A New Generation of Biological Aerated Filters

B. Bigot, MSc*, X. Le Tallec, PhD** and M. Badard***

Abstract

Biological filters with fixed submerged beds are normally used for secondary or tertiary treatment and are recognized for their good performance. These processes are designed to meet, simultaneously, strict requirements of quality and operation. The achievement of the discharge consent requires the use of fine media which features a large support surface for the growth of biomass. On the other hand, the achievement of long filter run times is intrinsically related to the use of coarse media. Nowadays, all biological filters have mono-media, which offers a compromise between these two conflicting criteria.

The B2A process is a newly developed compact filter which ensures high filtration performance and long filter run times, even when used for crude sewage. The technology has been in use since 1992 for nitrification/denitrification using an applied load of 0.7 kg/m^3. d to obtain an effluent quality of 20 mg/l total nitrogen. Further tests have proved its efficiency in the removal of carbonaceous pollution.

The B2A process is the first compact filter capable of treating screened crude sewage yet producing effluent qualities which are equal to that from conventional biological filters receiving settled sewage.

Key words: **Biological aerated filter; compact technology; primary treatment.**

Introduction

The activated-sludge process is a well-known technology; however, the process becomes difficult to extend or upgrade in order to attain more stringent discharge standards. This has led to the exploration of biofilter systems.

The biofilter processes, which have been developed during the last fifteen years, consist of immersed biological filters operating either in down-flow or up-flow mode[1,2,3,4]. They comprise compact units which combine filtration and aerobic/anaerobic biodegradation[5,6], and are used to remove SS, COD, BOD, amm. N, nitrate and PO_4[7], either at the secondary or tertiary stage.

In order to achieve optimum performance, it is necessary that parameters such as (a) the size of the medium, (b) the depth of the filter bed, (c) the water velocity, (d) the quality of the inlet water, and (e) the filtrate quality, are considered. To obtain the maximum cycle time between backwashes, a coarse medium has to be used in the filter bed; however, to achieve stringent standards on particulate pollution, a fine medium is necessary.

The multi-layer concept satisfies the above criteria. In a multi-layer filter, the main problem is to select media of different densities, so that they separate during the filter backwash. The depth of the layers is determined in order to prevent particulates passing through the last fine layer; moreover, the multi-layer technique leads to sufficient voids in the filter to ensure that the headloss is kept within limits – even when large amounts of SS are retained and high COD loads are applied.

In the case of rapid filtration, to achieve very low outlet SS concentrations without being limited by the cycle time, multi-layer technologies have been tested[8,9,10,11]. Following multi-medium filtration, direct flocculation can be carried out in a down-flow tri-medium filter without requiring a preliminary flocculation-clarification stage[8]. To satisfy a very low outlet SS concentration, even with a high inlet concentration, a process based upon the multi-media filtration is presented[9]. A two-filter system is able to achieve the best results: a down-flow dual-medium filter sand (0.5 mm) and expanded clay (2.3–3.5 mm), and an up-flow filter with 0.8–5.0 mm sand. A down-flow dual-medium filter is used to assess the feasibility of increasing the filtration rate for a groundwater plant[10]. By using two media in the filter, the filter capacity is doubled by increasing the filtration rate from 5 m/h to 10 m/h with lower headloss and longer filter runs of acceptable outlet SS concentrations. A uniform medium in a down-flow filter leads to a non-uniform distribution of deposits through the filter bed[11]. If the medium is non-uniform, the finest medium is on the top and the coarsest at the bottom, but the problem is worse – leading to a rapid clogging of the top of the bed. The solution is to use a coarse medium at the top to (a) ensure a penetration of the deposits into the filter bed, and (b) reduce the local clogging.

In all the cases, multi-medium filters are only used to remove the SS without being aerated. Many tests have been carried out on down-flow filters and up-flow filters, which have led to the design of the advanced aerated biofilter (B2A) based upon the multi-layer concept.

