A MODULAR CONCEPT FOR ON-SITE WASTEWATER TREATMENT

Ted O'Morchoe & Seamus Butler
BMS Asia Pacific Technologies Ltd, (Ireland)

Abstract

This paper describes the development of the BMS Blivet package sewage treatment plant where the advantages of different types of treatment were evaluated and incorporated into a new hybrid system. The paper details the evolution to a single tank in order to reduce on-site civil works and produce a true all-in-one package plant.

The export of the system from Ireland to the UK and later to Asia is discussed, as is the subsequent licensing of the technology in Australia, New Zealand, India and Canada.

The growing need for nutrient removal is highlighted and the use of the Blivet to treat various influent/effluent combinations, whilst keeping a modular approach, is described.

Experience of Australian conditions is related including the effect of varying temperatures, re-use for irrigation, fluctuating loads and treating the effluent from septic tanks in a Tasmanian township.

Keywords

compact, nutrient removal, modular, package sewage treatment, rotating biological contactor

1 Introduction

The BMS packaged sewage treatment system was designed in Ireland, which has a reputation for being a very green country. This is partly climatic, but also because it has a relatively unspoilt environment and some of the most stringent environment laws in the European Union. Ireland is sparsely populated (like Australia and New Zealand) so it has many small villages and rural developments that are best served by packaged sewage treatment plants. Ireland relies heavily on tourism and by their nature many tourist resorts are in remote areas where they must provide their own sewage treatment on-site. The design of all the systems and manufacturing for the home market and some export markets is carried out in the BMS factory in Ireland.

2 Development

In the early 1980's Seamus Butler was working as Contracts Director in a family civil engineering company. In order to diversify the company from dependence on the cyclical nature of Public Works Tendering he sought a manufacturing product in a niche market that would be compatible with his business/ technological experience to date. Through market research he decided there was a potential market for smaller 'package' type sewage treatment plants currently being imported into Ireland.

In 1982/83 he carried out a feasibility study on the Irish and UK package sewage treatment plant market. The broad conclusions from the study were there was a potential growth market due to stricter standards being introduced and none of the survey respondents were 100% satisfied with existing designs. Faced with a choice of becoming a licensee for an existing design or developing his own product, he chose the latter believing he could significantly improve on existing Rotating Biological Contactors (RBC) designs.

A research and development programme was commenced in 1984 culminating with the first prototype being installed for Longford County Council at the end of 1985. With some engineering and cosmetic improvements this plant was the basis for the BMS Aerotor, with currently 350 units operating worldwide.

3 Aerotor

The Aerotor is a hybrid combination of two tried and tested methods of aerobic biological treatment systems i.e. activated sludge and rotating biological contactors (RBC). Activated sludge systems normally consist of tankage wherein the sewage is mixed with oxygen, supplied by forcing air into the liquid (e.g. by compressors or surface agitation). Mixing the influent with the oxygen and providing a retention period produces a growth of suspended micro-organisms (activated sludge), which feeds on the organic matter rendering it, after settlement, relatively harmless. An RBC is a fixed film reactor which provides a solid surface area (media) to which micro-organisms (biomass) attach and feed on the organic matter as the RBC media is alternatively submerged in the liquid and presented to the atmosphere (ie oxygen) by rotation. Both the above processes occur in the BMS Aerotor.

An RBC is defined in the British Standard BS6297:1983 as "a series of closely spaced parallel discs mounted on a horizontal shaft." The BMS Aerotor is a series of enclosed drums on a shaft. The effluent enters the drums and comes in contact with an extensive surface area (media) within the drum. The natural bacteria (biomass) attach to the media and feed on the organic matter in the effluent. This fixed film provides an intensive surface area for biomass growth – thus the similarity to an RBC. However, as the drum rotates (at 6 rpm, deliberately faster than an RBC) the motion creates an active aeration of the liquid in much the same way as a surface aerator does in an activated sludge system – thus the similarity to activated sludge. Whereas an RBC makes only passive contact with the atmosphere the Aerotor actively aerates.

The shaft is often identified as a problem with RBC's. The Aerotor is not an RBC but the design objective was to incorporate the good points of an RBC and design out the faults. In an RBC shaft damage is caused by the effect of a heavily loaded shaft. As the BOD or organic load on an RBC increases the biomass will grow thicker as it is fed more. It gets heavier and increases the load on the shaft and bearings. The Aerotor is self-cleaning so that the layer of biomass never gets too thick, so that it stays aerobic and does not become anaerobic. The rotor is effectively floating so there is very little load on the shaft.

