Experience with an up-flow biological aerated filter (BAF) for tertiary treatment: from pilot trials to full scale implementation

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Abstract Biofilters can be added to existing non-nitrifying activated sludge plants for tertiary ammonia removal and effluent polishing. It is a convenient, efficient, and cost effective way of meeting more stringent consents. In order to prove this technology, a biofilter pilot plant was installed in a large activated sludge plant with challenging conditions, since almost half of the load is industrial effluent and the water temperature can be as low as 7°C. Trials were conducted over a two year period, providing the following information: low water temperature does not affect the process; the optimum rise rate at nominal flow is 8.5 m/h for this wastewater; the consent can be achieved for ammonia loads up to 0.94 $kgNH_4N/M^3$ media/day; about 50% of the post-secondary TSS and BOD can be removed in the BAF; a large proportion of industrial effluent has not had any noticeable effect on the beads after two years. A full scale plant with a nominal flow of 8257 l/s was then built and commissioned in summer 1998. Seeding was completed within three weeks of starting the filters. Two months later, a 28 day takeover was started. Results obtained on full scale plant during and after this test confirm the results obtained on the pilot.

Keywords Biological aerated filter; tertiary treatment; nitrification; temperature

Introduction

As a result of increasingly strict regulations on treated effluent quality, many existing wastewater treatment works need to be upgraded, especially with regard to ammonia removal. In these situations, submerged biological aerated filters (BAFs) as a tertiary treatment (Paffoni and Payraudeau, 1997, Rogalla *et al.*, 1994) are a very effective solution for three main reasons.

Firstly, their small footprint makes them easy to add to an existing plant where little space is available. Secondly, the capital costs of adding a tertiary treatment is much lower than the construction of a new prolonged-aeration activated sludge system. Finally, construction does not require any stoppage of or interference with existing reactors, which is important since discharge consents for the existing plant are still in effect during construction.

However, since the development of this technology is still recent, relatively few full scale plants are in use so far, especially large plants treating effluents which contain a large proportion of industrial discharges and which can be very cold (down to 7°C).

Before building the extension, a pilot plant with floating polystyrene beads as medium for bacteria growth (Tschui *et al.*, Zeghal *et al.*, 1996) a pilot of 63 m^2 was installed in 1992. Trials were performed for two years in order to prove the system and optimize the full scale design.

This paper presents the results obtained on the pilot, the benefits of making this pilot test and gives a comparison of the quality of the pilot and full scale plant treated water.

Full scale plant

Davyhulme Waste Water Treatment Works (WWTW) in Manchester (UK) is North West Water's largest wastewater treatment works. It serves a domestic population of 700,000,

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but with the addition of industrial loads, this figure almost doubles to a population equivalent of 1,350,000 and, therefore, proved a major test for BAF technology.

Sewage has been treated on the site since the 1890s, and in 1911 the activated sludge process was devised at the location. At present the works is a large non-nitrifying sludge plant which was required to upgrade in order to achieve its new and more stringent consent, which came into effect in January 1999; TSS<30 mg/l, BOD<20 mg/l and NH_4-N<5 mg/l as a 95%ile on spot samples.

The plant previously consisted of a traditional sewage treatment works, including screens, grit chambers, settling tanks and two activated sludge systems operating in parallel. An up-flow biofilter plant based on the Biostyr process has been designed to treat the effluent from the AS systems for ammonia removal before the flow is discharged to the Manchester Ship Canal (Figure 1). Effluents from the two AS streams are mixed prior to being treated by the biofilter plant. The plant treats a nominal flow of 27,750 m^3/h. The influent criteria for the biofilter are described in Table 1.

Due to the stringent consent expressed in the 95%ile in the spot sample the first process design has been made with 44 filters. To optimize this design a half-size cell for pilot trials has been built.

Biostyr process

The BIOSTYR process (Figure 2) is an up-flow filter filled with floating media retained in the cell by a cellar equipped with nozzles. The air is introduced at the bottom of the filter through an air grid. During the filtration the suspended solids are retained and the biomass increases. Then the filter has to be washed periodically. The backwash consists of alternating phases of water and air.

