Bristol Water
membrane filtration *cryptosporidium* barrier

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Bristol Water is responsible for the supply of 290Ml/d drinking water to over 1 million people in Bristol and the surrounding parts of Gloucestershire, Somerset and Wiltshire. Approximately 25 per cent of the company's water supplies come from ground water sources. Typically, these waters are good quality, hard waters with a low turbidity. In 1999, having undertaken a risk assessment of all their water sources to assess the potential for contamination by *cryptosporidium*, a number of ground water sources were identified where spikes of turbidity (up to 20 NTU) and total organic carbon (up to 7.4 mg/l) spikes had been recorded. This indicates that there may be a direct connection between the surface water and the groundwater and hence, the groundwater may be at risk of contamination from the surface by *cryptosporidium.*

Membrane filter house building at Sherborne *(courtesy Bristol Water)*

The Water Supply (Water Quality) (Amendment) Regulations 1999: (*Cryptosporidium* in water supplies) require water undertakers to carry out assessments to establish whether there is a significant risk from *cryptosporidium* in water supplied from their works. Where such a risk is established the water undertakers must use a treatment process to ensure the average number of *cryptosporidium* oocysts pre ten litres of water is less than one.To verify compliance with this requirement, water undertakers must ensure that the water leaving their treatment works is continuously sampled for *cryptosporidium* oocysts.

The monitoring system required a 1m^3 sample to be taken each day over a 24 hour period and to be analysed for *cryptosporidium* oocysts using a prescribed filtration process, The monitoring process is very labour intensive, leading to an annual cost of over £50,000 per site for *cryptosporidium* analysis.

An important exemption from the requirement for continuous monitoring is membrane plant 'capable of continuously removing particles larger than one micron'.

Feasibility study
Having identified the risk, Bristol Water commissioned Mott MacDonald to undertake a feasibility study to identify the most cost effective solution for protecting the drinking water supplies.

Bristol Water defined the following key design and performance requirements:

* treated water turbidity less than 1 NTU;
* *cryptosporidium* oocyst concentration in the final water to less than one oocyst in ten litres;
* consistent removal at least 3 log (99.9%) of the oocysts from the raw water:
* compact design;
* minimised wastewater production;
* modular design;
* ease of operation..

After reviewing a wide range of treatment processes, it was concluded that membrane treatment using micro or ultra-filtration membranes was the most appropriate technology for the following reasons:

* membrane treatment plants are modular - consequently the same basic design can be used at a number of different plants treating different flows;
* membrane filtration systems with Drinking Water Inspectorate approval for a continuous removal of particles larger than 1µm avoid the need for continuous monitoring;
* membrane treatment should be able to achieve greater than 4 log removal of *cryptosporidium* oocysts;
* membrane plants are generally compact;
* the volume of wastewater can be minimised by careful design of the washwater recovery system and optimisation of the membrane cleaning regime.

Construction contract
In May 2000, Bristol Water awarded the contract for the seven groundwater sites to the consortium of *Kalsep, Mott MacDonald* and *Hydranautics*. The site details listed below show the works output, number of modules and number of racks required.

Site	Output (Ml/d)	No, of Modules	No. of Racks
Frome	5	50	5 (x 10)
Alderley	5	50	5 (x 10)
Forum	2	20	4 (x5)
Sherborne	4	40	4 (x 10)
Charterhouse	2	20	4 (x 5)
Banwell	6	0	6 (x 10)
Oldford	15	144	6 (x 24)

Following the successful completion of the seven sites Bristol Water has extended the original contract to include an eighth, 18Ml/d site. Water from this site is due to go into supply in August/September 2002.

Each site required a substantial new infrastructure for the membrane system, such as a building and access road. As much standardisation as possible was used for both the design of the ultrafiltration system, and the design and layout of the building plus ancillary equipment. In each case the new membrane system had to link in with an existing chlorination system and in most cases, existing pumping systems. The building programme was further complicated by the requirement at some of the sites to maintain supply whilst bringing the new plant on line.

The common design approach enabled a cost effective generic design to be developed which could be applied to all of the sites, and reduced the implementation time scale as much as possible.

In order to provide flexibility in operation, each of the systems was designed so that it could be split into four, five or six racks. Backwashing, chemical cleaning, or any other shutdown would, therefore, result in a loss capacity of just 15 – 25%.

The modules are vertically mounted in the racks, with a single line of modules connected in parallel to a central feed manifold. Each module is, therefore, easily accessible. For larger systems, double lines of modules can be used to reduce footprint.

In order to ensure that the ultrafiltration system continues to provide a barrier against *cryptosporidium* it is necessary to monitor the integrity of the membrane. Particles counters have been installed, however, they are not sensitive enough on their own to assure complete integrity, since the level of particulates in the feed is so low. Accordingly, a pressure hold test, which is sufficiently sensitive to identify a single fibre break in a rack of 24 modules, was used to measure integrity.

Cleaning regime
The membranes are backwashed using permeate water for 30 seconds every 20 minutes. A similar wash, which uses hydrogen peroxide to disinfect the membranes, occurs every two hours. Hydrogen peroxide was chosen because it decays quickly and after being held for a period, the washwater can be discharged to a watercourse. Chemical washes using either acid or alkali are only needed every few months if the trans-membrane pressure drop remains low and the occurrence of turbidity is small.

Performance since completion
At Frome, the initial permeability (at 10 to 12˚C) of 270 lmh bar declined by approximately 8% during the first 20 to 30 days of operation before reaching a plateau of 250 lmh bar which has since been stable, although permeability appears to increase slightly at lower flux.

The design flux for the required productivity of 5 Ml/d was 110 lmh. At this level the backwash usage is 2.4% of the productivity. The average operational flux for the first 150 days of operation has been 91 1mh, with an average daily output of 4 Ml/d. The trans-membrane pressure drop at 91 lmh is 0.36 bar with a backwash recovery of 2.9%.

Permeate quality on each of the sites has been monitored by a particle counter. The count of particles larger than 2 µm immediately after backwash is approximately 10/ml for the first one to two minutes, falling to 0 to 1/ml. Turbidity, which is continuously monitored, is typically 0.06 NTU.

At sites which have occurrence of turbidity spikes in the feed water, or even sustained turbidity above 7 NTU, trans-membrane pressure can rise rapidly. In these circumstances the membranes require a higher frequency of chemical cleaning. Performance data now being generated is being analysed with a view to optimising the cleaning regime during turbidity events.■

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