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Biological Aerated Filters

BAF 3

Cranfield University
Wednesday 3rd March 1999

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3rd International Meeting on Biological Aerated Filters – BAF 3

Wednesday 3rd March 1999 - Cranfield University

Following the success of the first 2 BAF meetings held at Cranfield University, the School of Water Sciences is holding a third one day international meeting on Biological Aerated Filters.

Since BAF 2 work has progressed on the development and optimisation of BAFs in wastewater treatment. The process is now operated in the UK. Further refinements to the process have also increased the potential of BAF technology to a wider range of applications.

The aim of this 3rd meeting is to review the latest research work related to BAFs, examine operating experiences and consider future market potential for the BAF process.



COLNE BRIDGE (HUDDERSFIELD) WWTW BIOPUR PLANT PROCESS DESIGN AND PERFORMANCE

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Abstract

The complexity of the Huddersfield works and the issues addressed by the scheme design engineers are highlighted, including the need for a robust nitrification process due to the high levels of nitrification inhibition in the plant feed. Issues influencing the Biopur process selection are discussed and a detailed description of the Biopur process design is given, together with details on process commissioning and performance testing. Finally the plant performance to date is summarised together with a list of issues for consideration on future plants.

1. Introduction

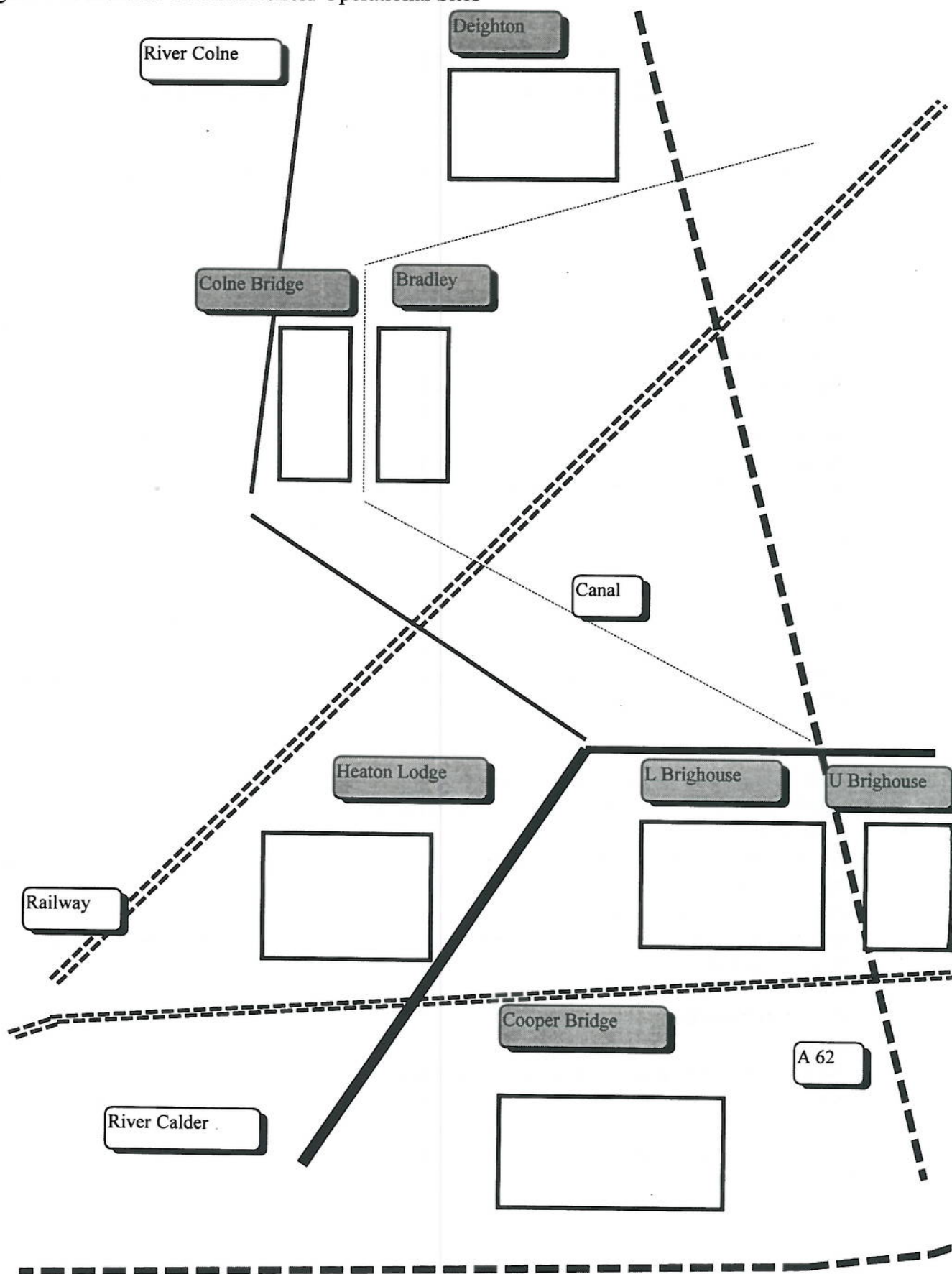
Huddersfield WWTW has been developed over more than 100 years to treat the domestic and industrial load from Huddersfield. The traditional industry was predominantly wool textiles, but dyestuffs, chemicals and engineering industry gradually developed in support of the textile industry (1). Today, Huddersfield is almost unique in the UK as a major works delivering effluent into an inland river system with over seventy per cent of the incoming load derived from heavy industrial sources.

Improvements in effluent quality were required as part of the NEP and UWWTD programmes, details of which are given in Table 1. The principle issues (listed in Table 2) faced by the design team included; the treatability of the sewage due to the nature of the trade effluent, hydraulic and biological overloading the existing Huddersfield plant and the constraints inherited from treatment on six separate treatment sites (fig 1). Tightening of the scheme completion deadline caused the original phasing proposals to be dropped in favour of a single phase scheme which comprised of three separate main contracts; this paper concentrates on the contract for the Biopur sidestream plant located at Colne Bridge.

2. Site Selection

To address the biological and hydraulic overloading of the Huddersfield filter plants, it was necessary to construct a sidestream plant. The plant was located at the Colne Bridge site with a new pipeline from Deighton. This reduced the reliance on the hydraulically overloaded Deighton carrier and also addressed the hydraulic problems on the Heaton Lodge/Cooper Bridge sites. Space on the Colne Bridge site was limited, so a relatively compact process was required.