A more serious problem occurs with an RBC when there is a power failure. The rotor stops but the effluent keeps on flowing. The submerged lower half of the rotor will keep growing and getting heavier and heavier. Meanwhile the upper half is drying out and dying. When the power comes on again the rotor is much heavier on one side than the other causing major problems such as bearing or even shaft failure. The Aerotor does not have this problem as 96% of the media is inside the drums. The effluent can only enter when the rotor is turning so in a stoppage the effluent by-passes around the rotors causing over-growth on about 2 % of the surface area so there is no out-of-balance load when it restarts.

Another difference from an RBC is that the Aerotors rotate at approx 6 revolutions/min (rpm) which is faster than an RBC which typically rotate at less than 1 rpm. This difference has the following effects:

- The largest Aerotor unit can treat three times DWF (Dry Weather Flow) while the smaller units can treat much larger variations (eg the B500 can treat up to 18 times

DWF). This is important in that diurnal or flow variations are often more marked in smaller installations;

- At times of excessive/storm flow the Aerotor motion tends to have a balancing effect, i.e. as the flow exceeds the forward pumping rate of the Aerotor, the level will tend to rise in the first compartment. As the level tends to rise the forward pump rate increases due to a longer contact with the rotor inlet ports. Eventually, of course, if the flow continues to exceed design levels, the Aerotor will be by-passed - at a 375 mm "back-up" level;
- The design of the Biozone Tank is such that the Aerotor is self-cleansing, i.e. there is no deposition of sludge or 'dead' corners. RBC units require a collection and often an additional pumped return of deposited sludge - the Aerotor does not.
- The internal vanes of the media are constantly being scoured due to the speed of rotation and trapped air bubbles. This self-cleansing velocity maintains a thin homogeneous biomass growth preventing excess growth (which can be septic) or internal bridging;
- Due to the Aerotor arrangements in separate compartments, the flow pattern induces all the effluent to make contact with all the media before passing to the next stage. This eliminates bypassing which is prevalent in RBC's. The arrangement is actually the epitome of 'plug flow' which is conducive to graduated proliferation of contrasting biomass cultures in separate compartments; and
- The use of active aeration, caused purely by the turning of the rotors, sucking in air which is then forced through the effluent makes the system considerably more efficient than either an RBC or an activated sludge plant alone. It also means that on start up there will be some treatment before the biomass becomes established.

Uniquely the level at which liquid leaves the Aerotor is higher than that which enters it. This is effected by the rotating motion of the rotor, which in mechanical terms is a PUMP. It provides a net head gain of 375 mm. This provides the following advantages:

- Automatic recirculation of any proportion of treated effluent under gravity i.e. without pumps;
- As the Aerotor is a discreet unit that can stand above ground the net lift permits its use as an adjunct to an existing (eg overloaded) plant without affecting existing pipework levels and arrangements;
- The higher outlet level allows the discharge to be further away if there is a gravity outfall (e.g. approx 250 m in a 150 mm pipe);
- The rate of recirculation can be adjusted (by use of hand stops in the final compartment splinter box) to suit operational conditions. An example might be an amenity facility, which has minimal usage during weekdays and maximum usage at weekends. The operator can go on total recycle during the week and minimal recycle at weekends. This permits the biomass condition on the rotors to be maintained for optimum performance;
- The gravity recirculation facility increases at times of increased flow thereby providing a buffer against irregular flow rates.

The power consumption of the Aerotor is smaller than an equivalent RBC and significantly smaller than an equivalent activated sludge plant. Typically the motor size of a 400 equivalent person (EP) Aerotor is 0.75 kW compared to 4 or 5 kW for an activated sludge plant.

To summarise the main points:

- The Aerotor is not an RBC but it has taken the advantages of an RBC, added the aeration from the activated sludge process and removed the disadvantages of the RBC;
- The Aerotor is a fixed film reactor with an active aeration element.

4 Blivet

In 1988 after two years of producing the Aerotor it became clear that much of the market, especially smaller private sector clients, wanted to minimise the civil works carried out on-site and that an all-in-one package was required.

