ABSTRACT

Anaerobic technology is used extensively for the treatment of food, meat and agricultural-based industrial wastewaters. Historically, large completely mixed anaerobic digesters much like sewage sludge digesters were used. More recently the use of high rate fixed film and sludge-blanket reactors has gained popularity. These reactors require low land area, achieve high loading rates and are cost-effective with energy recovery. There is now a significant data base, both pilot and full-scale, indicating that high-rate anaerobic technology is a sound option for the treatment of high strength industrial wastewaters. Even more encouraging have been the very recent advances in reactor design, specifically the development of a hybrid reactor, which combines fixed film and suspended growth reactor systems. This technology is effectively treating noxious wastewaters from the pulp and paper industry as well as wastewater generated in the food and agricultural-based industries.

To assess and verify the appropriateness of design criteria of the hybrid reactor, especially for the treatment of high solids and O&G wastewaters, an R&D program was conducted to develop and optimise, via pilot plant testing, a hybrid reactor system for treatment of wastewater from an abattoir and septage treatment plant.

A 1.3 m$^3$ hybrid anaerobic pilot plant reactor was designed and built in March 1989. It was commissioned and operated for a 9 month period on the wastewater discharged from an abattoir and a 5 month period on the effluent from the septage treatment plant.

The reactor was sized to minimise the effects of scale up with an active height of 3.5 m and diameter of 0.73 m. Design of the pilot plant, containing a suspended bed of bacteria at the bottom and a fixed film system in the top section, was based on COD spatial loading rate of about 6 kg/m$^3$ reactor volume/day, upflow velocity <0.5 m/hr,
hydraulic retention time >4 hr, inlet nozzle velocity >1 m/s, temperature 36°C, and pH between 6.8 and 7.2. The reactor was designed to provide recycle of effluent and/or sludge. It was fully instrumented with a temperature and pH control system. The reactor was seeded with sludge from an anaerobic abattoir lagoon. Feed and effluent samples were taken to develop removal efficiency data and the sludge was measured for biological activity. Gas was analysed for flow and chemical constituents (CH₄, CO₂, H₂S).

The results of the pilot trial at the abattoir indicated that a spatial organic loading of 8 kg COD/m³ of reactor volume per day could be sustained. This exceeded original design value of 5.7 kg/m³/d. Removal efficiencies were within the range of original design criteria with achievable values of 70%, 75%, 65%, 70% for COD, BOD₅, TSS and Oil and Grease respectively. Post settling of the effluent from the reactor allowed for removal efficiencies of 80, 90, 85 and 85% respectively, which is higher than total COD removals utilising a UASB high rate reactor.

Hydraulic requirements were achieved but it was found more appropriate to utilise a HRT of >5 hours to achieve the removal efficiencies required. The gas production was calculated at 0.3 m³ per kg COD destroyed (c.f. design value of 0.25 m³/kg COD). The sludge production was estimated at 0.15 kg sludge per kg BOD₅ destroyed.

The test results show that the wastewater produced from the abattoir was amenable to high rate anaerobic treatment and that post settling of the effluent provides for further improvement in effluent quality.

A full scale plant was thus designed for a spatial COD loading rate of 8 kg/m³/d, to achieve removal efficiencies of COD, BOD₅, TSS and oil and grease of 80, 90, 85, and 85% respectively. The reactors were sized as 3 cylindrical tanks 3.5 m high and 7.1 m
diameter. A full scale system at the abattoir was costed at $1.3 million. This would
save $370,000 per annum in sewer discharge and offer an energy credit of $63,000 per
annum. The operating costs for such a system would be $75,000 per annum. However,
the existing DAF units can be shut down, saving the abattoir $85,000 per annum in
operating costs. Thus, installation of a hybrid reactor system can provide a nett annual
credit of roughly $440,000, or a payback period of less than 3 years.

Treatment of the septage plant effluent was possible via high rate anaerobic treatment as
long as tight pH control and separation of industrial wastewaters containing high sulphate
and heavy metals were excluded from the feed. A full scale plant was designed with
removal efficiencies of 70, 75, 85 and 85\% of COD, BOD\textsubscript{5}, TSS and oil and grease
respectively, at a spatial COD loading rate of 7 kg/m\textsuperscript{3}/d. To achieve this a single
cylindrical reactor was chosen with a height of 5.8 m and diameter of 6 m with an HRT
of $>7$ hours. A full scale pretreatment system was costed at $280,000 and would offer
savings of around $150,000 per annum in sewer discharge costs. Annual operating costs
would be $60,000, thus overall payback period is also about 3 years.

The hybrid pilot plant reactor showed its suitability to treat both a slaughterhouse and
septage plant effluent at loading rates which made the system a cost effective method to
pretreat these wastewaters prior to sewer discharge to reduce trade waste discharge fees
and generate a fuel (biogas) which could be utilised to supplement plant energy
requirements. The hybrid system was shown to be particularly suitable for handling high
oil and grease content and be capable of relatively rapid recovery from toxic shocks and
always maintain a low solids content in the final effluent.