Figure 1 : Schematic of Huddersfield Operational Sites



3. Design Flows and Loads

The critical hydraulic limitation of the filter plants of 118 TCMD was used to determine the flow split to the sidestream plant, which would eliminate the need for costly hydraulic upgrades on the filter flow stream. This gave a maximum flow to be shed to the sidestream plant of 103 TCMD or 47%. Table 3 gives further details of the flow and load split. The Cooper Bridge filters would therefore be loaded at 0.04 Kg BOD m³.d which is lower than the strict process loading requirement and would readily achieve the required effluent ammonia standard. The disused recirculation system at Cooper Bridge was refurbished to ensure adequate wetting following the hydraulic download.

Table 1: Huddersfield WWTW NEP & UWWTD Consent Requirements

	SS	BOD	(% rem)	COD	(% rem)	NH ³	Date
UWWTD	-	25	70	125	75	-	12/00
UWWTD (Upper tier)	-	50	70	250	75	-	
NEP	30	20	-	-	-	8	12/98
NEP (Upper tier)		56				30	

Concentration limits are ninety-five percentiles in mg/l. UWWTD compliance measured by composite samples, either final effluent concentration limit or per cent removal limit applies. NEP measured by spot samples on final effluent. Ninety-five percentile compliance assessed by EA look-up table. NEP upper tiers require one hundred percentile compliance.

Table 2: Main Problems at Huddersfield WWTW

1.	FFT limited to 164 TCMD through Deighton carrier.
2.	Hydraulic constraint of 118 TCMD at Heaton Lodge
3.	Poor condition of Heaton Lodge pumps
4.	Hydraulic restriction and asset condition of Heaton Lodge - Cooper Bridge carrier
5.	Organic overloading of Heaton Lodge/Cooper Bridge filters
6.	Hydraulic constraints of Cooper Bridge filters
7.	Hydraulic constraints of Cooper Bridge humus tanks
8.	Hydraulic constraint in Huddersfield final effluent carrier

Table 3: Huddersfield WWTW Design Flows and Loads

	Crude	Settled	Colne Bridge	HL/CB Filters
BOD Load	38.0	23.78	11.18	12.6
Ammonia Load	2.82	2.94	1.38	1.56
SS Load	-	28.7	13.5	15.2
Flow to Full Treatment	221	-	103	118
Average Daily Flow	117	-	55	62
Dry Weather Flow	52	-	24	28
Loads in Tonnes/d.				
Flows in TCMD				

4. Process Selection

4.1 Mixture of Municipal and Chemical Streams

Trade effluent from two chemical industry customers is passed via direct pipeline to the Deighton site downstream of primary treatment. The initial design concept was to protect the new sidestream plant by sending only Municipal sewage for treatment and to send the remaining Municipal sewage plus the chemical effluents for treatment down the robust, low rate biological filters at Heaton Lodge and Cooper Bridge. It was recognised that by doing this the concentration of chemical effluents treated by the filters would significantly increase, particularly during the night. To assess the effect of this increase, rolling tube lab work was commissioned. The results of this work showed that the expected nitrification performance of the filters would have deteriorated significantly under these conditions. Consequently it was agreed to completely mix the Municipal and Chemical flows before the flow split.

4.2 Process Robustness

The decision to mix the Municipal and chemical flows prior to the flow split to the sidestream plant meant that the sidestream plant would be exposed to the full treatment inhibition in the Huddersfield sewage. Although steps were being taken to reduce the levels of inhibitory substances in the sewage via agreements with our industrial customers, there was a recognition that this was a difficult technical problem which may not be fully resolved in the given timescale. Process robustness was therefore considered to be of paramount importance in process selection.

4.3 Procurement

The IChem E Red Book form of contract seemed most appropriate for this project as the flows and loads to be treated were easily defined and the preferred site was relatively free from other interferences, leaving the contractor a free hand in the engineering and construction of the plant. Also, as the inhibition presented a major process risk, the innovative ideas of process contractors was a valued factor in this form of contract. A detailed design brief was included in the tender documents which included pilot plant results and Nitrification Inhibition data to highlight the need for robustness.

4.4 Process Selection

Various pilot trials had been carried out with limited success. An activated sludge pilot treating Municipal sewage indicated that carbonaceous treatment was straightforward, but nitrification required Powdered Activated Carbon (PAC) dosing which would have a significant operational cost. A common feature of earlier trials based on the activated sludge process were a high level of suspended solids in the effluent associated with pinpoint floc. The Biopur process had not been piloted, but it was offered by Kvaerner Water as a three stage process with two carbonaceous stages protecting the nitrification stage.

This was important as the separate stages of carbonaceous treatment could significantly reduce nitrification inhibition as observed at Heaton Lodge and Cooper Bridge. In addition, in normal operation the process cells are completely mixed and operate with a high level of recycle. Both of these features would balance and dilute any inhibitory substances in the effluent thereby reducing the effect of toxic shocks. Also PAC dosing to deal with periods of peak inhibition was proposed. This would be dosed into the second stage, where some degradation of inhibition would already have occurred, thus lowering the overall PAC requirement.

The project team agreed that the process was the most robust and compact of those offered, consequently the Biopur process was selected.

5. Operational Flexibility

On such a large and complex site, treating difficult wastes, it was recognised that flexibility around the strict process design of the Biopur sidestream plant was important to cater for transient events or long term changes in influent quality. Such flexibility can often be built in at little expense if it is considered at the process design stage and the design brief was written accordingly. Below is a brief summary of the flexibility built into the Biopur scheme.

- Colne Bridge Flow Mixing/Splitting Chamber
 - ratio flow control of total Huddersfield flow between 26% and 52%. Design is 47%.
 - constant flow control to Colne Bridge
 - Municipal effluent or full mix of Municipal and chemical effluents to Colne Bridge.
- Biopur feed pumps can deal with full range of flows passed on by flow mixing/ splitter chamber
- Biopur hydraulic design caters for full range of flows passed on by flow mixing/ splitter chamber
- DN cells can be automatically changed to C cells if effluent nitrate levels fall.

6. Biopur Plant Design

As previously stated, a robust solution at Colne Bridge was required. Without any benefit of pilot trials, Kvaerner Water proposed a three stage submerged fixed film process of Biopur DN + Biopur C + Biopur N corresponding to pre-denitrification, carbonaceous and nitrification stages.

Past experience suggested that the fixed film process offers greater process stability and resistance to toxic compounds than a suspended growth process.

