THE FIBRA FILTER

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Abstract

This paper presents some preliminary information concerning a new process for particle separation, the 'Fibra Filter', which potentially offers substantial performance and cost advantages over contemporary methods. The process is based on passing contaminated waters through an 'in-line' bundle of fibres which are compressed at a downstream section. Periodic compression and decompression on an automatic cycle allows suspended particles in the influent water to be retained and then flushed to waste efficiently and with low energy consumption. Several field trials have been undertaken recently with the technology which have demonstrated its performance and versatility in application to a range of industrial wastewaters. Some empirical performance information is presented, together with suggestions for areas of more detailed study to establish the fundamental behaviour of the process and to quantify its comparative advantages over conventional filtration methods.

Introduction

This article is a preliminary review of the newly developed Fibra filter process. This process was established in the UK in 2003 by the firm Fibra Ltd which bought the IP from the original owner, BioFilter AS of Norway, in order to commercialise the technology worldwide. The process, which is the subject of patent applications[1], is claimed to achieve the following in liquids: (a) filtration of particles to sub-micron levels; (b) aeration and oxygenation through the formation of micro-bubbles; (c) non-chemical flocculation and coagulation; and (d) separation in emulsions and liquid mixes. This article reviews only the application of the Fibra process for the filtration of aqueous suspensions since this has been the principal objective of recent field trials, for which performance data is available.

The basic principles of the filter can be seen in Figure 1 [1]. The filter consists of an 'in-line' fibre bundle, located in a cylinder and anchored at the inlet end (Figure 2). The influent flow to be treated and containing suspended particulates, moves from the inlet end towards a predetermined downstream point where a flexible compression device bears on the fibres in an inwardly radial direction, thereby constricting the flow. As a result particles are retained in the interstitial gaps between the compressed fibres as the flow proceeds. The gaps, which are predetermined by selection of the fibre size and by the degree of compression (bladder pressure), therefore define the performance characteristics of the filter. However, in most applications it has been shown that filter conditioning occurs very rapidly which contributes to retention efficiencies far in excess of that defined by the theoretical interstitial gap size. The Fibra filter is cleaned by forward flushing (Figure1b), using the influent water to wash through the particle deposits in a similar manner to the principle of upflow granular bed filters.

Operational information

Depending on the nature of the water being processed, the current 10 cm diameter Fibra filter has a flow rate of between 0.5 and 2.5 m^3/h. Capacity expansion can be achieved by

[1] International Patent Application PCT/EP01/10707. 'Device and Method for Filtering a Fluid', and International Patent Application PCT/DK02/00288, 'Contacting Liquid with a Gas'.

connecting two or more units in parallel, as shown in Figure 3. The compression of the fibres during normal operation causes a flow pressure loss of typically 1-2 bar, although this depends on the nature of the water being treated and the performance required. Consequently, a pumped supply is required to achieve the desired flow rate. The Fibra unit has a casing made from 316 grade stainless steel and the fibres, approximately 0.1mm in diameter, are of PBT polyester or 6-12 Nylon. Compression devices are available in a range of natural and synthetic materials to suit the particular conditions. Flushing may be carried out rapidly by manual operation, or very rapidly using automated control. Using automation, flushing can be controlled by differential pressure, by decreased flow rate, by volume processed, or by elapsed time. During flushing, outflow is diverted either back to the influent or to waste, the compression ring deflates and the retained filtrate is ejected. In most applications, the flushing process is carried out by the influent water. The flushing process is also normally aided by the injection of compressed air, which vigorously shakes deposited material from the fibres. The flush cycle, under automated control, typically takes 10 seconds which, given that flushing may be required every hour (although differing influents will have different flushing requirements in order to maintain performance), causes minimal disruption to process flow.

Treatment Performance and Case Study Observations

In accordance with classical filtration theory, it is expected that the capture and retention of particles within the influent suspension is through progressive size exclusion, together with the various transport mechanisms such as sedimentation, diffusion, and hydrodynamic effects [2]. Given that there are assumed to be up to 300,000 fibres per bundle, it can be estimated (assuming a square packing of circular fibres) that in the zone of compression the porosity of the fibre bundle is in the region of 20%, and the nominal pore dimensions are 40µm (minimum) by 100µm (maximum). It is likely that under high compression the fibres will distort leading to a significantly lower porosity and pore size. In view of this it is expected that filtration efficiency will be high, although this will be moderated by the high pore velocity that may be in the range of 0.5-2.5 m/s. In terms of total collector specific surface area, ~3000m^2/m^3, the fibre bundle is equivalent to a fine sand granular filter. A particular feature and advantage of this type of filter is the progressive narrowing of the pore spaces between the fibres in the direction of flow up to the point of compression. This allows a natural grading through size exclusion of influent particles and the resulting pressure loss is lower than it would be otherwise.