Multi-Medium Biological Aerated Filters

Down-Flow Filters

The Biocarbone process is a down-flow biological aerated filter (BAF) which combines aeration and clarification in one unit by using a granular mono-medium for both biofilm support and filtration[12]. In such a filter, the SS

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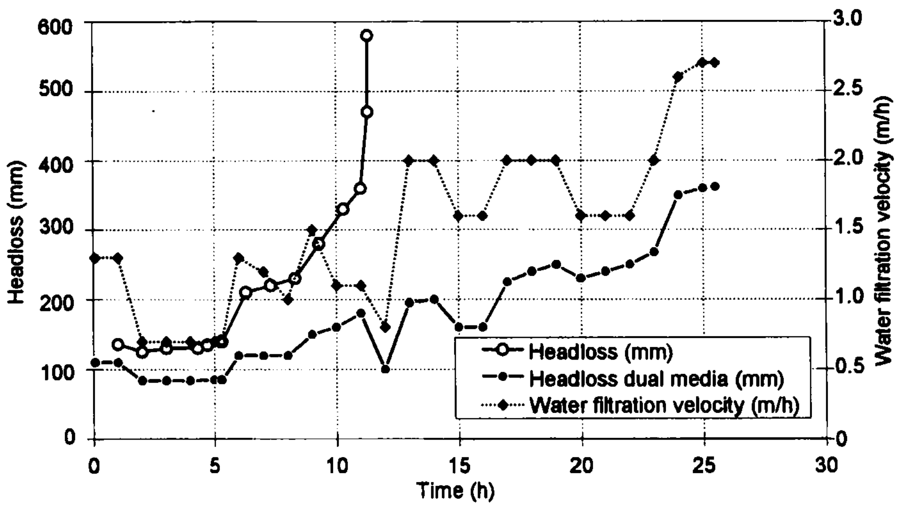

Fig. 1. Dual filter and classical filter: comparison of filter runs

are retained at the top of the filter where there is local clogging. To prevent such clogging, a dual-medium Biocarbone unit was incorporated in a full-scale plant at Le Touquet in Northern France[13]. The dual-medium filter consisted of expanded clay (3.3 mm and density 1.6 g/cm^3) and pumice (4.6 mm and density 1.1 g/cm^3). The Biocarbone cells were 33 m^2 and the depth of the filter bed was 2.0 m. Under experimental conditions, the mono-medium filter had to be backwashed after 12 hours' operation, but the other filter was still not clogged after 24 h. In terms of carbonaceous pollution removal, the applied load of COD on the dual-filter (6.6 kg COD/m^3. d) was higher than the applied load on the normal filter (5.5 kg COD/m^3. d). This resulted in a higher outlet concentration for the dual filter (89 mg/l COD) than the normal filter (79 mg/l COD), but both filters satisfied the standard. However, the dual filter was much easier to operate than the other, only requiring backwashing once per day. Fig. 1 illustrates a comparison of the clogging between the mono and dual filters.

The main difficulty in such a dual filter was to maintain the classification of the pumice and the expanded clay. Because pumice is an expensive medium, the development of a down-flow dual-medium BAF did not proceed.

Up-Flow Filters: B2A

For the treatment of wastewater, the up-flow BAFs are now widely used as secondary or tertiary treatment and are being recognized for their performance[1,2,3]. Such processes are always operated after primary sedimentation. To further reduce the size of the plant, the solution could be to feed crude sewage directly onto the BAF.