With the proposed three stage Biopur process it was envisaged that the toxic and inhibitory compounds would be arrested over the first two stages leaving the last and critical nitrification stage relatively unencumbered. Stagewise treatment also promotes biological selectivity and provides for a greater chance to biologically degrade compounds that are toxic or inhibitory in nature.

The Biopur purification process consists of fixed biomass cells which are characterised by the use of structured packing as support for the micro-organisms. The biomass carriers are normally submerged and have a high specific area. The geometry of the structured packing guarantees an optimum distribution of the sewage, scouring air and backwash water and has very low pressure drop across each filter unit. It also ensures that high oxygen transfer efficiencies are achieved in the Biopur cells. The excess biomass and retained solids are removed by periodic backwashing using scouring air and washwater. Furthermore, no attrition or loss of carrier takes place during the backwashing operation. A typical Biopur configuration is shown in Figure 2.

For the design of the Biopur DN + Biopur C + Biopur N system a recirculation of treated effluent to the head of the Biopur DN serves as the source of nitrate-nitrogen. The nitrate-nitrogen serves as the electron acceptor in the Biopur DN process unit and only a low process air is required for mixing and to overcome diffusional resistance in the DN stage.

However, in the second stage Biopur C and the Biopur N units process air is required and flows in a countercurrent mode to the settled sewage flows.

The three stage Biopur process for Colne Bridge incorporates an additional control where, if the nitrification in the third stage is affected, the process automatically runs as a Biopur C + Biopur C + Biopur N process. By converting it to a Biopur C + Biopur C + Biopur N system process air is input directly to the first stage giving more control of the reaction kinetics. The conversion of Biopur DN + Biopur C + Biopur N process to Biopur C + Biopur C + Biopur N process under upset conditions gives greater process confidence to deal with toxic or inhibitory compounds under varying conditions of influent.

Without benefit of piloting it was recognised that if the transgressions of toxic and inhibitory compounds are major and of a magnitude that cannot be dealt with effectively by the three stage Biopur process, there needs to be a fall back situation.

The option of powdered activated carbon dosing upstream of the second stage Biopur C was considered. The plant has a provision for dosing maximum 30 mg/l of powdered activated carbon along with storage facilities.

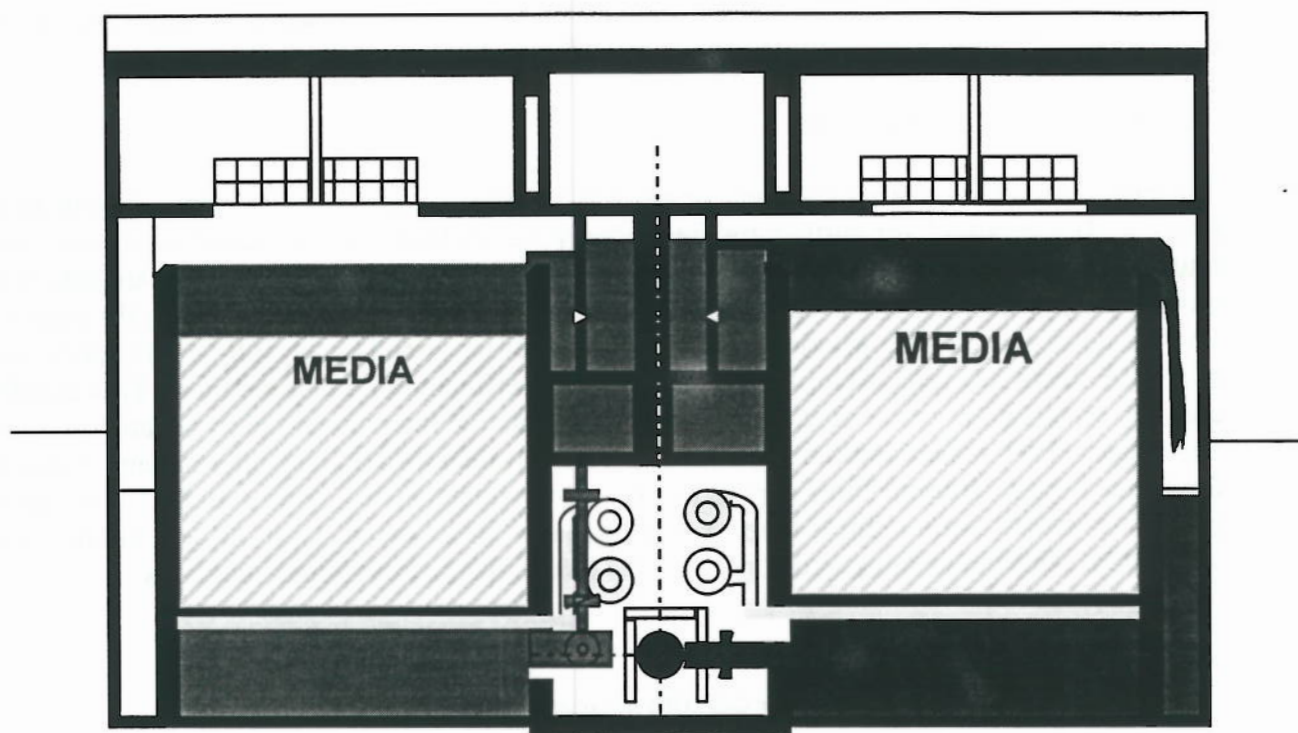


Figure 2 : Typical Biopur Cell Configuration
Left cell under operation – right cell under backwash

It was however, recognised that piloting was needed to be done to determine the optimum activated carbon selection and to determine the efficacy of the activated carbon treatment.

Biopur Plant – Design Summary

Biopur cell size	12m x 6m
No of 1st stage cells	5
No of 2nd stage cells	5
No of 3rd stage cells	10

7. Commissioning Activities

7.1 Aeration Testing

Aeration evaluation tests were carried out on one Biopur DN cell and one Biopur N cell. The method used to evaluate aeration capacity was based on the standard practice of deaeration using anhydrous sodium sulphite catalysed with cobalt chloride and reaeration using duty blowers. Dissolved oxygen monitoring during reaeration of cell contents was carried out using auto logging dissolved oxygen meters.

The guaranteed aeration intensity values were $45 \text{ gO}_2/\text{m}^3$ air at an aeration velocity of 10 m/hr for the Biopur C cells and $65 \text{ gO}_2/\text{m}^3$ air at an aeration velocity of 10 m/hr for the Biopur N cells.