A range of applications has been identified to date [1], and these are as follows:

- Broad-spectrum particle filtration
- Pre-filtration for membrane filters
- Industrial wastewater
- Humus-laden groundwater clarification (brown water)
- Laundry waste water treatment
- Food and beverage applications (filtration of product *and* wastewater)
- Domestic sewage oxidation
- Landfill site leachate water treatment
- Mine and quarry water treatment
- Metal cutting lubricant/coolant filtration

The Fibra technology has been laboratory-, or field-, tested in a variety of applications and two methods of treatment have been treated, either continuous flow single filtration or batch treatment with recycle (multi-filtration). Broadly, the results have been very encouraging in terms of the treatment performance obtained, and the operational service requirements. With regard to treatment the key factors that affect the degree of performance achieved are the flow rate, the number of passes the flow makes through the unit, and the specification of the fibre bundle. With regard to the latter, all of the field trials so far have used the Nylon material. A brief summary of some recent trials of the Fibra filter are given in Table 1, and in Figure 4 which shows an example of the effect of bladder pressure on treatment performance. The operational and treatment data from these trials are somewhat empirical and incomplete, and information on the flushing performance was not available. The results show that the general removal of particulates is high (~80%), as expressed in overall units (eg. total solids and turbidity), and particularly when the liquid makes two passes through the unit. That this occurs at a relatively high flow throughput (~15m^3/m^2h) and low energy consumption (<100W per m^3/h) indicates that the technology may be superior to some comparable filtration methods. For example, it is interesting to note that the flux rates for micro filtration membranes (pore size ~0.4µm) are 2-3 orders of magnitude lower (~0.01 to 0.15 m^3/m^2h).

Discussion

The advantages claimed for the Fibra technology are as follows[1]: (a) precise control of particle sizes; (b) high deposit capacity; (c) flushing can be carried out with waste water; (d) forward flushing; (e) automatic flushing capability; (f) very simple to use; (g) low energy consumption; (i) no consumables except electricity; (j) very durable and robust construction. Most of these claims have so far been supported empirically through laboratory and field trials of limited duration, but there remains a need for more careful and thorough investigation in order to quantify and confirm these advantages. For example, the following areas of further investigation are suggested in order to establish the mechanisms, and degree, of treatment provided by the technology, and how to optimise the operation:

- The relationship between particle removal and influent concentration, with run time, flow rate, nature of fibres, nature of influent particles and influent water chemistry (eg. pH, temperature, ionic strength).
- Relationship between particle size cut off and compression (bladder) pressure.
- The capability for reducing dissolved organic and inorganic matter.
- The potential for enhanced treatment by the prior addition of chemical coagulants or oxidants (eg. ozone, hydrogen peroxide).
- Relationship between retained deposit volumes and pressure loss.
- Frequency and efficiency of flushing.
- Long term changes in process performance.
- The performance of alternative fibre materials.

In addition to undertaking specific fundamental tests as indicated above to better understand the process, it would be useful to evaluate the Fibra technology directly in parallel with appropriate alternative filtration technologies, such as a pressure filter or membrane process. This could be done for a range of water qualities and industrial applications to allow a direct comparison to be made of both the technical and economic advantages of the Fibra process with other technologies. One aspect of particular interest for study is the combination of gas mixing by the unit (formation of micro-bubbles) with particle filtration, as in the case of applying ozone as an oxidant to the influent water. Recent work by the author with a granular media filter [3] has found that pre-oxidation can enhance particle filtration significantly, and this phenomenon may be enhanced substantially in the case of the Fibra filter through its ability to create micro-bubbles, thereby leading to greater ozone mass transfer.

Overall, and on the basis of the preliminary evidence so far, the Fibra process offers some substantial advantages over existing filtration technologies, particularly in regard to it having a defined particle cut-off, an efficient forward flush method of cleaning (by simple relaxation of the fibre compression), low energy consumption, and a simple robust method of operation. The present technology is based on a 10 cm diameter filter unit but a much larger unit is under development and will be available in the near future.

Acknowledgements

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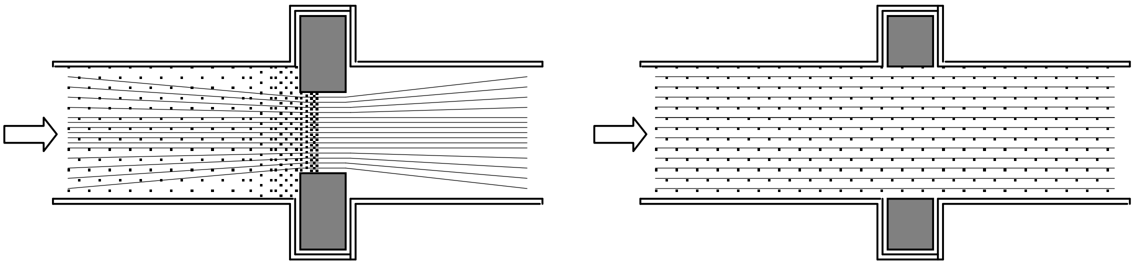
Author's Biography

Nigel Graham is currently Professor of Environmental Engineering at Imperial College London. He has Bachelor and Master degrees in Engineering Science from the University of Cambridge, and MSc and PhD degrees from Imperial College London in Environmental Engineering. He is a professionally-registered engineer and a Fellow of the Institutions of Civil Engineers and Chemical Engineers. Most of his career has been spent in academic life at Imperial College London, but he has undertaken sabbatical periods in Nigeria and Hong Kong.

