EVALUATION OF ALTERNATIVES TO CONVENTIONAL DISC SUPPORT MEDIA FOR ROTATING BIOLOGICAL CONTACTORS

A. J. Ware*, M. B. Pescod* and B. Storch**

*Department of Civil Engineering, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, UK
**EFLO International, Bath Road, Padworth, Reading, UK

ABSTRACT

A variety of biofilm support media for rotating biological contactors, both aerobic and anaerobic, are reviewed in the light of experience gained from laboratory, pilot-scale and full-scale operations. Currently there is no clear economically superior replacement for conventional HDPE moulded discs for aerobic treatment plants. As little anaerobic full-scale operational work has been carried out it has been speculated that random-packed media and twin-walled polycarbonate sheets could provide a substitute support material in anaerobic treatment units.

KEYWORDS

Rotating biological contactor; rotating media; biofilm; disc media; packed-cage media; anaerobic treatment; brewery wastewater treatment.

INTRODUCTION

In the cost-conscious world of municipal sewage treatment a successful treatment process must be either significantly better functionally or more competitive in cost terms than alternative processes. Since the aerobic rotating biological contactor (RBC) has not been demonstrated to be significantly superior to conventional aeration plants in process terms, it must compete primarily on price for many of its potential applications. Thus the manufacturers of RBCs are often not only competing against each other but against alternative treatment processes. Despite its often higher capital cost the aerobic RBC has become increasingly popular as a small-scale wastewater treatment plant because of its easy maintenance, low sludge production and, more importantly, its comparatively low power requirements. However, to remain competitive a manufacturer must keep all costs to a minimum. One of the key cost areas in the fabrication of an RBC is the biological film support material.

Outside the municipal sewage treatment application of the aerobic RBC there is great scope for the anaerobic version of the RBC to treat many of the industrial wastes presently considered suitable for treatment by other anaerobic processes. It is in this anaerobic field that the RBC could prove to be even more successful than it has been in aerobic treatment. Conventional anaerobic continuously stirred tank reactors have proved less than successful, due mainly to settlement problems, and the remaining competition is either anaerobic filters or a form of suspended bed. These latter forms of treatment require careful monitoring and high pumping requirements to maintain process stability. The advantage of the anaerobic RBC is its ability to withstand a moderate solids loading without blocking and the simplicity of the process equipment, with no requirement for intricate process control.
EFLO International (Bath Road, Padworth, Reading, U.K.) have collaborated with the Department of Civil Engineering, University of Newcastle upon Tyne, (U.K.) in operating a pilot-scale anaerobic/aerobic RBC treatment plant to treat a brewery effluent. The results of which are published elsewhere (Ware and Pescod 1989). In the current paper EFLO’s production and experimental aerobic biofilm support media are examined, as are laboratory and pilot-scale aerobic and anaerobic biofilm support media used by the University.

In compiling the information for this paper the authors have come across one serious problem. The majority of EFLO’s plants have been installed at small sewage works operated by Water Authorities in the U.K. and under the current practice of not installing any flow measuring equipment in these small plants, it has been impossible to estimate plant loading rates. This has not only prevented any accurate assessment of media performance but also has deprived Water Authorities and manufacturers alike of the core performance data necessary to appraise both the process and equipment fully. One has only to examine different Water Authority specifications on surface loading rates to see that there is no accepted standard. Even different manufacturers design their plants for different surface loading rates. It cannot be unrelated to this lack of core data that many engineers simply take a dislike to the RBC and relate the case of ‘the one that never produced a good effluent’ as justification. In all probability, if investigated thoroughly, the problem will prove to lie in some other quarter than with the process or the equipment.

When it comes to monitoring the quality of the effluent, most U.K. Water Authorities are so financially restricted that samples are only taken for analysis if there appears to be a problem. Indeed, in some areas plants are fortunate if they are monitored twice a year. It is not surprising that process engineers cannot evaluate particular plants given such meagre data. In view of this lack of field performance data, the review of media in this paper has been restricted to physical attachment of biofilm and robustness of materials.