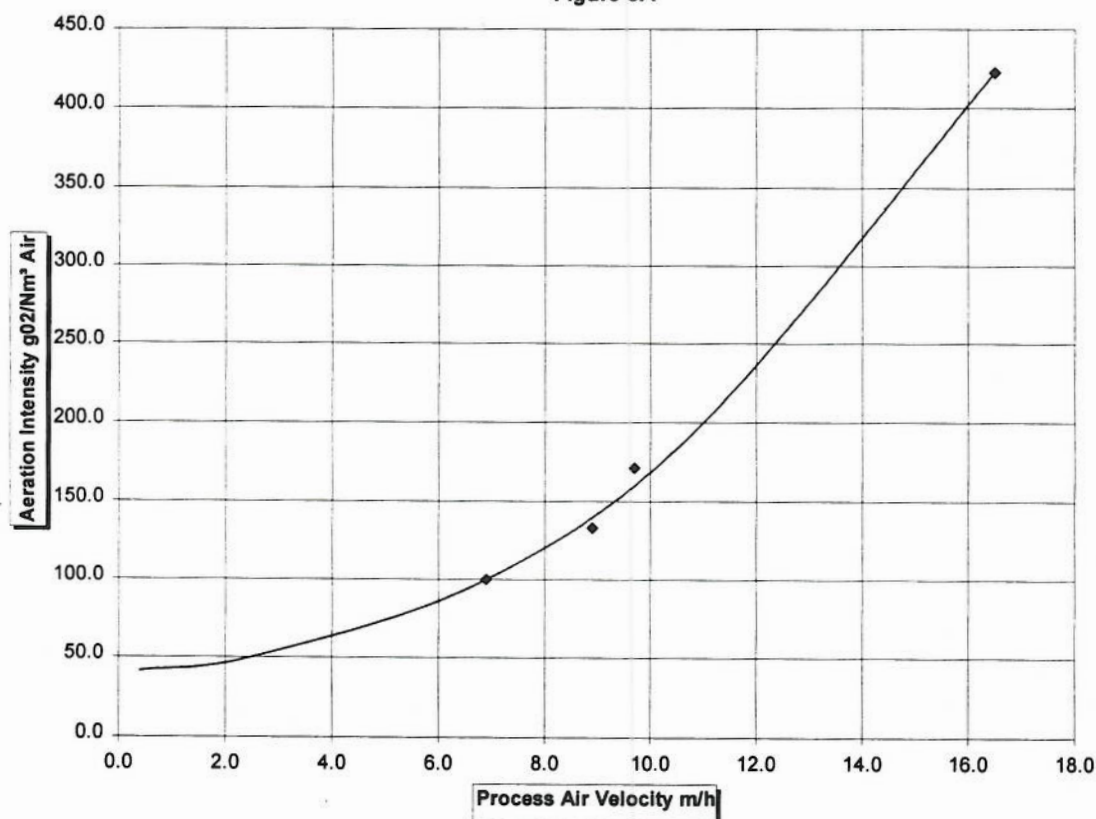
The aeration evaluation tests demonstrated aeration intensity values much higher than guaranteed. The aeration results are depicted in Figure 3.

7.2 Seeding and Acclimatisation

The major constraint during commissioning was the limited capability to return Biopur treated flows to Huddersfield for further treatment (only 12 TCMD via the sludge treatment filtrate return line). This required the plant to be achieving at least the interim consent standards before more than 12 TCMD could be applied to the plant. Seeding therefore started with the plant very lowly loaded and treating Municipal effluent only before applying the full Municipal/chemical mix to the plant. A very useful feature was the final effluent ammonia monitor. This enabled a constant watch to be made of the effluent ammonia and if the concentration began to approach the consent level, action could be taken to shed load to the Huddersfield filter stream. Breach of the Colne Bridge consent limit during process acclimatisation was thus avoided. This facility proved so useful that a control loop to automatically shed load on high effluent ammonia was developed. This could safeguard consent in the future during toxic shock incidents.

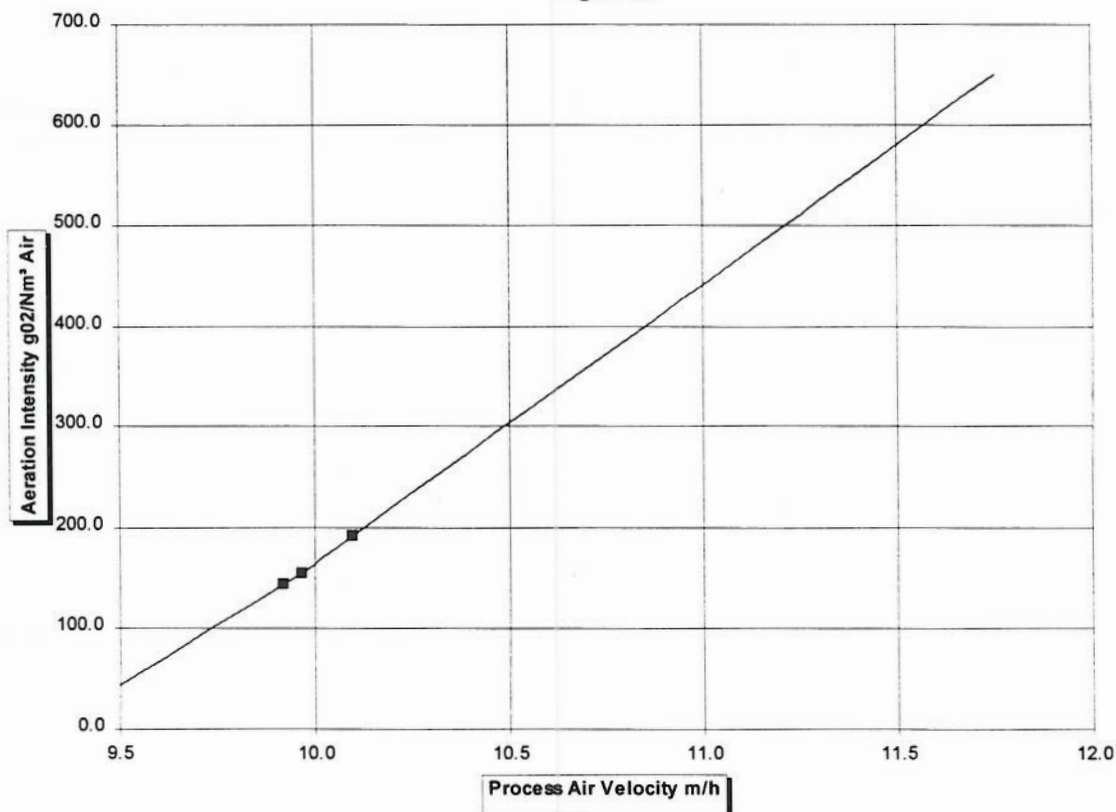
Biopur Cell (DN) Aeration Evaluation Test
Aeration Intensity vs. Air Flowrate

Figure 3A



**Biopur Cell (N) Aeration Evaluation Test
Aeration Intensity vs. Air Flowrate**

Figure 3B



Seeding of the Biopur cells was done using nitrified sludge from the Cooper Bridge wastewater works. The initial seeding of the plant with Cooper Bridge sludge commenced on the 26 March and was completed on 8 April.