As with the original development of the Aerotor, BMS sought to invent an all-in-one package that was a significant improvement on existing competition. Having established the Aerotor as a singularly successful unit it was decided to maintain the Aerotor as a discreet unit and "build" the all-in-one package around it.

The use of lamellar or parallel plates for enhanced settlement of solids in liquid flows has been utilised in industrial wastewater treatment and in pre-treatment of potable water, for quite a long time. However, the application of such technology to primary settlement, and to a lesser extent final settlement, was relatively novel. The idea was attractive both from the enhanced efficiency it offered over traditional settlement arrangements and the potential for miniaturisation. Obviously the more compact a system could be the more bonuses it offered to both customer and manufacturer.

The outstanding feature of the Blivet is the marriage of parallel plate settlement with the unique features of the Aerotor. This combination has produced the most compact and efficient package sewage treatment plant available worldwide.

- Minimal site works are required. The Civil Works normally entail excavation, flat concrete support base and backfilling
- Transportation is simplified with the standard unit width of 2.3 m
- The relatively small 'footprint' makes it eminently suitable for confined sites or high amenity areas (e.g. the footprint for 400 EP is 2.3 m x 11 m)

The most commonly used method of primary settlement in smaller sewage treatment plants is a horizontal flow Primary Settlement Tank. The capacity usually works out at 8 to 12 h retention at DWF, which creates a major size problem for designing an all-in-one package.

The BMS application of parallel plates creates a greater surface area for capture and settlement of solids dramatically reducing the required retention period i.e. typically by two thirds! Due to the fact that the primary settlement is at the receiving end of the raw sewage, all shapes and sizes of solids must be catered for. Therefore, the parallel plates are preceded by a full-length baffle which directs the raw sewage downwards, and prevents most of the floatable solids from travelling further into the system.

Despite a typical residence period of three hours, the Blivet primary settlement section is also more efficient at removing settleable suspended solids than its equivalent Primary Settlement Tank. This permits the Aerotor sizing incorporated in the Blivet to treat a larger (approx 25%) EP than a similar Aerotor in a typical "separates" layout. This is due to the removal of a significant proportion (>20%) of BOD by the efficiency of the parallel plates.

After passing through the primary settlement zone the settled sewage passes over a notched weir and enters the Aerotor system. At the end of the Aerotor, due to the inherent net lift, the flow is split in the splitter box, back to the primary settlement zone via recirculation or on to final settlement.

Much the same criteria applies to final settlement as to primary settlement except in this case it is treated effluent containing humus. Humus is a mixture of living and dead organic matter which is a by-product of the aerobic reaction within the Aerotor. The solids are finer than in raw sewage and for that reason the parallel plates are closely spaced in this zone. Settled humic solids are removed periodically into the common sludge storage area by a small submersible pump activated by a timer typically set for 2 min. pumping every hour.

Having passed through the final set of parallel plates the treated effluent then passes across a weir and out the outlet. It should be noted that this outlet is 150 mm higher than the inlet due to the net lift of the Aerotor.

The last distinct element to be described in the Blivet is Sludge Storage. Sludge is the semi-liquid by-product of primary settlement and final settlement (typically 98% water). The standard UK industry norm for a package plant is for a three months sludge storage period. Without the addition of a very expensive means of dewatering sludge within the unit, it is therefore necessary to provide this volume at the base of the Blivet unit. It is generally accepted that sludge accumulates at approx 5 L/head/week e.g. a 300 PE plant will have 1500 L/sludge/week. The Blivet units are designed to store 13 weeks sludge for the appropriate EP.

A correctly sized Blivet operating on normal domestic strength sewage (approx 250 mg/L BOD and 300 mg/L TSS.) will produce a 20 mg/L BOD and 30 mg/L TSS final effluent. Better quality standards can be achieved using a Saran Filter. This fabric mesh, placed across the top of the final settlement tank, improves the final effluent quality from 20/30 to 10/15.

5 Exports

From the design stage it was realised that exports were necessary for the growth of the company. To this end the BMS Aerotor has a rotor diameter of 1.6 m permitting shipment in a standard width marine container. The BMS Blivet has been designed so that the complete unit will fit into a standard container for shipment with minimum assembly required on arrival. This ensures safe and inexpensive shipping worldwide.