Description of Filter

The process is based on the multi-medium concept described above, together with knowledge of the biological aerated filter[14]. Particles sizes range from a support medium of 40 mm gravel, up to a final layer having a diameter of 1–4 mm, according to treatment objectives. Domestic sewage is introduced into the bottom of the filter, following grit removal and fine screening. Air is blown into a distribution grid embedded either in the granular bed or in the bottom of the filter (Fig. 2). To remove the particulates retained in the filter

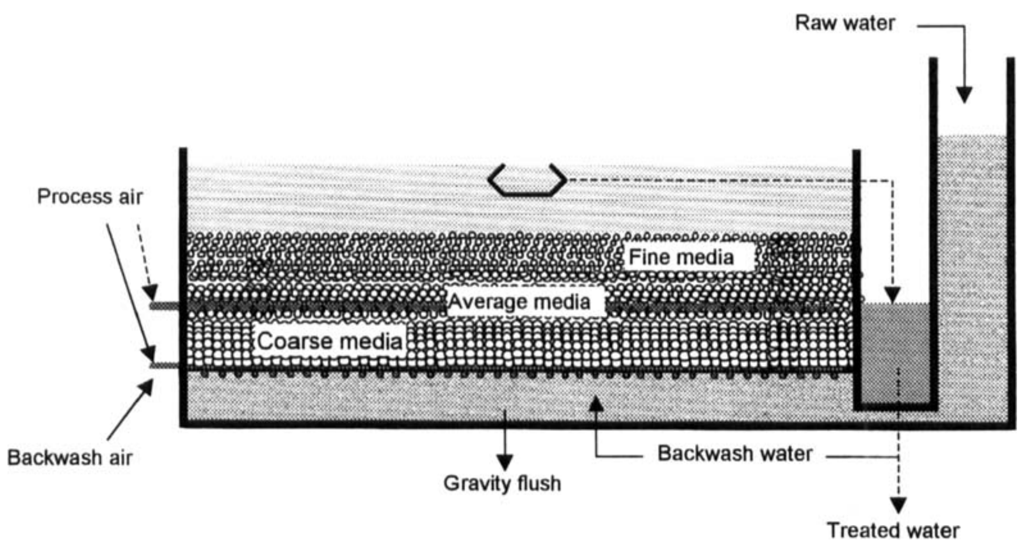

Fig. 2. Diagram of B2A multi-layer filter

and the extra biomass, a backwash is carried out in two stages. The first stage consists of a gravity flush to remove the large particulates which accumulate in the coarse medium. The second stage is to use air and water to wash the extra biomass out of the filter. Finally, a water phase is used to ensure re-classification of the different uses of the media.

Daily analysis of the influent and effluent is carried out for total COD, SS, total nitrogen and amm. N. Influent and effluent particulate pollution are monitored continuously with turbidity measurements.

Removal of Carbonaceous Material

In this study, the objective was to define the performance of the B2A to achieve secondary treatment standards for different hydraulic conditions. In order to test the process, a pilot plant (1 m^2, 4 m depth) was filled with media from 40 mm down to 3 mm, and fed with screened crude sewage. In order to test the effect of the liquid velocity on the carbon-removal efficiency, both weak and strong crude sewage was used. The main characteristics of the experiment were as follows:

Inlet COD:	300–600 mg/l
Inlet SS:	150–300 mg/l
Water velocity:	3–10 m/h
COD applied load:	8–30 kg COD/m^3. d

Because of the use of multi-media, the filtration process was very efficient in the B2A filter and, for a given filtration velocity, the daily removal of SS load was constant. To satisfy the European standards (125 mg/l COD and 25 mg/l BOD for 95% of the time), the COD applied load had to be 10–15 kg/m^3. d. Sometimes the requirement could be less stringent and only 75% of the carbon pollution had to be removed; then, a COD load of 20–25 kg/m^3. d could be applied.

In order to evaluate the use of the B2A process, a comparison between settled sewage and crude sewage was carried out; in terms of COD removal, the results were similar. However, because the crude sewage contained a higher concentration of SS, this resulted in a higher headloss across the filter. the filter runs were also reduced.