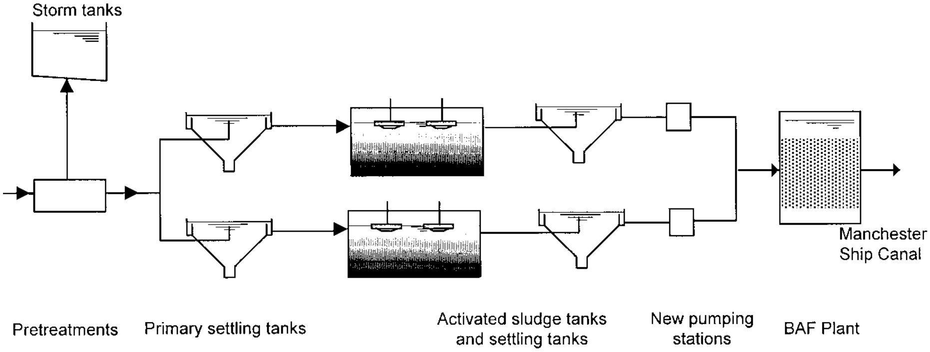

Figure 1 Davyhulme plant schematic

Table 1 Influent characteristics

	Units	Mean	90%ile	Max
Flow	m^3/h	17190		29750
BOD	mg/l		44	
SS	mg/l		58	
NH_4–N	mg/l		32	
BOD load	kg/m^3 media/day	0.57	1.12	1.46
SS load	kg/m^3 media/day	0.74	1.45	1.88
NH_4–N load	kg/m^3 media/day	0.42	0.74	0.94

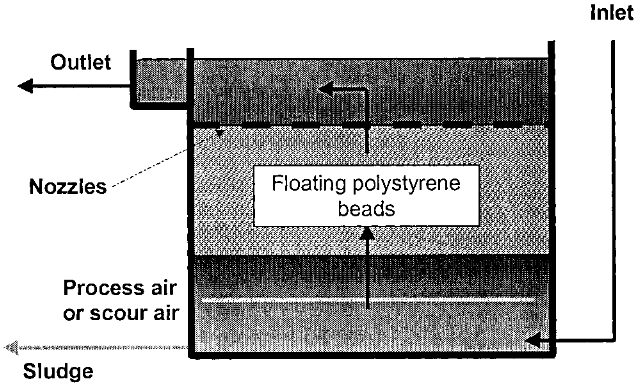

Figure 2 Biostyr process - principle

Pilot trials

The pilot plant was 63 m^2 in surface area and filled with 3.5 mm diameter beads. It was fed by two variable speed pumps in order to treat a flow proportional to the total plant throughput. The maximum flow velocity was 6.7 m/h. The pilot was equipped with on line instrumentation which allowed us to adapt through an algorithm the amount of air blown into the cell.

Four test periods have been planned in 1992-93, one per season, to cover different quality of wastewater and different temperatures. Each day 5 samples have been analyzed on treated water and then 600 samples have been analyzed during this trial.

The following graph (Figure 3) gives the results obtained during this period and shows that 95% of the samples are lower than 2.5 mg/l.

Complementary tests have taken place in 1995 with higher velocities up to 10 m/h.

The global results of these trials provided the following information.

- Low water temperatures do not affect the process. Between November 1993 and March 1994, heavy rains maintained the influent temperature between 8 and 10°C. It even went as low as 7°C. The outlet ammonia concentration always remained below 1 mg/l.

