New Developments

These articles are based on papers from IAWQ's *Sewage into 2000* conference, Holland, August 1992

Lifting the lid on airlift reactors

Two aerobic airlift reactors have been at work in Holland for five years. Their development and performance was the subject of a paper by J J Heijnen and M C van Loosdrecht, Delft University; R Mulder, Paques bv; R Weltevrede, Gist-Brocades bv; and A Mulder, TNO.

Increasingly onerous demands on wastewater treatment technology are creating a market for aerobic airlift reactors. This nuisance-free, technology is compact, generates little sludge and is light on energy.

Two airlift plants have been treating waste satisfactorily in Delft, Holland, since 1987. Their development represents the successful technology transfer from pilot scale trials to commercial operations.

Nearly a century of biological wastewater treatment has spawned numerous processes. However, they are marred by inherent weaknesses of large size, noise and low efficiency.

Compact anaerobic treatment has emerged to overcome some inadequacies. But aerobic post-treatment is till needed to remove residual COD, ammonium and sulphide.

Conventional treatment has also been challenged by tighter nitrogen controls and increasingly problematic sludge production. Standards on noise, odour and aerosols from treatment plants are also being tightened, requiring costly plant modifications.

Enclosed airlift technology appears to meet all these demands. The system includes an internal airlift reactor located beneath a settler, all topped by a degassing space. The reactor provides oxygen for mixing and to suspend the biofilm carrier particles.

The mixture of air, water and carriers is first degassed in the annulus connecting the upper space and the settler. A mixture of water and carrier then flows downward into the settler space. Particles settle in that space while treated water flows upwards and out of the reactor. Settled particles return to the reactor, not by pumping, but by a secondary air lift.

The amount of biomass that can be accumulated in the reactor depends on biofilm thickness and carrier surface area. Since oxygen seldom penetrates more 0.1mm in aerobic biofilms, greater thicknesses do not boost aerobic conversion.

Biofilm surface area is a function of the solids volume fraction in the reactor and diameter of carrier particles. Since the amount of carrier is limited by its effects on oxygen transfer, a maximum fraction of 10% was assumed in developing the Delft plants.

The optional particle diameter is around 0.2mm, since smaller sizes reduce settling velocities. Larger diameters would limit the surface area and, consequently, the biomass. Cost and mechanical strength considerations limited the choice of carrier to natural minerals.

In this reactor type it is essential to keep the carrier material in suspension. Also, the three phase separator should retain carrier inside the reactor, since only very limited solids wash-out can be tolerated.

These aspects were studied on a 11m high, 200mm diameter pilot plant reactor and finally compared with the full scale plant measuring 19m high and 4.5m across.

Airlift liquid circulation velocity, vital for keeping carrier material in suspension, was measured by an ultrasonic device, yielding three important results:

- At low gas velocity, the circulation velocity is higher than the single bubble rise velocity (0.25m/sec). So gas circulates in the downcomer in accordance with findings that gas hold-up is nearly the same as for a bubble column;
- Adding carrier material decreases circulation velocity. A critical superficial air velocity exists (0.005-0.015m/sec), below which circulation cannot be maintained;
- Circulation velocity without carrier agrees well with literature correlations for the liquid velocity.

Gas superficial velocity and carrier concentration appear to have the same effect on the full scale and pilot reactors.

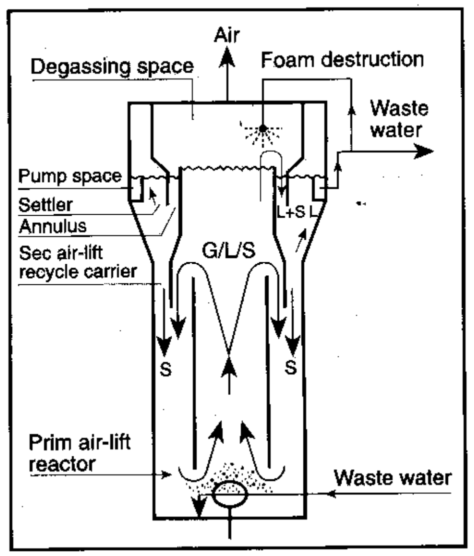
However, liquid circulation velocities are higher at full scale, in accordance with the cube root effect of the reactor height. Also, the carrier remains in suspension at full scale, even at low gas velocities.

These results suggest that the full scale airlift suspension reactor can be considered ideally mixed for liquids and solids. Sampling of the reactor contents at different heights revealed no gradient in solids concentration.

The trials revealed that the scale-up of the three phase air-lift suspension reactor was successful in terms of gas hold-up, liquid circulation, oxygen transfer and solids hold-up.

Studies on aerobic purification of anaerobic effluent containing sulphide, residual COD and ammonium were also undertaken, first in laboratory and pilot scales.

The 300m³ Delft reactors incorporate basalt carrier of 0.23mm diameter at a concentration of 140kg/m³. Carriers are kept uniformly in suspension at a superficial air velocity of 42mm/sec. Wastewater residence time is two hours.