His technical and research interests include the performance and development of a wide range of unit processes in water and wastewater treatment, and in the management of water supply systems. These have lead to the publication of approximately 170 scientific papers in journals and conference proceedings, and the editorship of several books, over the last 15 years. In recent years Professor Graham has focused his research studies on oxidation, coagulation and filtration processes, and his current work on filtration includes the combined use of pre-oxidation and granular media filters, and the development of computer-based process models.



(a) (b)

Figure 1. The Fibra filter: (a) filtering mode; (b) flushing mode.

Figure 2. The Fibra fibre bundle and housing.

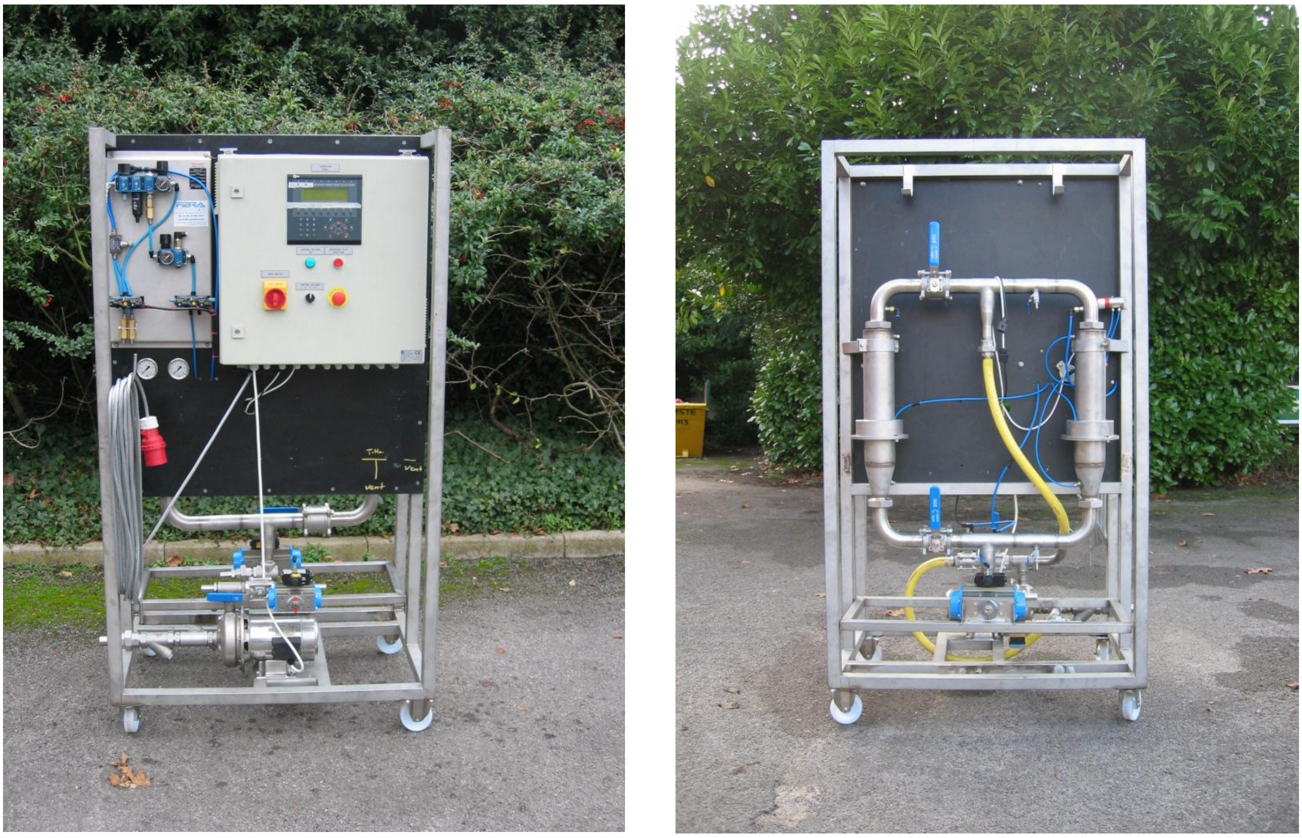


Figure 3. The Fibra automated filter (2 units in parallel).