AEROBIC SUPPORT MEDIA TYPES

The commonest media type is the disc or disc derivatives. Many variations now exist, ranging from plain flat discs through corrugations to cellular meshes, all of which are designed to give extra surface area per unit volume (specific surface). However, as the medium gets more complex its cost increases. There have been several attempts to produce modular media, such as mesh tubes, that can be fixed together to build up a drum shape. The common link in all these types is that most manufacturers use their own specially constructed media, the cost of which is governed by the quantity they require.

However, at the laboratory and pilot scale, random-packed high-voidage plastic media has been successfully used as a substitute for discs (Pescod and Norton 1983). The advantage of random-packed plastic media is the cost: as a mass-produced item, its cost can be one third or less that of discs. Whilst the use of random media is not new, polyethylene balls have been used. Few manufacturers are commercially exploiting it.

In the University of Newcastle, particular interest has been taken in aerobic packed-cage RBCs run at laboratory and pilot scale using a variety of media shapes. The fullest study has been reported on by Pescod and Norton (1983) in which an aerobic RBC cage unit containing Norton Chemical Company’s Plastic Bioring 25 was operated at a peripheral velocity of 9.4 cm/sec with 43% submergence treating a milk waste. A variety of loading rates, between 6 and 711 g COD/m²d, were applied with varying degrees of operating efficiency. Biofilm growth was readily established and quantified as the project progressed.

In one case cited, the unit was loaded to 15.5 g COD/m²d at a short hydraulic retention time (HRT) (1.81 hr). After 7 weeks of operation, organic removal was around 80%; however, after 13 weeks, organic removal was reduced to around 20%. This reduction was caused by excessive biological growth on the media blocking the interstitial spaces and causing an effect similar to ponding in trickling filters. The trial was repeated with only 70% of the media packing in the cage. No problems were experienced in establishing a biofilm despite the cage not being full. After 7 weeks, the organic removal was again around 80% but, after 13 weeks, organic removal had risen to 90%, indicating that the ponding condition had been overcome. Movement of the media caused continuous 'sloughing' of the biomass. Pescod and Norton do, however, point out that the ponding effect was probably aided by the small media size used and the same effect would not be so likely to occur on a full-scale plant.

It was from this base that field trials on full-scale plants were undertaken. The first trial was conducted on a 2.2 m diameter cage unit rotating at 2 rpm treating the total...
Disc support media for rotating biological contactors 115

effluent from a restaurant. Initially, the media chosen was Acalor 120 but experience here and at another site proved it to be too fragile to withstand the shear forces exerted. The replacement media chosen was a 200 mm Mass Transfer ring. After initial packing, the media continued to compact and further material was added to maintain a completely packed cage. Despite such efforts, some gaps in the packing remained and there was a small amount of movement of the outer layers of the media.

During several months of operation only a very thin aerobic biofilm built up on the visible outer layers of media. The small amount of media movement that occurred was enough to keep the exposed outer surfaces clean of biofilm. All aspects of wastewater contamination were explored and no significant difference between this and similar effluents being satisfactorily treated elsewhere could be found to explain the lack of normal thick biofilm growth. The most likely explanation seemed to be excessive turbulence caused by relatively large pieces of media and their random arrangement.

These observations were reaffirmed by the operation of a 3.5 m³ packed-cage reactor treating a brewery effluent in both the aerobic and anaerobic modes. In this reactor the Acalor 120 media was replaced with a more robust 97 mm ring manufactured by Mass Transfer. Originally operated in an anaerobic mode, no significant biofilm growth occurred even on the inner surfaces of the ring in 9 months of operation. There was little opportunity for growth on the outer surfaces of the ring as the tumbling action of the media in the cage was excessive. This was brought about, initially, by an inability to further repack the cage once anaerobic operations began, and later, by the breakup of media caused by the same excessive tumbling.

When operated for three months in the aerobic mode, without refilling the cage, the tumbling action again kept the exposed outer surface of the ring relatively free from biofilm growth. Where media was trapped in the mesh of the cage, biofilm growths were moderate on both internal and external (outside of the mesh) surfaces. However, those rings containing a piece of broken media wedged between the septa had, on close examination, a significant biofilm development in this area despite being able to tumble with the other media. This was in contrast to disc media, which readily established a significant biofilm growth under similar conditions.

