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Biological Aerated Filters

BAF 2

Cranfield University
12th June 1996

Organised by:
The School of Water Sciences, Cranfield University
In conjunction with The IChemE Water Subject Group

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**2nd Symposium on Biological
Aerated Filters (BAF2)
12 June 1996**

Following the success of the first BAF symposium held here in 1993, Cranfield University's School of Water Sciences is holding a second one day symposium on Biological Aerated Filters.

Over the last three years there has been a great deal of work on the development and optimisation of what has become one of the leading processes in wastewater treatment. The aim of this second symposium is to introduce recent work carried out in this field, bringing together many of the world's leading exponents of BAF technology and its application.

BAF2 represents an ideal opportunity to update your knowledge of these developments.

BAF2 Programme

- 9:30 Registration and coffee
- 10:25 Chairman's morning introduction
- 10:30 Trouble shooting and optimisation of BAF systems.
A Smith, Thames Water
- 11:00 Pilot scale comparisons of floating/sunken media and up/downflow BAFs.
A Mann, School of Water Sciences, Cranfield University.
- 11:20 Combined treatment of dairy and municipal wastewater in BAFs.
Howard Rundle, Tetra (Europe) Ltd.
- 11:40 North European experience of BAFs.
P Sagberg, Veas, Norway.
(to be confirmed)
- 12:00 The Poole Harbour wastewater treatment works.
P Brewer, Wessex Water Engineering.

12:30 Lunch

- 2:00 Chairman's afternoon introduction
- 2:10 The moving bed biological aerated filter
T Stephenson, School of Water Sciences, Cranfield University
- 2:30 Operational trials of different proprietary Lamella and BAF systems.
F Budge, Halcrow Consulting Engineers and D Gorrie, Grampian Regional Council.
- 3:00 Aeration optimisation in biological aerated filters.
P Pearce, Thames Water.
- 3:30 Operating performance and future development of the Biobed system.
A Cantwell, Brightwater Engineering.
- 4:00 *Close of Meeting and Tea*

The School of Water Sciences

The School of Water Sciences is the UK's only academic centre to specialise in process technologies for water and wastewater treatment. The school has considerable experience in research and development, working with many of the world's leading water companies and organisations concerned with water and effluent treatment. This experience ensures that the school is well positioned to offer consultancy and research and development related to these process technologies. The School has particular expertise associated with biotechnological applications including BAFs.

In addition to research and development and consultancy, the School of Water Sciences is recognised as a leading centre for the training of process technologies with funding from the EPSRC and approval of its programmes from the IChemE and CIWEM.

BAF and the biotechnology short courses have been developed to advance the understanding and implementation of these technologies.



EXPERIENCES WITH BIOLOGICAL AERATED FILTERS FOR TREATMENT OF SETTLED SEWAGE AND DAIRY EFFLUENT

Howard Rundle

TETRA Processes, Rock House, Stockhill House, Nottingham, NG6OLJ

1 Introduction

For the purposes of this paper, Biological Aerated Filters are defined as units which effect both biological oxidation and removal of suspended solids.

Two plants are described which are designed for partial (or roughing) treatment of settled sewage, and settled sewage with dairy waste, and some of the lessons learned from these are described. These plants are CoLOX units which is a trade name for a BAF using sunken mineral medium, normally operated in upflow mode.

2 Froghall Sewage Works

The works is located in Staffordshire. Several surrounding works have been closed and treatment centralised at this site. As a result, a more restrictive discharge consent was applied. The purpose of the CoLOX unit was to reduce the BOD load applied to the existing filters to enable them to produce an effluent which reliably complies with the consent. The whole works serves a population of 3,300 with a DWF of 806m³/d.

The site is in a valley with very steep sides and no land is available to extend the bacteria beds. The site is subject to flooding. The BAF plant consists of 2 No. upward flow reactors, each with 4.0m. of 2 mm. silica sand medium. The medium is supported by graded gravel layers placed over a nozzleless filter bottom system. This plant treats 432m³ of primary effluent per day to remove 60 kg/d. of BOD. The BAF was not required to produce a nitrified effluent.

Screened settled sewage is pumped to the base of the units by individual progressive cavity pumps. Process air is supplied from a compressed air system which enables easy (manual) variation of air flow. The air is injected into the bottom of the unit via stainless steel air laterals. Effluent passes via a clear well (this allows storage of effluent for backwashing) and is discharged to the inlet of the existing bacteria beds.