Table 1. Summary of recent laboratory and field trials of the Fibra Filtration unit [1]

Type of liquid	Flow rate (m^3/h)	Single pass/ Batch (No. passes)	Treatment performance	Comments
Cooling water from a concrete saw: Suspended solids ~ 900 mg/l Turbidity – 149 NTU UV-Absorption (360nm) – 0.26	0.12	Batch (1 and 2 passes)	One pass removal: 71.1% suspended solids, 61.1% turbidity, 57.5% UV-abs. Two pass removal: 82.2% suspended solids, 97.3% turbidity, 91.5% UV-abs.	Laboratory trials
Water containing drilling flour: UV-Absorption (360nm) ~ 0.35	0.12-0.18	Single pass	Reduction in UV-Abs: 79.4% at 0.18m^3/h 88.4% at 0.12m^3/h	Laboratory trials
Cutting and cooling oil	n/a*	n/a	Change in volume weighted mean size: 33µm – before Fibra unit 8.8µm – after Fibra unit	Field trials
Silt-laden ground water: Turbidity – between 0.36 and 1.42	n/a	Single pass	Reduction in turbidity: 55-76%	Field trials
Concrete waste water: Suspended solids – 170 mg/l Turbidity – 84 NTU Calcium – 220 mg/l Total hardness – 5.3 mmol/l	0.50-0.80	Single pass	Reduction: 92.3% suspended solids, 92.4% turbidity, 73.2% calcium, 75.5% total hardness	Field trials
Pressed grape juice: Total solids – 3.3 g/l	n/a	Single pass	Reduction in total solids: 81% (bladder pressure>3 bar (see Figure 4)	Field trials

n/a* - not available

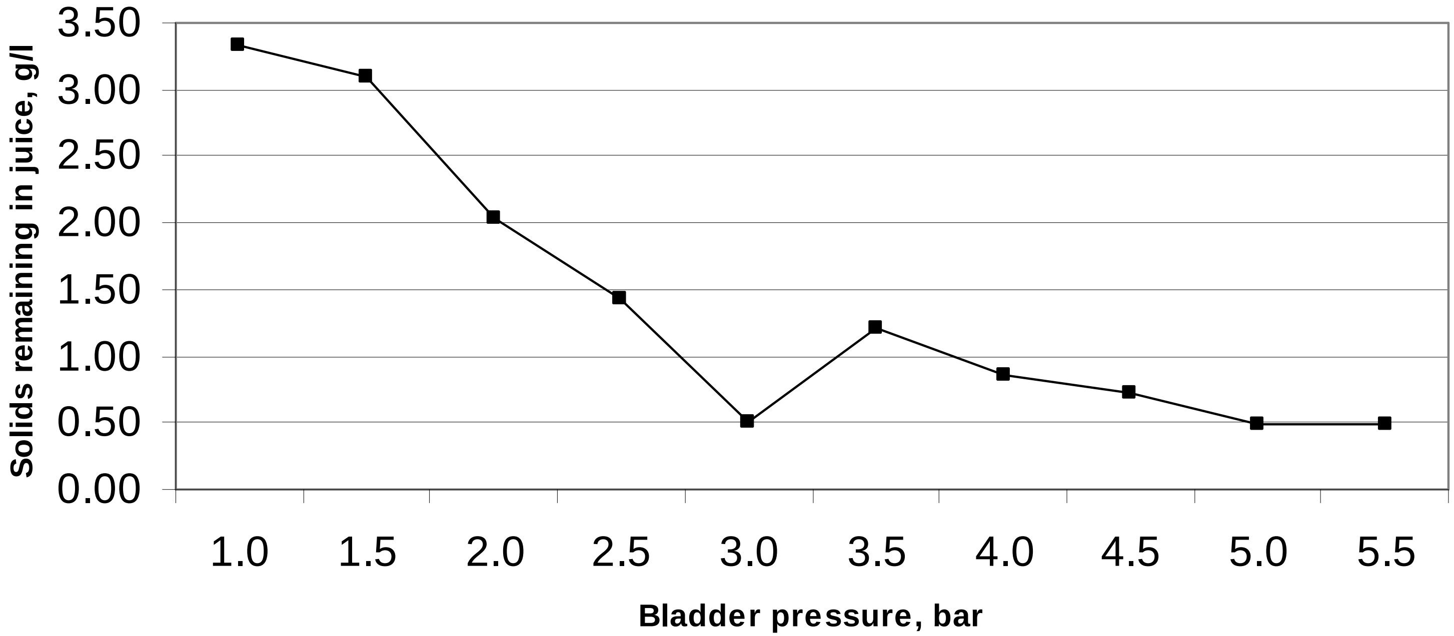


Figure 4. Filtration of grape juice by the Fibra unit.