The first BOD result for the effluent sample indicated that the Biopur plant had totally seeded for BOD removal in less than two weeks of start of seeding (refer Figure 4 – Plant Acclimatisation – BOD).

Performance build-up for nitrification took more time. At the Biopur pilot plant which was running concurrently with the main plant, various ways of speeding up of performance build-up for nitrification were investigated. One of the speed-up options which was tried on the pilot plant which was running concurrently was use of specialist biomass developed by Interbio at their laboratories to degrade polychlorinated compounds, aliphatic and aromatic compounds, solvents and benzene. However there was no need for specialist seeding on the main plant since the Biopur plant started showing evidence of nitrification performance around the middle of June 1998, taking around 12 weeks from start of initial seeding (refer Figure 5 – Plant Acclimatisation – NH₃N).

Foaming

At the commencement of seeding foaming was observed in all three stages as expected. The foaming died down after performance was established. The influent to the plant has strong variations in composition and load and a severe change in feed is reflected in recurrence of foaming which again disappears as the plant adjusts to the feed. The colour of the foam can also be blue or reddish pink reflecting the underlying colours of the influent to the plant.

Excessive foaming was experienced during commissioning and also several times since. This, as stated, is most likely a function of the process and the nature of the sewage. In windy conditions this can be a health hazard with rafts of foam blowing over the site. The possibility of foam nuisance was recognised during scheme development and a contingency to apply water sprays and netting was included in the scheme. This is now being implemented.

PAC Dosing

Jar tests conducted by Yorkshire Water in their laboratory indicated that PAC was efficient in removal of nitrification inhibition in the feed. PAC dosing was also tried in the Biopur pilot plant. The pilot plant results showed that the PAC removed nitrification inhibition but there was also a loss of biological activity characterised by a deterioration in BOD and ammonia removal. The exact reason for loss in biological performance with use of PAC was not investigated nor were any optimisation studies carried out for the type of PAC used. PAC dosing was not tried on the main Biopur plant since it was achieving the required performance without use of PAC. Work is on-going at a laboratory scale to duplicate and understand the loss of performance during PAC dosing of the pilot plant.

8. Biopur Plant Performance

The Biopur performance was tested over a 28 day testing period. The performance results are as given in the following paragraphs. The plant was operated on the Biopur DN + Biopur C + Biopur N mode during the performance tests.

8.1 Nitrification Inhibition Removal

The nitrification inhibition in the influent to the works was tested by Yorkshire Water using a respiratory method that compared the influent sample to a standard bio-degradable sample using a pure culture of nitrifiers. One of the intentions behind installation of a pilot plant for the Colne Bridge influent was to try and develop a greater understanding of the relation between treatability and nitrification inhibition which could be used for trade effluent control. However this was found hard to establish. Besides the nitrification inhibition percentage the EC50 value (or the number of dilutions required to obtain 50% nitrification inhibition) is important with regard to treatability.

The nitrification inhibition levels in the influent were as high as 89% with EC50 values of 2.7. The nitrification inhibition removal across the plant was around 70%. The nitrification inhibition results for the performance period are shown in Figure 6. The nitrification inhibition analysis were done at intervals for the 28 day testing period.

8.2 BOD, NH₃N, COD, TSS Plant Performance

The plant performance for the various parameters for the varying nitrification inhibition levels are shown in Figures 7 to 10.

The Biopur plant met its performance requirements even with the high nitrification inhibition in the feed.

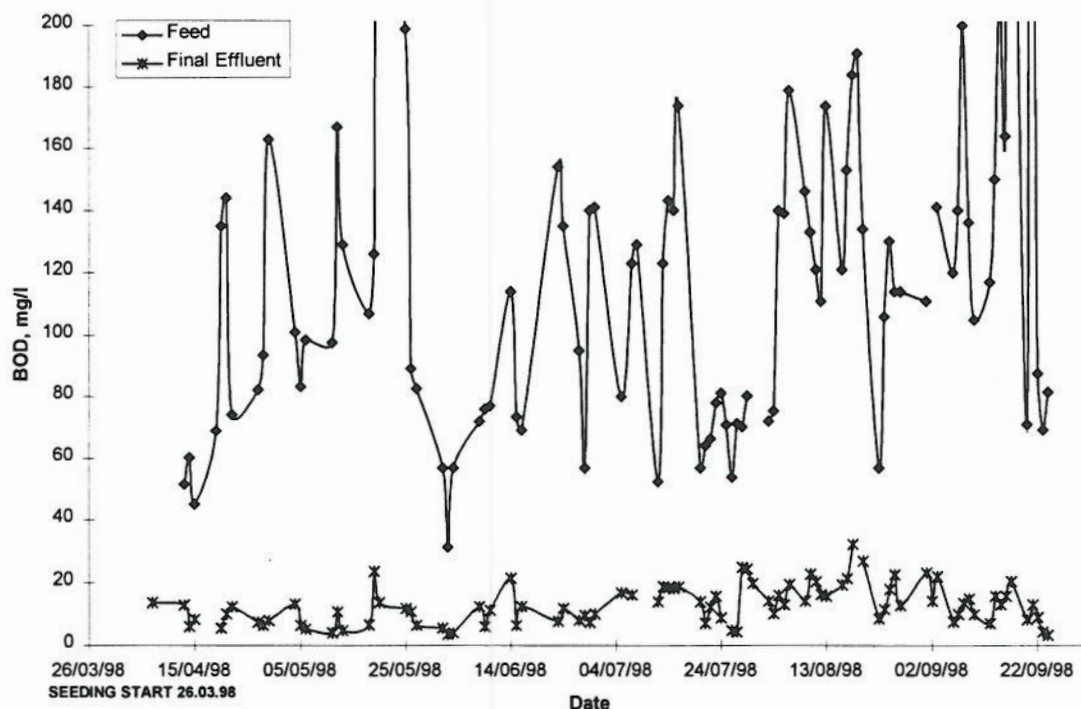
8.3 Biopur Sludge

The backwash wastewater from the Biopur plant is settled in a backwash clarifier. The settled sludge (around 2.5 – 3% w/w solids) is dewatered in a belt dewaterer and then dried using a fluidised bed dryer.