Backwashing is carried out once per day. It consists of an intense air/water wash, with the air being injected through the same pipework as the process air. Dirty backwash water is stored in a balancing tank before being returned to the works inlet at a controlled rate.



All pumps etc. are suitable for immersion in case of flooding and the electrical control panels have been raised on a plinth above flood level.

The unit was commissioned in the first week in November 1993, and good BOD removal was achieved almost immediately.

Average influent and effluent analyses for the first 11 months' operation are shown in Table 1.

Table 1 Froghall BAF - Operating Results

Month	Flow m ³ /d.	BOD mg/l		SS mg/d		NH ₃ mgN/l	
		In	Out	In	Out	In	Out
November 1993	432	103	35	117	38	30.4	23.5
December 1993	432	57	8	80	13	12.9	10.7
January 1994	432	58	5.8	82	8	11.4	3.3
February 1994	450	67	10.1	99	14	15.4	4.8
March 1994	350	63	6.3	80	10	12.4	2.3
April 1994	374	109	17.2	120	27	21.7	9.7
May 1994	500	104	11.3	126	11	25.2	10.6
June 1994	380	96	8.3	122	12	27.2	13.0
July 1994 *	520	120	10.5	122	9	29.2	15.0
August 1994 *	624	114	15.8	143	18	27	18.5
September 1994 *	700	82	10.7	123	11	16.7	11.2

* Results for more highly loaded Reactor

Main points on these results are:-

- (i) The average sewage strength was lower than expected, particularly during the winter. This was due to an infiltration problem on the sewerage system.
- (ii) BOD removal was established very quickly, despite the unit being commissioned during the winter.
- (iii) After the first month, the effluent BOD averaged 10.4 mg/l.
- (iv) Although nitrification was not required, the unit started to nitrify after about 1 week, and nitrification became established after about 4 weeks. During the rest of the winter of 1994, about 80% nitrification was achieved. This was despite operating at temperatures of below 5°C.



- (v) Conversely, in the summer months, nitrification fell and only about half of the ammonia was oxidised. This reduction is probably due to the higher carbonaceous load due to the stronger sewage.
- (vi) Overall, the applied BOD loading averaged 1.3 kg. BOD/m³.

Each of the two reactors was backwashed once per day. The overall volume of backwash water was 30m³ or 7% of the average flow. In addition, a further 18m³ of water was run to waste following backwashes to allow effluent quality to recover following a backwash. Overall return liquors were therefore 11% of the normal flow. Solids production was 0.87 ± 0.16 (mean $\pm 2 \times \text{s.e}$) kg of solids per kg BOD applied.

Since its commissioning, the plant has performed well and the works effluent has remained within consent. Very little operator attention has been required.

One problem which has arisen, however, relates to the position of the ColOX plant in the flow sheet. As designed, the ColOX plant has preferentially taken flow, with any excess being passed to the bacteria beds. Because of the excellent performance of the ColOX plant, the load passed to the bacteria beds is normally very low. As a result, the beds have not had biomass available to treat shock loads. The system has now been modified to increase the load to the bacteria beds.

3 Packington

The Packington Sewage Works treats flow from a population of about 16,000. In addition to this, effluent is received from a dairy and a soap factory equivalent to a population of 19,000 hd. The works was using double filtration and chemical dosing was being used to the primary tanks to reduce load to secondary treatment. Severe ponding was being experienced on the bacteria beds.

The BAF unit was designed to treat a flow of 2680m³/d. (about 40% of the works flow).

The plant consists of 4 No. cells, each containing a nozzleless filter bottom, gravel support layers and a silica sand filter medium to a working depth of 4M. A further two cells have been constructed but have not yet been filled.

The plant was commissioned on 22 June 1995. Results for the first week of operation are shown in Table 2.



Table 2 Packington CoLOX Plant Maturation

	BOD mg/l		TSS mg/l		NH ₃ mgN/l		Days Since Starting
	In	Out	In	Out	In	Out	
22 June 1995	455	237	174	150	33	30	0
23 June 1995	158	61	146	47	33	14	1
24 June 1995	321	65	119	53	31	23	2
25 June 1995	368	46	163	41	34	32	3
26 June 1995	287	27	118	60	35	26	4
27 June 1995	333	22	150	16	24	23	5
28 June 1995	-	35	112	15	23	-	6
29 June 1995	208	10	114	12	23	-	7
30 June 1995	373	29	180	50	-	-	8

These results show that after only 3 days operation, the plant was achieving 90% BOD removal.

