Is there life left in activated sludge?

The year 2013 marks the centenary of the activated sludge process. MWH technical director **Ajay Nair** asks whether it is still relevant, what has changed and shares his idea of the perfect AS plant

A quick survey of water engineers confirms that we all still love the activated sludge (AS) process, although some despair of it if they have to operate a poorly designed system. It is definitely still relevant as It is essential technology enabling us to meet recent environmental legislation, including tighter standards. These would be difficult to achieve using technologies such as the other much loved process – the trickling filter.

Over the last two decades things have changed considerably. Land footprint used to be the biggest issue in wastewater design; power cost less than 5p/kWh and consents were very different. Total biochemical oxygen demand (TBOD) hovered around 25mg/l; ammonia was starting with values around 10mg/l; phosphorus and nitrogen were not considered and disinfection to meet bathing water standards was still a glint in the legislators' eyes.

Plants were designed by civil engineers wielding empirical relationships, and modelling software sometimes ran slower than real time. Today, we have tighter ammonia consents, phosphorus removal is commonplace and nitrogen removal becoming so. Key concerns include current and future power costs.

Therefore, to make best use of AS technology, we must 'design for efficiency', by considering daily and seasonal tariffs and extremes of climatic conditions – especially as AS can use more power than less effective trickling filters.

Efficient AS

My design for a highly efficient AS plant for now and the future would focus on a relatively traditional system, using technology in play today such as a nitrifying AS process using fine-bubble diffused aeration (FBDA). Important considerations in the design of FBDA are alpha factors.

They are a measure of how efficient a diffuser is and have a huge impact on overall plant efficiency. They are heavily influenced by their operational environment, making it essential that all the consequences of design actions on this aspect are understood.

FBDA performance has improved significantly in recent years. Aeration systems today often quote a value of 8% per m – compared to the previous 5%. However, while diffusers increase efficiency, an increase in back pressure can be required to overcome any extra resistance and achieve improved oxygen transfer.

Similarly, recent studies show a marked drop-off in the first two years owing to the deterioration rate of performance in diffusers,

> "The AS process has many years left as the cornerstone of treatment plants. With continual evolution, I am looking forward to what the next twenty years will bring, but also hoping for a revolution in the way we treat wastewater."

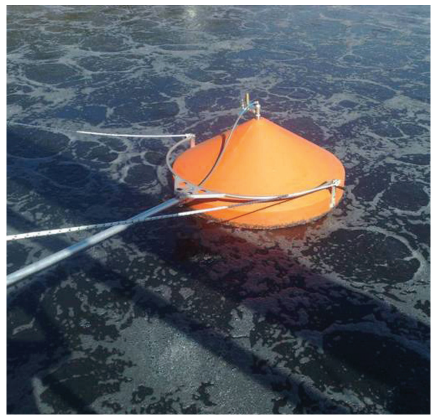
both in terms of backpressure and transfer efficiency. We now understand alpha is not constant during the day and can vary by as much as 100%, especially in the early stages of the AS reactor.

Research is still limited, but AS plants including a denitrification zone find it reduces fouling and increases alpha values. This results in a denitrification credit for oxygen and alkalinity plus an alpha credit, further reducing energy consumption.

The penalty for including a denitrification zone for mixing and return pumping is minimal, so inclusion can be justified by energy savings and improvements in effluent stability. Mixing technologies have progressed significantly if installing anoxic zones for either selection or denitrification.

Invent hypermixers in situ at an AS plant in Stratford CT , USA

Hypermixers being installed in Washington DC, USA



The Alphameter helps engineers understand how the alpha value in an AS system constantly changes

Twenty years ago, recommended energy intensity for mixing was 10W/m^3. With today's mixers running 24/7, even this modest consumption contributes significant values. Fortunately, systems like the 'hyperclassic' mixer can give large savings by reducing energy input to less than 1.5 W/m^3.

Performance

As influent wastewater has high levels of variability, it is important that the system can respond with the minimum of control error to maximise efficiency. By far the best control system for aeration is a most open valve system (MOV) with airflow control on each zone, cascaded to a dissolved oxygen (DO) set-point.

This system could be further improved by using a direct measure of the 'fouled' alpha value to calculate an actual airflow set-point rather than relying on the DO set-point error. Using off-gas measurements, the Alphameter is now commercially available and has demonstrated savings through improved control.

This technology, opens up exciting possibilities enabling us to understand how this parameter constantly changes, get insight into cleaning and replacement regimes and to improve design.

FBDA reactors are inefficient. The majority of the oxygen demand is required at the front end. However, FBDA diffusers are most affected by wastewater conditions and have the lowest alpha factor at the very front of the AS reactor.

Capacity

Historically, AS reactors have been overdesigned, so we know there is spare capacity. This is typified by practically zero ammonia levels, two-thirds down the reactor.

Indicating the last third is simply mixing even though this is the most efficient part of the reactor. To operate with greater efficiency, we must adjust the ammonia 'flight path'.

Using instruments and process control models in real-time, it is now possible to control demand in the reactor to balance airflow, make better use of the efficient parts of reactor and avoid wastage reaching minimum airflow for mixing. Significant savings have resulted when this approach has been implemented, even where highly sophisticated DO control systems are already in place.