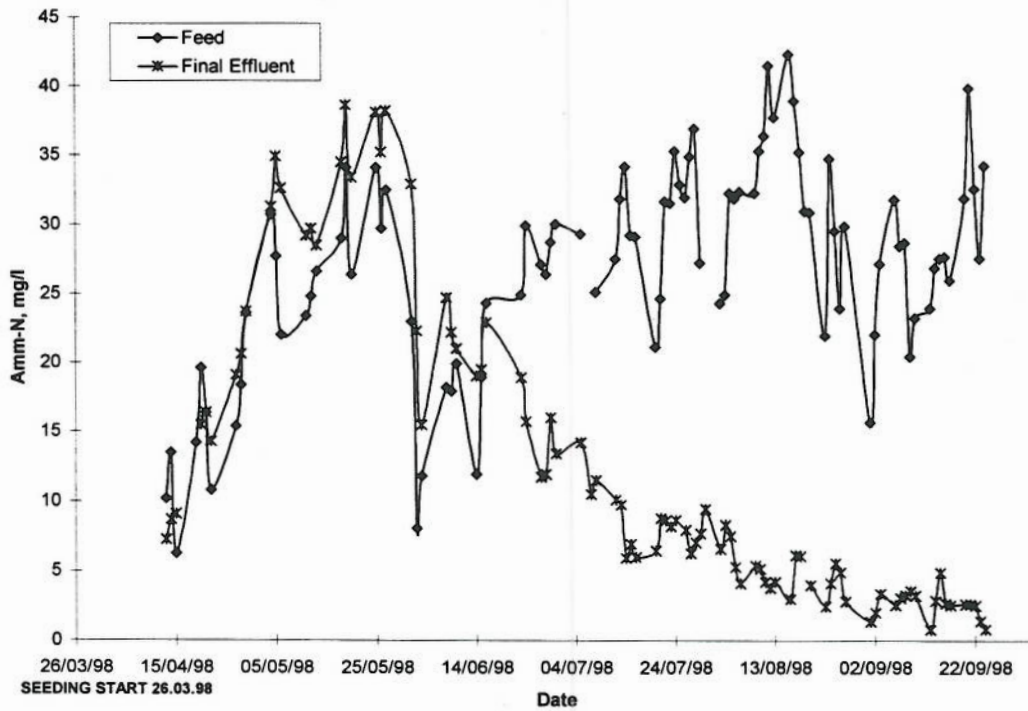
Controlled sludge generation measurements were not carried out in the reported period of performance results. Under average design conditions the total predicted nitrification and carbonaceous sludge is around 0.65 kg TSS/kg BOD₅ applied.

The Biopur sludge was found easy to dewater and dewatered sludge was in the range 16 to 20% solids w/w with polyelectrolyte used around 3 kg/tonne DS. The guaranteed dewatered sludge consistency was 14% solids (w/w) from the belt dewaterer.