Fig. 3 shows the link between the dimensionless COD applied load, the inlet COD concentration, and the outlet COD objectives. This curve was based upon the results obtained with settled sewage used as feed. The figure shows that when the inlet water was concentrated, the COD applied load was lower than the one corresponding to the dilute sewage

Primary Nitrification

Normally, the nitrification process needs a preliminary stage to remove carbonaceous pollution. With the B2A process it was desirable to prove that, with only one stage, the ammonia and carbonaceous pollution could be removed without a problem. The main characteristics of the tests were as follows:

Inlet COD:	300–600 mg/l
Inlet SS:	150–300 mg/l
Inlet amm. N:	30–70 mg/l
Water velocity:	1–3 m/h
COD applied load:	2–12 kg/m^3. d
Amm. N applied load:	0.5–1 kg/m^3. d
Temperature:	14–17°C

Compared with the carbon-removal configuration, the water velocities for the primary nitrification were lower to limit the COD applied load; this parameter varied from 2 kg/m^3. d up to 12 kg/m^3. d, which corresponded to an amm. N applied load of 0.2 kg/m^3. d to 0.9 kg/m^3. d

Fig. 4 shows results obtained with the B2A used as a primary nitrification BAF. For all COD loads, when the amm. N applied load was lower than 0.7 kg/m^3. d, the B2A was able to achieve more than 80% efficiency (average = 90%).

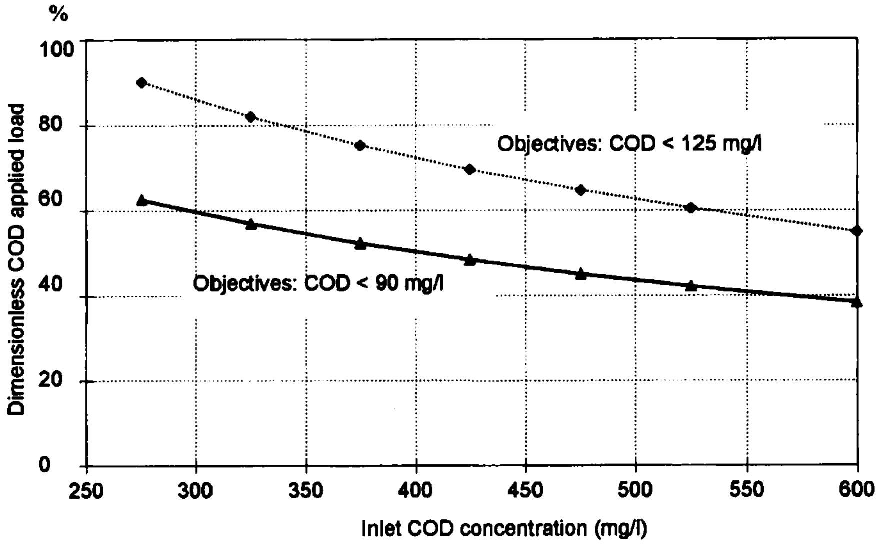

Fig. 3. Carbon removal: dimensionless COD applied load vs inlet concentration and treated-water objectives

