nitrate measurements as a feedback control. The ammonia setpoint controls the amount of aeration for ammonia oxidation, and the nitrate setpoint prevents excess oxygen being recycled to the anoxic phase, which would adversely affect denitrification.

The online ammonia-nitrate sensor is typically installed in the effluent channel and the target ammonia set point is 1mg/L or lower. This can be used in combination with DO feedback control (i.e. a cascade control set-up) to optimise the aeration throughput and power usage.

3.5 Feed Forward Control

This aeration control strategy correlates the aeration system throughput (blower speed, air flow or no of surface aerators) based on plant's incoming flow or pollutant loads. This in turn would be a feed-forward control regime (i.e. an open loop set-up).

Rosedale WWTP recently implemented a feed forward aeration control strategy which controls the process air flow based on the flow entering the BNR basin. The operators manually adjust the preset set-points to obtain the desired dissolved oxygen in the aeration tanks. The reported air demand reduction is in the order of 20% (communications with Paul Bickers).

A variant of this feed forward control strategy is to operate the aeration system based on incoming ammonia load. This requires an influent flowmeter and online ammonia analyser in the influent channel. A case study reported 15% aeration demand reduction by switching to feed forward control based on online ammonia analyser reading in the primary clarifier (Walz, T, 2009)

It is possible to set-up a cascade control based on the feed-forward control of influent or primary effluent ammonia loads (via online analyser readings) and feedback control based on bioreactor dissolved oxygen or effluent ammonia for a more sophiscated aeration control regime.

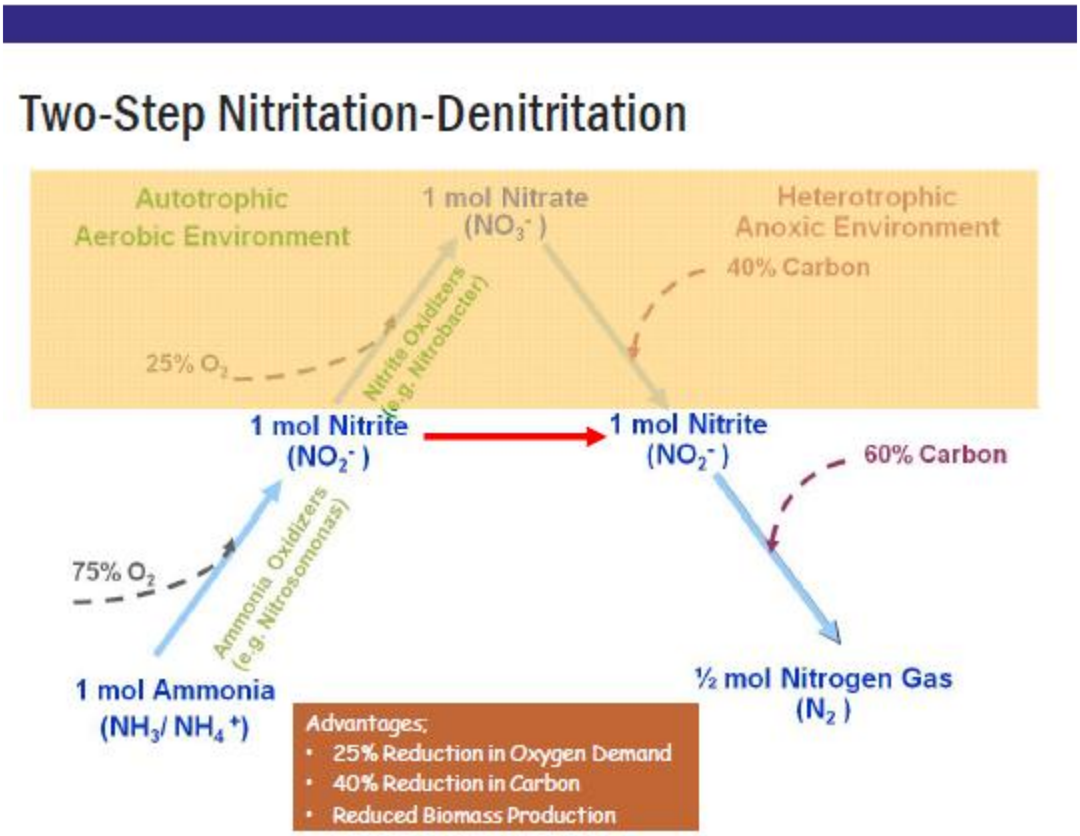
Mangere WWTP is currently implementing a field trial based on this aeration control strategy. Their findings are expected to be available by end of 2012. (communications with Sanjay Kumarasingham)

3.6 Intermittent Aeration

This aeration control method requires the aeration supply to be intermittently switched ON and OFF to optimise ammonia oxidation and nitrite reduction.

This method achieves optimisation by avoidance of nitrate formation (which requires more energy). In addition, it also reduces the consumption of supplementary carbon source. This aeration control method is usually found in Sequencing Batch Reactor (SBR) or oxidation ditch processes.

Figure 3: *Aeration Power Saving via Nitrite Pathway (Jaminez, 2012)*



One of the process suppliers claims that potential savings is between 20 to 40% as a result of adopting this control strategy.

4.0 AERATION CONTROL STRATEGY COMPARISON

A desktop Biowin modelling exercise for to compare the relative savings potential of aeration energy use was undertaken.

1. Manual Timer Aeration Control
2. Dissolved Oxygen Aeration Control
3. Ammonia/DO Cascade Aeration Control
4. Feed Forward Aeration Control (Based on incoming flow)

For benchmarking purposes, the aeration control strategies are compared in a model plant of a 5MLD MLE treatment process. This process consists of 1300 m³ anoxic reactor, 2000 m³ aerobic reactor, 300m³ final aeration cell and 400% internal mixed liquor recycle. The aeration supply can vary between 1800 and 4500Nm³/hr.

The table below summarises the aeration demand of the various control strategies.

Table 1: *Process Model Results Comparing Various Simple Aeration Control Strategies for a typical 5MLD Desktop WWTP*

	Aeration Control Strategies	**Avg. Air Flow (Nm³/h, rounded)**	**Savings**
0	Fixed Aeration Throughput (75% of total)	3400	
1	Manual Timer	3100	-
2	Dissolved Oxygen Feedback	3100	-
3	Ammonia/DO Feedback Cascade	2500	20% for Manual Timer/DO
4	Flow-based Feed Forward	2720	15% for Manual Timer/DO

The above model results demonstrate the potential power saving of various aeration control regimes. Assuming a 15-20% saving in aeration power can be realised, this equates to $14,000 to 20,000 per annum at power rate of $0.22/kWh.

However, it must be noted that the above models are in essence a desktop exercise, and the actual savings in aeration power would be dependent on the following factors:

- Reliability and accuracy of online instrumentation
- Procedures for maintaining the instruments
- Process control loop tune-up
- Equipment maintenance regimes
- Operator’s confidence in the control set-up

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