Trials were carried out at full scale to examine the effects of media orientation and movement on the development of aerobic biofilm. Two units were set up as follows:

Unit 1: the media were stacked in nylon nets so that movement could be eliminated. The nets were arranged so that media rings lay along the axis of the shaft.

Unit 2: the media were again stacked in nylon nets to eliminate movement. The nets were arranged so that the media rings followed the circumference of the cage in the outer layers.

The result was that biofilm grew on both sets of media. Performance data at different loading rates (applied to the respective plants) had not been conducted at the time of preparation of this paper and thus this effect of orientation has yet to be assessed fully. In units where the nylon nets became detached, biofilm growth was severely restricted.

Placing the media in nylon nets is labour intensive and, coupled with the added cost of cage construction, reduces the savings resulting from using random media from a third to about a half. This cost may be too great if the likelihood of them breaking free is still high and the additional cost of re-fixing is considered.

This study of the use of random media in aerobic RBCs has proved that media of the designs used are unsuitable for use as random-packed media in aerobic RBCs. With careful design it may be possible to develop a media with the correct attributes for biofilm growth in a packed cage.

As a result, moulded discs, despite their expense, are still the most attractive media option for manufacturers. A material to be suitable for such discs must possess two essential qualities: one, it must permit and retain biological film growth and, two, it must readily and inexpensively mould into durable self-supporting sheets. High-density polyethylene (HDPE) has proved to be a very suitable medium, fulfilling both these requirements. However, care must still be taken to ensure that banks of discs have sufficient support to ensure they do not collapse under the weight of biofilm as the discs age. It has been known for some configurations of disc banks to eventually collapse if carrying a heavy biofilm for a protracted period of time.
Since discs are vacuum-formed from sheets, one-piece discs are limited by the size of sheet available and the availability of suitable forming machines. The largest sheets available, of the correct grade material, are 2.26 m x 1.70 m. Larger diameter discs, therefore, have to be constructed of two or more pieces. The commonest construction is a 'cheese wedge' arrangement where each component of the disc requires restraint.

At present, there appears to be no suitable replacement for HDPE as a moulding material. In a search for alternative materials that do not require moulding, HDPE being too flexible unmoulded, Flocor, an aerobic filter packing and a twin-walled polycarbonate plastic sheet, was investigated. The Flocor packing, which comes in one-half metre cube sections, was cut into wedges and fitted like cheese wedges into the rotor. As would be expected, a biofilm developed readily and there was no problem in retaining it on this material. However, after a couple of months of operation, small pieces of media were found floating in the biozone. A closer examination revealed that the glue used to fasten the sheets together had come unstuck. As a result, when end-retaining panels were removed the whole structure disintegrated. Up to this point, Flocor had seemed quite a promising alternative.

In the case of polycarbonate sheet, the two walls are separated by septa giving a plate of 10 mm square tubes. This compares with the 14 mm spacing between two adjacent HDPE discs and has the potential effect of greatly increasing the surface area per unit volume of rotor. Area densities can be increased from 100 to 120 m²/m³ for HDPE discs to over 200 m²/m³ for polycarbonate discs. This compares with between 75 and 120 m²/m³ for the random media investigated. Whilst media density is not a shortcoming of conventional discs in aerobic treatment, except in cases of very low surface loading rates, it may be of great value in an anaerobic reactor.

As with the HDPE sheets, there is difficulty in obtaining polycarbonate of sufficient size for large rotors. However, trial and full-scale aerobic treatment plants have been constructed using this material. The major concern in using these sheets was that the tubes could become blocked with biological growth, which would significantly reduce the surface area available for treatment. Operational experience has shown that biofilm does build up on the inside of the tube walls, although complete blockages do not appear to occur. There have been cases of fouling of the tube openings after several months' operation caused by the build-up of fibrous material from within the sewage. This problem is easily overcome by the periodic application of a brush.

ANAEROBIC SUPPORT MEDIA TYPES

The anaerobic RBC concept was first introduced by Tait and Friedman (1980). Since then quite a few reports have been produced, exploring various aspects of the process (Ware and Pescod, 1989; Shapiro and Switzenbaum, 1984).