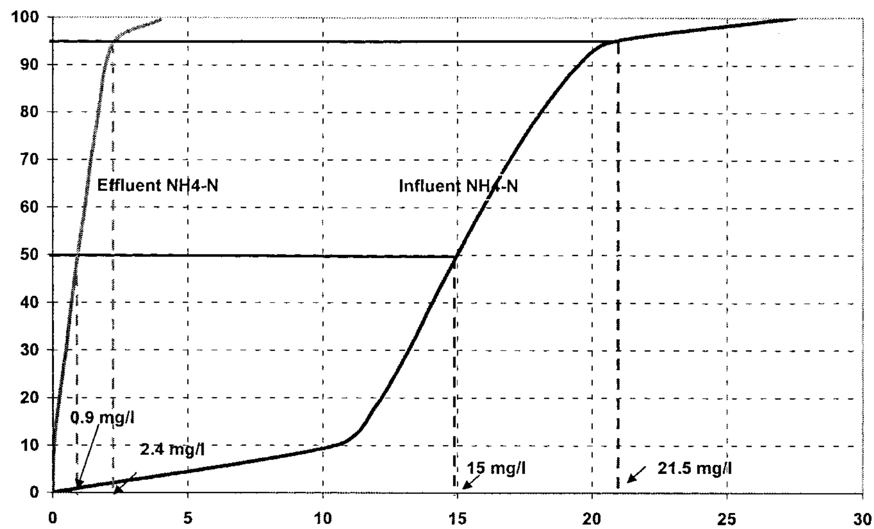

Figure 3 Frequency distribution of the inlet and outlet NH_4-N concentration

- The optimum rise rate at nominal flow is 8.5 m/h for this effluent, and the consent for ammonia can be achieved for ammonia loads up to 0.94 kgNH_4-N/m^3 media/day.
- About 50% of the post-secondary TSS and BOD can be removed in the BAF, with an average TSS load of 1.3 kg/m^3/d.
- The wastewater, which contains a large proportion of diverse industrial discharges, did not affect the nitrification or have any noticeable detrimental effect on the beads after two years.

After these tests, the initial design was modified and the number of the cells was reduced to 36.

Full scale experience

A full scale plant with a nominal flow of 8257 l/s (plus washwater return) was then built and commissioned in the summer of 1998. It consists of 36 cells, each having a surface area of 113 m^2 and 3 metres depth of polystyrene media. Five blowers provide centralized aeration. A washwater tank holds backwash waste, which is pumped upstream to the primary settling tanks for sedimentation and recycling.

On-line analyzers monitor inlet and outlet pH, turbidity and ammonia concentration.

Seeding was completed (i.e. the plant could nitrify the full ammonia load) within three weeks of starting the filters and at a temperature of 17°C. Two months after seeding, a 28 day take-over test was started. The ammonia removal results are given in Figure 4 below.

The outlet ammonia concentration remained below 1.0 mg/l for the duration of the test. This performance was confirmed during the subsequent operation of the plant as indicated in the figure 5. The backwashing interval was stabilized at three days for each filter.

The ammonia load varied between 0.1 and 0.7 kg NH_4-N/m^3 media/day during testing. The reactivity of the process allows a total ammonia removal for peak loads up to 0.84 kgNH_4-N/m^3 media/day (value reached after take-over test). For higher peak loads, the effluent ammonia concentration rises above 1.0 mg/l but stays below 5.0 mg/l for the nominal load of 0.94 kgNH_4-N/m^3 media/day.

The required aeration rate is calculated from the inlet flowrate and the inlet ammonia concentration. On each cell, a first control loop sets the position of the air flow control valve, so all the cells get the same aeration rate. Then a second control loop monitors the positions of all the air flow control valves and, by varying the blower speeds and the number of blowers in operation, ensures the most open valves are 80% open.