Using real-time control and monitoring has also generated amazing improvements to the stability of final effluent performance. This

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An Alphameter Hood in situ on an AS plant during its development

has increased our confidence, in taking out unnecessary conservatism, reducing footprint and dealing with the challenge of tightening consents.

Next - environment reactive consents? This would mean we could change our effluent quality to reflect the watercourse flow, meeting water quality and reducing carbon impacts simultaneously.

Probes

Significant results can be achieved with just a few strategically placed ammonia and DO probes. Examples of advanced real-time control have been operating successfully for over three years within United Utilities, Southern Water and Wessex Water's operations.

Making the best use of reactor management systems means designing against convention. Traditional tapering of diffusers needs to be revisited to avoid losing savings because of the cost of higher airflow per diffuser.

A move to a more uniform aeration grid down the reactor must be considered. The number of control zones also needs careful consideration.

There are moves towards two zones of control and reliance on tapering as the preferred method to minimise capital. However, moving from two to three and then four can create significant energy savings and improve effluent stability.

Design improvements

As design considerations become more complex; to understand operational efficiency and compliance, we must expand the use of dynamic simulation tools. For instance coupling process modelling with mechanical system performance models gives us more than the average, minimum and maximum design points.

Blower technology has also moved on, with more efficient systems from APG-Neuros, Aerzan and Lontra. Using 'flight-mode' to establish internally the best operating point to deliver the required airflow can bring massive savings. If we provide flexibility to hit this, the small capital penalty is worth it.

However, benefits will be obliterated if the system is not analysed and the right one installed. What is crucial is designing for load and for tariff. Triads and daily tariff periods are ever-increasing, with values of over 19p/kWh for certain periods of the day. The challenge for today's process engineer is minimising power consumption during these times while maintaining compliance.

Adding infrastructure which allows extended 'go-slows' is key in modern-day plant.

Another improvement is running at the appropriate sludge age to reflect growth conditions. This reduces aeration demand propagated by bacterial endogenous respiration (the energy used to 'eat the dead') and provides more potential for gas production in anaerobic digesters.
I have not touched on hybrid systems or emerging alternatives.

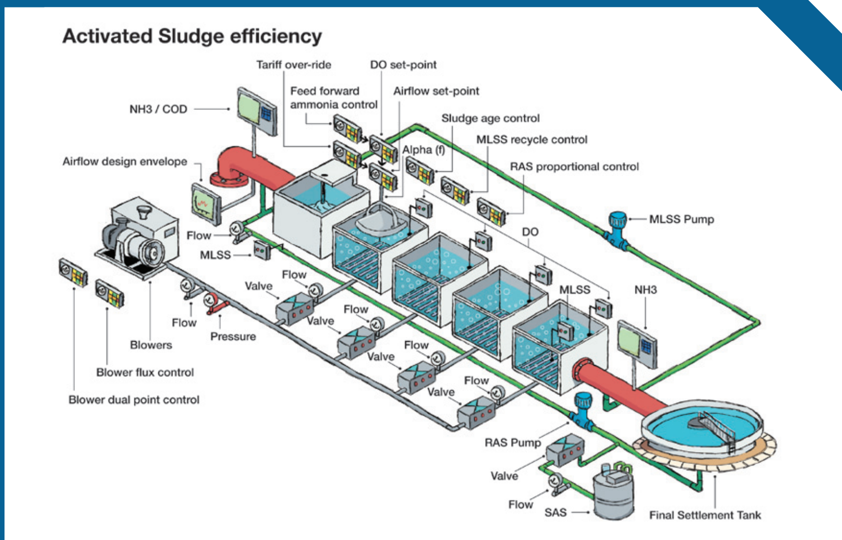
wwwAerobic granular activated sludge is becoming a reality with some exciting changes using microbial carriers to isolate good from bad bacteria.

I have focused on FBDA, but surface aeration units have improved in efficiency and advanced demand control can be used with it in plants to improve efficiency. However, the improvement is much less than AS as alpha deteriorates down the reactor in a surface aerator. Other advances include the fluidic oscillator (micro-bubbles), which it may be possible to retrofit to existing diffuser systems.

Evolution or revolution

Today, although we have better tools, new technologies and more integrated compliance and energy design, process, mechanical and control engineers face an even bigger balancing act designing treatment plants. So, in my view, the AS process has many years left as the cornerstone of treatment plants.

With continual evolution, I am looking forward to what the next twenty years will bring, but also hoping for a revolution in the way we treat wastewater.



Activated sludge: my ideal plant

My ideal plant would be a Modified Ludzack-Ettinger (MLE) configuration – that is a big, fat anoxic zone - using FBDA without a significant diffuser taper. The airflow demand envelope would be calculated with an MOV airflow control delivery system incorporating an off-gas airflow set-point.

I would have feed-forward ammonia control with at least three, if not four, control zones with an integrated blower management system.

Depth would be driven by available footprint, but calculated by site performance and blower type. Blower arrangement would be selected by system modelling, based upon my process modelled airflow envelopes – likely to be of multiple units to give turn down flexibility.

I would also have sludge age control to keep operating at the biological 'sweetspot'. Last but not least, I would have used a process model to refine the design based upon a well characterised influent.