As the anaerobic RBC is not subject to the same rate-limiting factors as the aerobic process, namely transfer of oxygen into the liquid phase, much higher densities of biomass per unit volume may be employed without detriment to the system. It is under these conditions that the limitations of the formed disc become apparent. Since random media can have a higher specific surface area per unit volume it was considered as a simple method of uprating a given size of unit without recourse to reducing the hydraulic retention time.

Initial studies were carried out by Pescod and Norton (1983) using the same equipment as in the earlier mentioned aerobic work, but now treating a brewery effluent. For such a small diameter unit it had quite a high peripheral velocity, 9.4 cm/sec, and, perhaps more significantly, the high number of revolutions produced a great deal of turbulence. Despite these conditions a biofilm developed, the thickness of which was estimated to be not more than 0.08 mm.

The work of comparing the performance of discs and random media was continued by Echaroj (1986). A disc media reactor was loaded up to a volumetric loading rate (VOLR) of 20 kg COD/m³d, or an areal organic loading rate (AOLR) of 157 g COD/m²d, with removal efficiencies between 94.7 and 46.5%. The maximum COD removal of 95% was achieved at a volumetric loading rate as high as 8 kg COD/m³d, or an AOLR of 63 g COD/m²d. In the case of the packed drum reactor, the operation was conducted up to a VOLR of 24 g COD/m³d, or an AOLR of 132 g COD/m²d, with removal efficiencies between 94.8 and 53.0%. A maximum removal of about 94% was achieved at a volumetric loading rate as high as 8 kg COD/m³d, or an AOLR of 44 g COD/m²d. Maximum loading rates were attainable 140 days after start-up.

The disc media reactor was found to support more attached biofilm than the packed-cage
Disc support media for rotating biological contactors

Disc support media for rotating biological contactors, thus providing higher organic removal at the same areal loading rate. However, because of the higher surface area provided by the packed cage reactor, its organic removal efficiency was found to be higher at the same volumetric organic loading rate.

In the light of this work a full-scale anaerobic/aerobic treatment plant incorporating an anaerobic packed-cage was constructed by EFLO International and sited at a brewery (Ware and Pescod 1989). Operating at only 38% submergence and 2 rpm, as stated earlier, no significant growth of anaerobic biofilm was detected after some 9 months' of operation under a variety of conditions.

The anaerobic biofilm was quite different from the aerobic growth. An aerobic biofilm will establish itself on a surface more readily than an anaerobic film (Echaroj 1986). Aerobic biofilms are also more robust; this is apparent when an aerobic film becomes too thick, develops an anaerobic inner layer and, as a result, the outer layer is shed. One consequence of this is that, if anaerobic RBCs are to succeed on a full scale, the peripheral velocity must be much lower than that conventionally used for aerobic plants. There is, after all, no requirement for a high peripheral velocity to maintain aeration. Given lower peripheral velocities and 100% submergence it may be that packed-cages will work at full scale.

If polycarbonate sheets are to be employed as support media then the construction of the small diameter tubes is such that, to provide adequate movement of liquor over the whole biofilm, the rotor must operate partially submerged. This would obviously reduce its effective media density, although it should still maintain an advantage over conventional discs.

CONCLUSIONS

Conventional HDPE moulded discs, despite their relative expense compared with alternative materials like random-packing, are still competitive when all other construction costs and performance are taken into account.

The value of the competitive media evaluated can easily be removed by customer resistance. There is little point in developing an effective alternative to moulded discs if the customer does not perceive it as such. Fortunately, most customers are happy with the alternative constructions.

A cage packed with loose random-media, although inexpensive, proved to be an unsuccessful method of rotor construction. A completely randomly packed cage is still a long way from being a practical success, given the present designs of media available.

Various methods of restraining random-packing have proved that adequate biofilms can be established on the media. However, these extra restraints greatly increase construction costs such that they become comparable with conventional discs.

A polycarbonate twin-walled sheet has proved to be a useful material for small units adopting low areal organic loading rates.

The use of alternative media in full-scale anaerobic units remains largely speculative, in view of the few tests carried out. Polycarbonate twin-walled sheets and randomly-packed cages may prove to have a useful role, given the correct design of plant.

REFERENCES