Colne Bridge BIOPUR Plant
Figure 4 Plant Acclimatisation - BOD

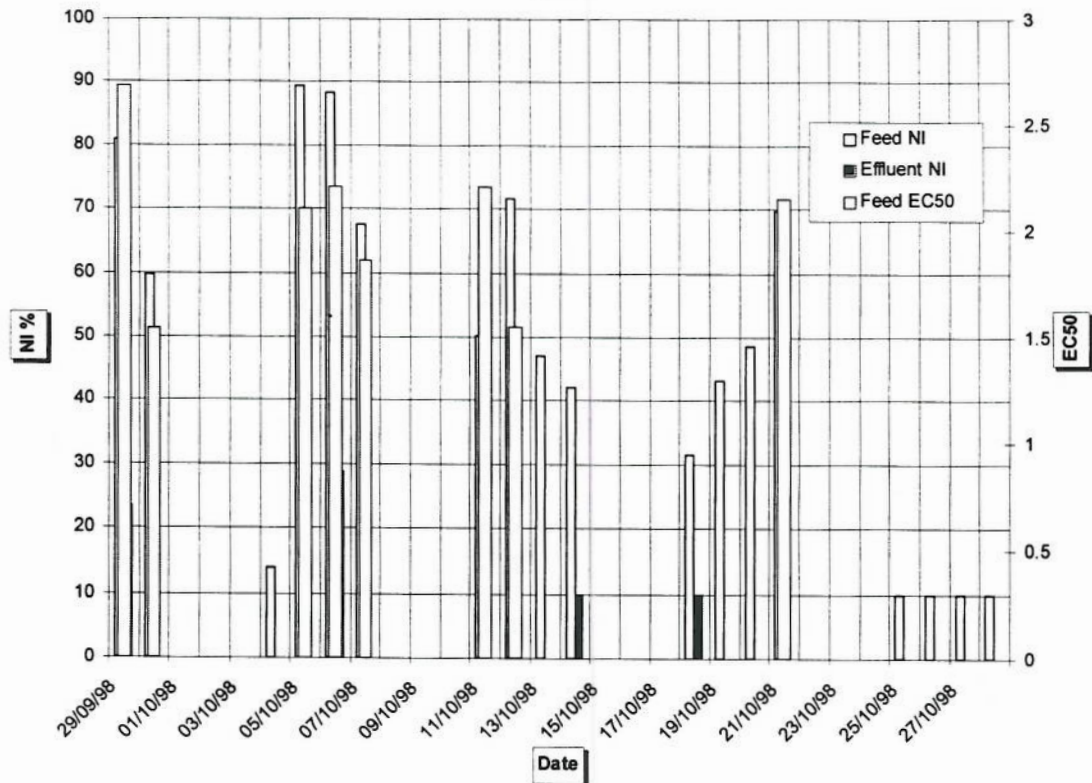


Colne Bridge BIOPUR Plant
Figure 5 Plant Acclimatisation - Ammonia



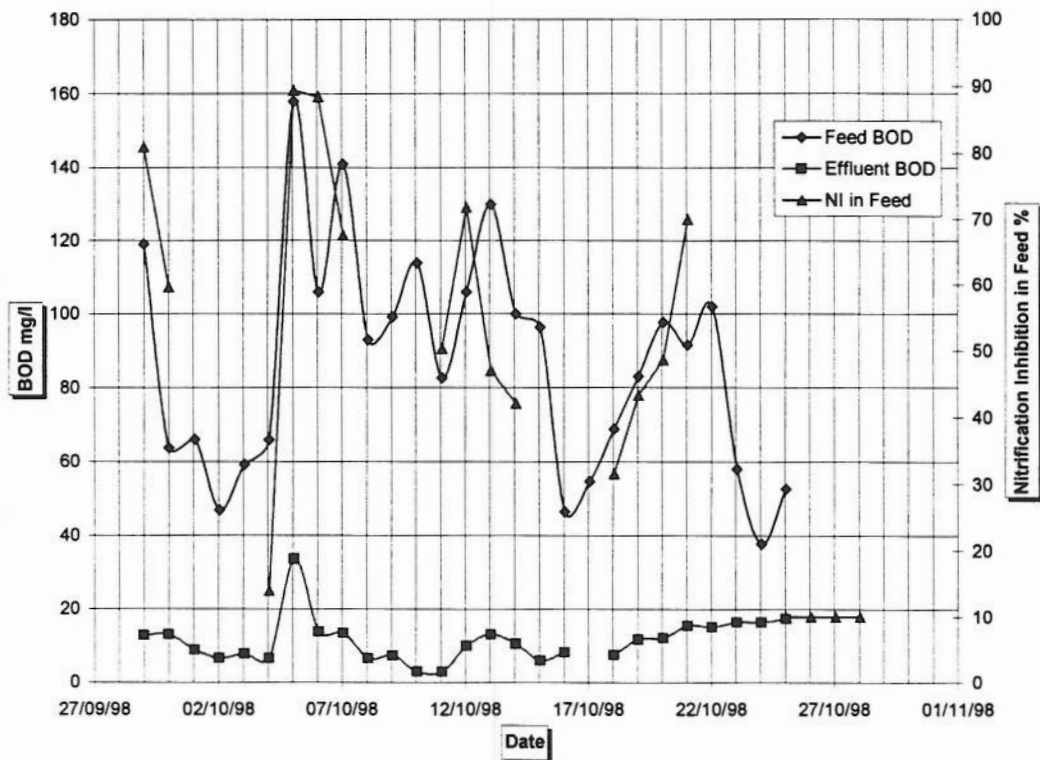
Biopur Performance Test #1
Nitrification Inhibition Values

Figure 6



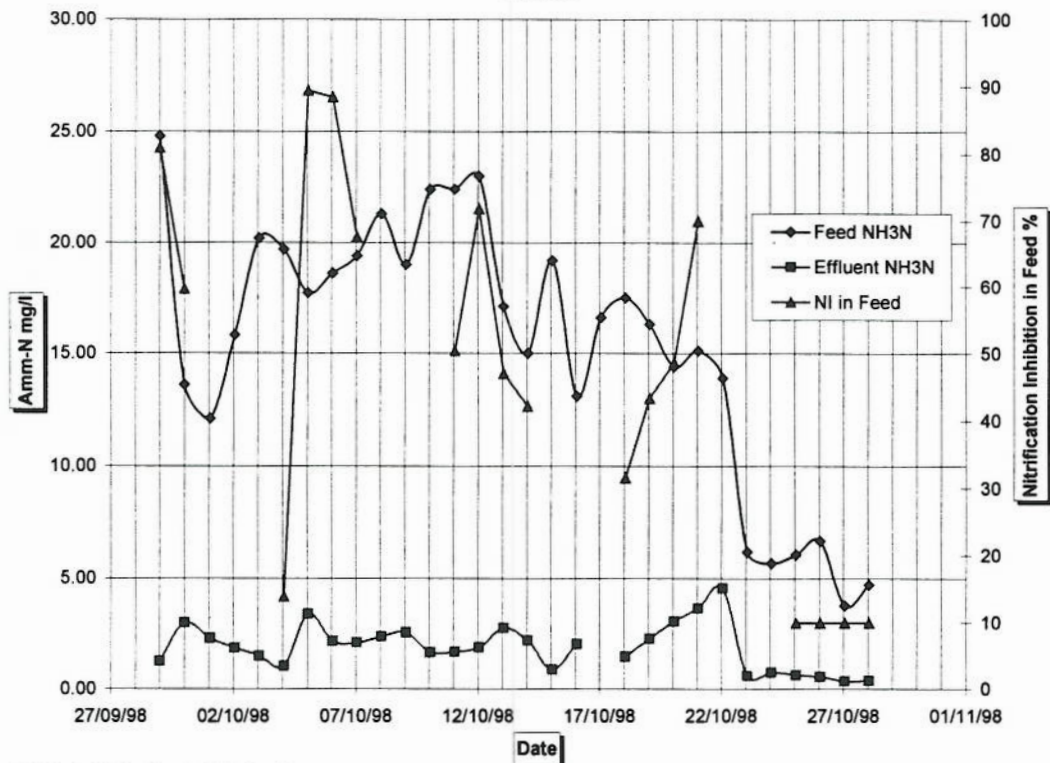
Biopur Performance Test # 1
Biological Oxygen Demand Composite Sample Results