Initially BMS developed an export market in the UK in the early 90's but when this slowed down in 1993 the company looked at exports to Asia. It may seem strange to export something as basic a sewage treatment plant half way round the world but it makes sense if you have a pre-fabricated compact plant that requires very little civil works.

In 1993 the first Blivet was sold to Thailand for a cable factory and in 1994 the next one went to Singapore for a trial with the Ministry of Environment. Since then systems have been installed in Hong Kong, China, Korea, the Philippines, Indonesia, Pakistan and India.

In 1994 an associate company Bannow Exports Ltd was established to handle exports to the Asia Pacific region and other territories outside Europe and an associate company, BMS Asia Pacific Technologies (BAPT) was set up to licence the technology in the same region. In 1995 BAPT signed a technology transfer agreement with an Australian company Kelair Pumps Australia Pty Ltd, who are now manufacturing the BMS Blivet and Aerotor under licence in their factory just outside Sydney. In June 1998 a licence was signed with a New Zealand group who have established a new company Blivet Aerotor NZ Ltd to manufacture there.
To date, several hundred BMS Blivet Packaged Treatment plants have been installed throughout the world, many in remote locations where maintenance is not always as good as would be found in Australia.

6 Modular Approach

The final effluent standards that have to be met are changing and evolving. Initially, most plants only had to meet 20/30 criteria, then some required 10 or 5 mg/L BOD in sensitive areas. As environmental awareness becomes more widespread, nutrient removal is often required. This will vary much more from project to project and country to country. Disinfection is often also required, although that also varies from country to country. Re-use for irrigation has become very common (except in Ireland where there is too much rain).

Nutrient removal can be obtained by a combination of standard modules. If only ammonia removal is required then an additional aerobic stage is used i.e. an Aerotor followed by a further final settlement tank. At higher temperatures an under-loaded system will give nitrification on the last rotor after the carbonaceous stage is finished and additional modules may not be needed. If de-nitrification is required two Blivets in series will be similar to the Bardenpho process (Metcalf & Eddy, 1991). A single stage biological system will remove at most 90-95% BOD so if the influent is highly concentrated two Blivets in series will be required. For flows greater than approx 100 m^3/day (400 EP) two or more units can be installed in parallel. This is often recommended for flows above 50 m^3/day (200 EP) so there is 50% redundancy, although the Blivet is so simple this is not always required.

The modular approach can also be used for a project that is being built in stages. Many housing projects need the cash flow from selling the first houses to fund the later ones. If they can also install the sewage treatment in stages, this can significantly assist their cash flow.

A large hotel in Barbados has three parallel streams, each with two Blivets in series as there is a high BOD influent and a requirement to remove ammonia. The effluent is re-used for irrigation on a golf course and has to meet a disinfection standard of <2 Fecal Coliform Units/100mL. This is achieved with a sand filter and UV. The local Ministry of Health requires a chlorine residual, so there is a sodium hypochlorite dosing system as well.

7 Australia

The first units were installed in Australia in 1996. Higher temperatures had already been experienced by Blivets operating in South East Asia, so that was not seen as a problem. The first unit was in a conference centre but one problem that was encountered was caused by the back-wash from the spa pools. As with any biological system high concentrations of biocides will affect biological activity.

The second installation was in a small residential conference centre for a mining company where there were large fluctuations in usage. In spite of this it met the 20/30 final effluent standard it was designed for and was able to meet a P standard that was imposed later by the use of phosphorus free detergents. Normally a reduction of about 20% in P can be expected; if more is required ferric salts are dosed in the final settlement tank.

There is an interesting system in Tasmania where a Blivet has been installed in a small township to treat mainly the discharge from septic tanks in a school, a pub and a number of residences. The results are very good and more importantly for the neighbours there is no odour in spite of treating a septic effluent.

Kelair have now installed about 25 Blivets and have exported from Australia to China, Papua New Guinea, the Philippines, Pakistan and Indonesia. Within Australia they have had the most success in Tasmania with a range of customers from councils to mining companies to forest parks and even a detention centre.

8 Conclusion

The BMS Blivet provides a modular system that can be used for a wide range of situations from large flows to phased developments to nutrient removal and this paper has attempted to show that the system can provide appropriate technology for on-site sewage treatment.

References

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