Results for the first three months' operation are shown in Table 3. (Very few data are available following this).

Table 3 Packington CoLOX Plant. Results for 4 months' Operation

	Flow m ³ /d	BOD		TSS		NH ₃	
		In	Out	In	Out	In	Out
July 1995	2765	261	25	140	31	31	17
August 1995	2765	302	22	142	25	32	16
September 1995 *	2765	210	24	113	30	29	11
October 1995	2765	362	22	175	23	31	12.5
Design	2765	250	37	-	-	-	-

These results show that the unit is receiving a stronger sewage than the design values and is producing a better effluent than required. Average loading is 3.7 kg BOD/m³d. but on individual days, this has risen to above 5 kg/m³d.

There is virtually no nitrification. the loss in ammonia is accounted for by the biomass growth.

Each unit backwashes twice per day. Backwash volumes amount to about 20% of throughput. Because of the nature of the plant, it has not been necessary to optimise backwashing but it is believed that this could be reduced to about 15% if required.

Sludge production is between 0.7 kg d.s. per kg BOD and 1.3 kg d.s. per kg BOD. The sludge is co-settled in the primary tanks without any problem.



Chemical dosing to the primary tanks has been reduced but is still applied occasionally during periods of high load.

4 Lessons Learned from BAF Installations

Several significant lessons have been learned during operation of these plants. these relate to the following:-

Position of the BAF plant in the process flow sheet.

Simplified process control

Effect of loading on performance and backwashings

Recovery of effluent quality following backwash.

4.1 Position of the BAF Plant in the Process Flow Sheet

Positioning the BAF plant (or any roughing plant) on a side stream simplifies process control but may cause shock loading to the main process during high flow periods. This has proved to be a problem at Froghall which has necessitated changes in the proportion of flow side-streamed.

4.2 Simplified Process Control

One finding has been the speed with which carbonaceous oxidation is established.

It has also been found that reactors can be switched off and re-started rapidly. This allows reactors to be brought on and off line very rapidly to cope with seasonal and diurnal variations in load.

4.3 Effect of Loading on Performance and Backwashing

Comparison of data from Froghall and Packington shows that a BOD removal of about 90% is achieved at both plants, despite the difference in loadings (Froghall $1\text{kg.BOD/m}^3\text{d.}$ and Packington $\sim 4\text{ kg/m}^3\text{d.}$). Pilot plant work has achieved similar removals at loadings up in excess of $6\text{ kg/m}^3\text{d.}$ On this basis, BAF's could probably be loaded at much higher loadings than are currently used. The limiting factor is the ability of the backwash to remove the accumulated solids. Not only must the backwash remove the solids which are collected in the bed due to filtration, it must also remove solids which are formed as a result of biological activity. A BAF 4m. deep, loaded at, say $4\text{ kg.BOD/m}^3\text{d.}$ will produce about 16-20 kg. of solids per m^2 of filter



area per day. With a downflow system, this can accumulate at the filter surface and cause blinding. With an upflow system, the solids will be more evenly distributed through the bed but a more powerful backwash system will still be needed to force the solids upwards through the bed. It is likely that the effectiveness of the backwash system will be the factor which limits the maximum load which can be applied to a BAF unit.

4.4 Recovery Following Backwash

With most upflow systems, the dirty backwash water is transferred to a zone above the medium. When the reactor is brought back on line, this water is displaced into the effluent.

At Froghall, effluent is diverted to waste for one hour following backwashing. At Packington, the contents of the zone above the medium are "dumped" prior to re-establishing flow. Both of these methods are effective in minimising deterioration following return to service. Despite this, methods which reduce backwash water volumes and energy consumption are under development and will be applied in the next generation of reactors.

5 Process Selection

Biological Aerated Filters are one process in a range of processes available for sewage and industrial effluent treatment. Others include anaerobic processes (e.g. UASB), activated sludge, submerged aerated filters, bacteria beds (high rate and conventional). Particular advantages of BAF's are their small footprint and their ability to cope with varying loads. Set against this is the relative complexity of the process control. It is important that proper consideration be given to the process requirements in selecting the process route and that the Biological Aerated Filter process is applied in situations where it is appropriate.

6 Conclusions

The paper has described the operation of two upflow BAF's in Treatment of Settled Sewage and of a mixture of settled sewage and dairy waste. Treatment has been effective in both cases and lessons have been learned from these applications. BAF's are valuable processes but their application needs to be considered in terms of the site and process requirements as a whole.