Figure 7



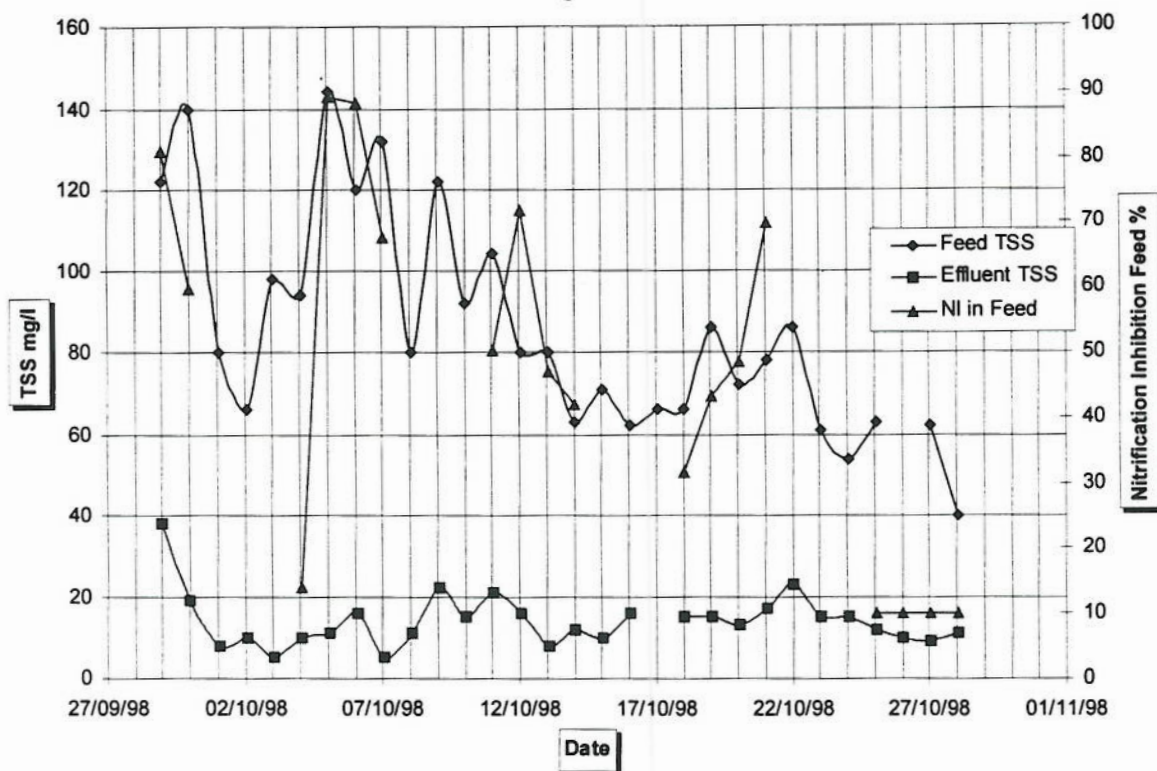
Biopur Performance Test # 1
Ammonical Nitrogen Composite Sample Results

Figure 8



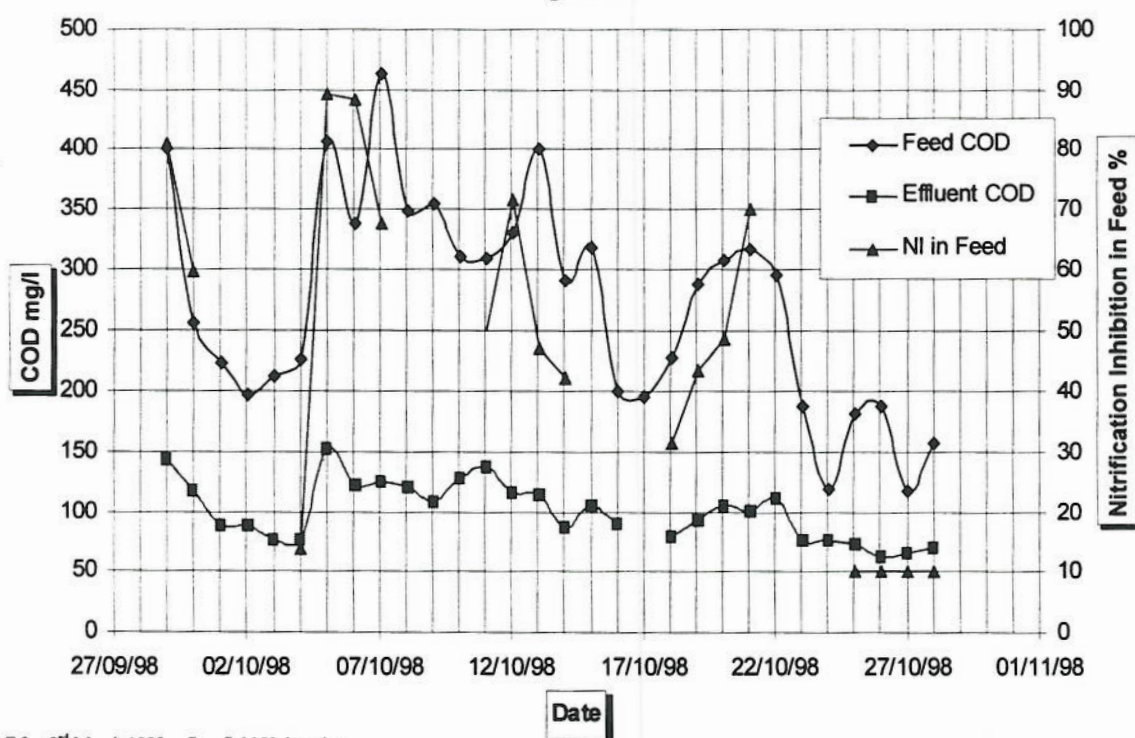
Biopur Performance Test # 1
Total Suspended Solids Composite Sample Results

Figure 9



Biopur Performance Test # 1
Chemical Oxygen Demand Composite Sample Results

Figure 10



9. Summary

9.1 Effluent Quality

The process has passed one performance test to date with a further three to be carried out. The influent loads during the performance test were generally lower than design, the exception being ammonia which at time reached design levels.

The first performance test passed with one BOD failure (three allowed on look up table) for which there appeared to be no explanation.

During dry weather the effluent COD will not meet the 125 mg/l limit with certainty, however this is associated with the hard COD in the plant feed. The COD removal performance of Huddersfield will be assessed on % removal of COD over the whole complex.

The Biopur process selection was made primarily on the judgement that the nitrification performance would be robust and the consistent ammonia removal to date, without recourse to PAC addition, justifies this, particularly when the nitrification inhibition levels in the plant influent are taken into account. Much of this success must be attributable to the three-stage design giving an overall nitrification inhibition removal of 70%. However, the establishment of nitrification was slow, taking 3-4 months and future projects may need to build this time into the overall project programme, particularly where there are inhibitory substances in the plant feed.

9.2 Other Issues

9.2.1 Noise

The use of thin stainless steel pipework on variable speed blowers has caused problems with resonance occurring at certain frequencies and various noise abatement measures have been put in place to alleviate this.

9.2.2 1st Stage Nozzles

The first stage nozzles are a new design to adapt to both DN and C requirements. The present nozzles work well on DN mode but are not optimum when in C mode. A new nozzle design has been developed and will be installed after testing.

9.3.3 Aeration Testing

The high efficiencies suggested by the aeration tests cannot yet be confirmed from routine operational measurements as automatic dissolved oxygen control was not possible during the first performance test. This was because the process blowers were run on fixed speed mode to keep the noise levels down, especially at night.

9.2.4 Operation Flexibility

The flexibility built into the plant design has already proved to be useful both during the commissioning and following take-over.

10. Acknowledgements

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11. References

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