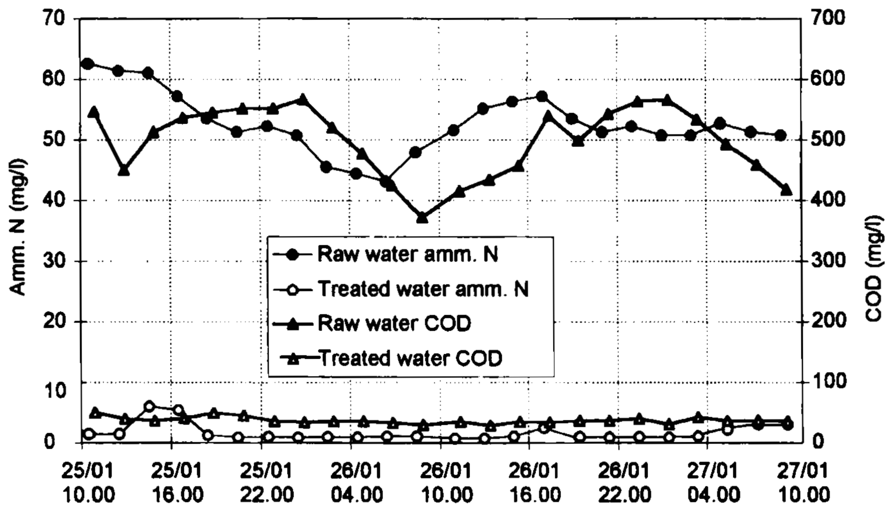

Fig. 4. Primary nitrification: typical results for amm. N and COD

Primary nitrification and denitrification

Because the B2A is fed with domestic sewage, the available organic matter is high and can be easily used to remove nitrates. By inserting the air supply within the filter bed and recirculating the treated water, the B2A process can be used as a primary nitrification/denitrification BAF. A full-scale filter, in this configuration, has been operating since 1992 at Gratentour in France (Fig. 5), and results from a six months' trial period are presented in Figs.6(a) and 6(b). The basic design characteristics of the plant, together with an analysis of the influent and effluent, are as follows:

Inlet COD:	300–600 mg/l
Inlet amm. N:	35–70 mg/l
Water velocity:	3–5 m/h
COD applied load:	2–14 kg/m³. d
Amm. N applied load:	0.4–1.1 kg/m³. d
Temperature:	15–19°C
Average COD outlet concentration:	25–40 mg/l
Average amm. N outlet concentration:	0–4 mg/l
Average nitrate outlet concentration:	10–15 mg/l

The B2A process is also able to remove phosphorus to a concentration of 2 mg/l with the addition of a chemical. The precipitated phosphorus is removed with the backwash sludge without any clogging of the filter.