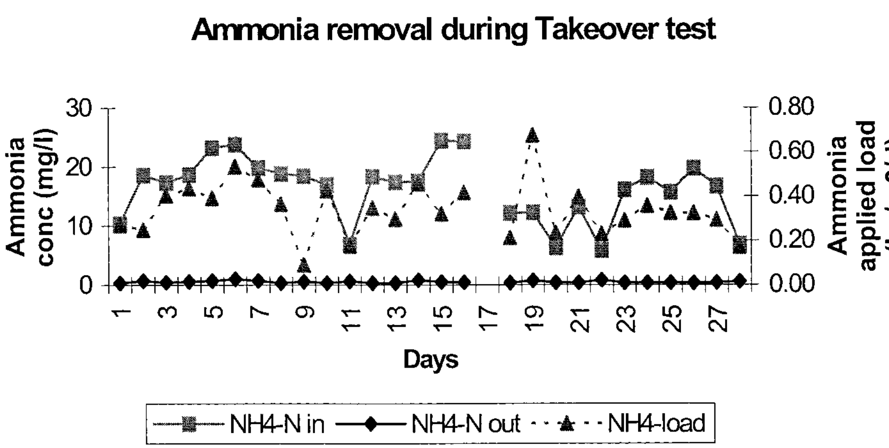

Figure 4 Ammonia removal during take-over test

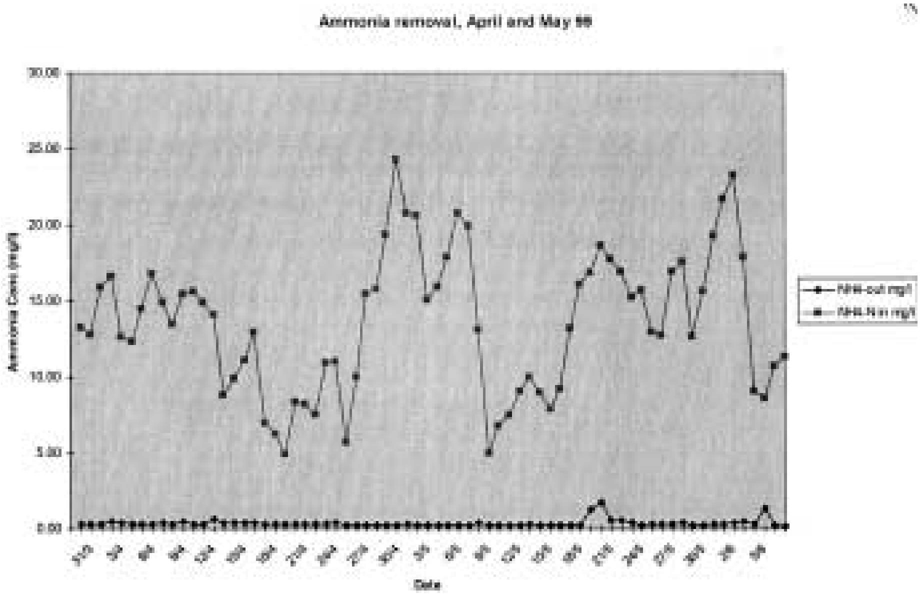

Figure 5 Ammonia removal during operation

This method of air production control and the use of large blowers (21 000 Nm^3/h each) makes the plant very cost effective to operate.

The power consumption used to oxidize the ammonia was 3.43 kW/kg NH_4-N. This value would have been lower if the ammonia load had been higher, since the oxygen transfer efficiency and the efficiency of the blowers are both higher for higher loads. (Additionally the minimum air flow rate for the blowers was often reached during testing.)

Performance comparison

After one year of operation data for the full scale plant were compared to the pilot plant results.

The first thing we can notice is that BOD and SS were significantly improved during the period of the test and the start up of the full scale plant. A reduction of 30% was observed. Oppositely the ammonia concentration was increased by 20%, the ammonia concentration was respectively 11.3 and 14.2 during the test period and the first operation period.

Nevertheless the comparison of the results (Figure 6) shows an excellent correlation between the two plants and then confirms the results obtained during the pilot test period.

Conclusion

The pilot plant tests followed by full scale plant commissioning and operation prove that this BAF technology is both convenient to install as a BNR retrofit and cost effective to build and operate. It has proven itself highly effective for ammonia removal even in challenging conditions such as an influent with a high variability, a low temperature, and a large proportion of industrial discharges.

The benefits of building an half-size cell have been demonstrated because of the reduction of the final sizing of the plant. More than this, the test has generated a lot of confidence in the process.

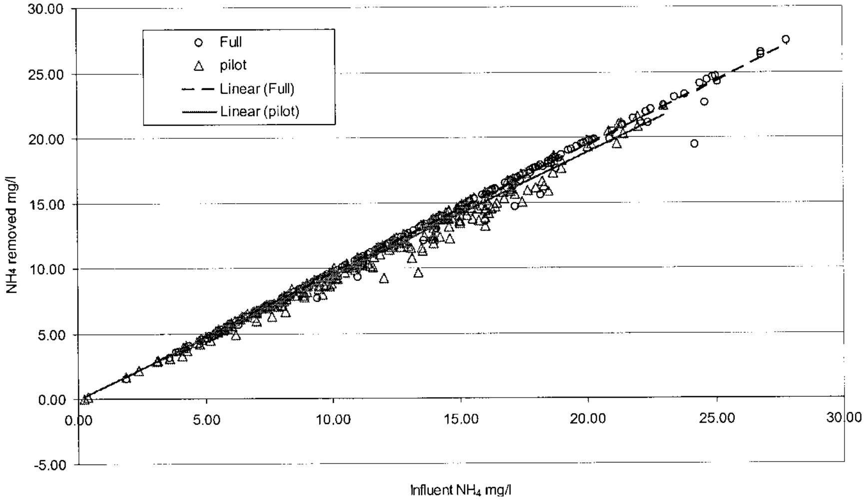

Figure 6 Comparison between the pilot and the full scale plant.

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