Configuration of the airlift reactor

The growth of biomass as biofilm on the carrier has been very impressive. Within five months the biomass concentration reached 40gVSS/litre and leading to 200mgVSS/g carrier.

In general, a biofilm thickness of 0.2mm was observed, but with occasional large fluctuations. Reasons for the fluctuations are not known, and show the need for a more fundamental understanding of biofilm dynamics in this type of reactor.

Carrier concentration remained nearly constant, indicating that the three phase separator prevented carrier wash-out satisfactorily. The volumetric hold-up of particles in the reactor reached a high 50%.

Purification performance has been satisfactory over the past few years. COD removal amounts to about 700mg/litre. All sulphide is oxidized to sulphate. Ammonium removal is about 70mgN/litre, which is then converted to nitrite. Performance so far indicates that:

- The enclosed design and complete oxidation of sulphide to sulphate removes odour problem;
- Solids COD entering and leaving the reactor are almost equal and there is no separate sludge withdrawal from the reactor;
- Contrary to pilot plant results, there was no full nitrification;
- Biomass concentration on full scale is double that in laboratory or pilot scales.

Full scale biological purification is satisfactory. Differences between the full and pilot scales are mainly due to changed wastewaters. Most notable is the absence of sludge production.

Full proceedings will be available soon from Pergamon Press, Headington Hall, Oxford, OX3 0BW, UK.

Ending sewer concrete sulphide corrosion

Acid formation in pressurized sewer systems can create major maintenance problems which can be avoided by biofiltration, according to J J Heuer and H J Kaskens, Royal Dutch Consulting Engineers and Architects.

Dutch engineers are using biological filters to halt the formation of destructive, foul smelling sulphur compounds in pumped sewer systems.

Filters remove hydrogen sulphide to prevent acid attack of concrete, but one pass is not enough to purge the compound's persistent smell.

The consulting engineer HASKONING developed the technique to deal with a national problem. Sewage from many small Dutch villages is pumped through pipelines to cities for treatment. Pressurized sewage often ends up in the atmospheric conditions of pump station sumps or in other sewers.

The linked anaerobic and aerobic conditions in pipelines represent ideal environments for the generation of hydrogen sulphide. And that is one step away the formation of sulphuric acid, which eats into the concrete sewers, threatening structural damage.

Sulphide formation depends on the oxygen content of the sewage. It is enhanced by long residence times in pressurized pipelines, and by higher temperatures. Sulphur compounds in sewage turn into hydrogen sulphide in three ways:

- Reduction of sulphate ions into sulphide ions by anaerobic bacteria. This happens just below the water surface in anaerobic mucus, which must be present for the reaction to occur. The amount of sulphide formed depends on the quantity of sulphate and velocity of sewage. At high velocities, the mucus layer decreases, retarding chemical processes;
- Transformation of proteins leading to formation of hydrogen sulphide and organic sulphur compounds. It occurs always and everywhere in the sewer. The amount of sulphide formed depends on protein concentrations in the sewage and temperature;
- Formation of hydrogen sulphide in sand or sludge at the bottom of the sewer by anaerobic bacteria.

Under aerobic conditions, the hydrogen sulphide and sulphur can react further. One possibility is for oxygen in sewage to convert hydrogen sulphide into sulphate ions, with no effect on concrete.

More worrying, the hydrogen sulphide can escape from the sewage to dissolve in water on the pipe's concrete surface. In that case, bacteria transform the sulphide into sulphur and, subsequently, into destructive sulphuric acid.

Various ways to avoid or reduce concrete corrosion exist, but they are mainly less than ideal. Solutions include:

- Avoiding hydrogen sulphide formation by shortening the residence period in the pipeline or diminishing the sulphur content of the water. Often both measures are technically impossible;
- Preventing hydrogen sulphide conversion into sulphuric acid by forced oxidation of sulphide into sulphate. This can also be done by using chemicals to precipitate sulphide ions or reduce bacterial activity. All are disadvantaged by the need for expensive, environmentally undesirable chemicals;
- Coating the pipelines with acid resistant material, at considerable cost and disruption.

The HASKONING method involves stripping hydrogen sulphide from sewage by turbulence, and removing it from air with biological filters.

A biofilter consists of organic carrier for micro-organisms. Polluted air passes through the filter and is adsorbed by the carrier material. Micro-organisms consume organic and odorous compounds in the air.

While biofilters deal with acid production, they do not reduce the odour concentration and emission sufficiently. Biofilters can remove odour components thoroughly, but produce smells of their own.

Another cause of persistent odours could be compounds that micro-organisms find difficult to degrade. Compounds like indole and skatole, found in animal faeces, are stable and not easily degraded.

A third reason could be the inability of biofilters to break down all hydrogen sulphide when suddenly high concentrations of organic sulphur compounds occur in the sewage.

To prevent further complaints about odours, HASKONING decided to lead outgoing air back into the biofilter. Filtering reduced hydrogen sulphide concentrations in expelled air to less than 0.01ppm the risk. That level posed no corrosion threat, and also put a stop to complaints about bad smells.