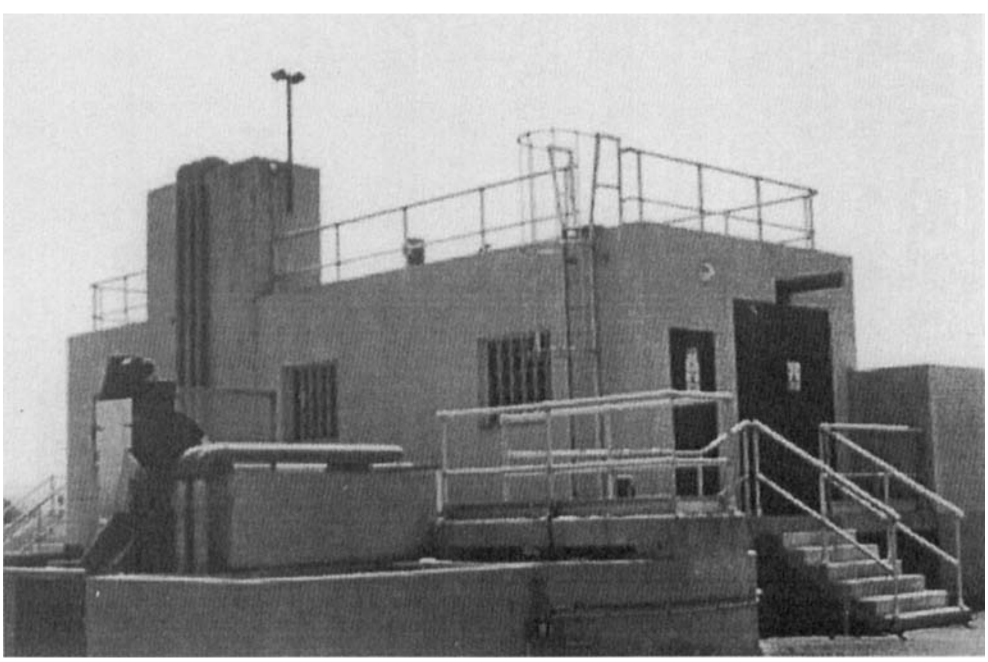

Fig. 5. View of plant using B2A as primary nitrification/denitrification process

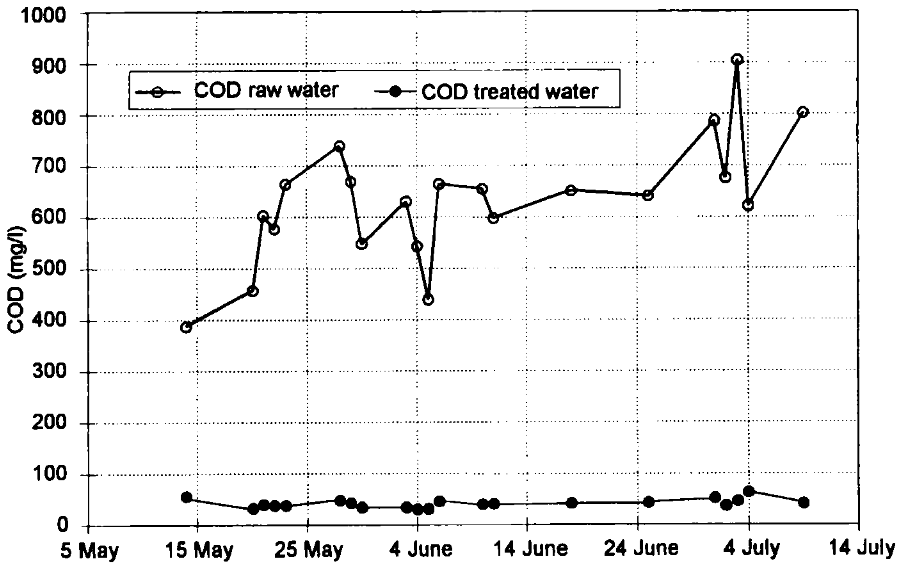

Fig. 6(a). Primary nitrification/denitrification: inlet and outlet COD concentrations

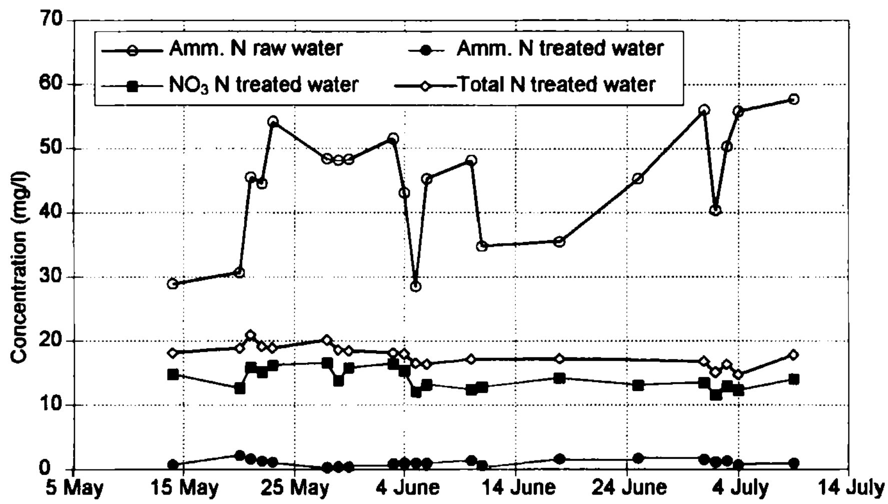

Fig. 6(b). Primary nitrification/denitrification: inlet and outlet concentrations of nitrogen

Conclusions

1. The B2A process can be used for primary carbon removal, primary nitrification or primary nitrification/denitrification. In all cases, high-quality effluent standards can be achieved using very high loads.
2. The use of a fine medium at the top of the bed leads to a high specific area and an efficient biological activity.
3. Operation of the sewage-treatment plant at Gratentour since 1992 shows that the multi-layer filters fed with domestic sewage are performing most satisfactorily. Moreover, using the statistical analysis of either the pilot-scale results or the full-scale results, tools for the design of the B2A have been developed.
4. During forthcoming years, new wastewater treatment plants (serving 10 000–50 000 population equivalent) will be built, with the B2A process either as a primary carbon pollution removal stage or primary nitrification/denitrification stage.

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