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An analytical index for evaluating manufacturing cost and performance of low-pressure hollow fibre membrane systems

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HIGHLIGHTS

- Paper presents costing structure of hollow fibre membrane module.
- An index linking manufacturing cost of hollow fibre membranes to its performance
- The paper shows that the index allows products used in water filtration to be compared.
- The paper proposes the establishment of standards to control the price of water.
- Paper is based on industry based research of Memcor® Products.

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ABSTRACT

Water and waste-water treatment through the use of the membrane filtration technology is one of the processes utilized currently to meet the growing demand for water. While new technologies can harness water from various non-traditional sources such as oceans, there remains the possibility of making drinking water more expensive through the use of costly water treatment equipment. To prevent this and ensuing catastrophes in the world, the water industry needs a strategy that keeps the price of water and price of products aiding the treatment of water controlled in to the future.

This paper firstly presents the need for the industry to focus on controlling the price of water. Secondly, since the paper focuses on low pressure hollow fibre membranes, the processes used for the manufacture of Memcor® membrane modules, from material preparation to packaging and testing are explained. Thereafter, through referencing the Memcor membrane module manufacturing process, an analytical model to determine the membrane module cost and membrane performance is presented. The model leads to the presentation of the Water Price Index (WPI) which is an index that evaluates the membrane module price against its design flux, expected life and efficiency. By targeting a low WPI, the water industry can control the price of water and water treatment equipment. Analysis indicates that membrane design flux and expected life are the key drivers in keeping a low WPI. The paper concludes after presenting results of a factorial study and recommending further research subjects.

1. Introduction

Water and waste-water treatment through the use of the membrane filtration technology is one of the processes utilized currently to meet the demand for water [1–3]. Water treatment membranes were first developed in the 1950s and 60s and improvements have progressively been made since then [4,5]. Membranes are used in a wide variety of separation processes, as a means of producing high quality water [6]. They are currently employed in almost all water treatment and purification applications including drinking water [7], wastewater and industrial applications [8,9] and desalination [10]. Water treatment processes using membrane filters reliably produce good quality water while keeping its environmental footprint to a minimum [11,12]. Another advantage is that membrane processes have low chemical consumption compared to other types of water treatment processes [13,14].

High quality water is recognised as an essential part of modern life and is also recognised as a resource which is fast becoming scarce. In fact, the demand for water is still on the rise due to growing population [15]. Population growth also increases the demand for water from the agricultural and industrial sectors making water a valuable resource [16]. Furthermore, with increase in the cost of establishing and operating

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water treatment plants due to increases in the cost of land, labour and energy, there is pressure on increasing the cost of water. Consequently, in many countries like Australia, a bottle of water at the petrol station can be dearer than fuel.

More stringent environmental regulations have continued to be imposed on water supplies adding further strain on costs [17–19]. In order to protect public health, water quality standards and guidelines have been established. Some of the guidelines and standards include World Health Organisation (WHO) water quality standards, WHO water quality guidelines, Environmental Protection agency (EPA) water quality guidelines along with water filtration product quality guidelines set by the National Sanitation Foundation (NSF, USA) and Drinking Water Inspectorate (DWI, UK) [20,21]. The most established reference document for membrane filtration in the water industry is the EPA Membrane Filtration Guidance Manual [3].

An economic assessment of membrane processes for water and waste water treatment was first presented in 1995 and compared with alternative processes [22]. The study was based on earlier research where a model of the capital and operating cost of low pressure membranes was presented [23]. Similar studies like studying the impact of increasing RO membrane permeability on the cost effectiveness of the RO desalting process have also been carried out [24]. A stochastic model to estimate the construction and operation of a Seawater Reverse Osmosis (SWRO) desalination plant has been reported in the literature [25]. Researchers have also further studied the cost of operating large scale MBR plants [25,26].

It has become evident through this study that current water industry regulatory standards fall short of controlling the price of water as they are only focused on water quality. Furthermore, while economic and cost models have been studied, there has not been sufficient direct emphasis on research output that aids in controlling the price of water in the long term while maintaining high water quality. As a result, the water industry is not able to steer itself towards product improvement and spontaneous technological progression towards this result. With water scarcity and pressure to meet drinking water requirements, the industry remains under immense responsibility to deliver affordable good quality and reliable water supply in to the future.

Therefore, the objective of this paper is to present an analytical index for evaluating the lifetime performance of low pressure hollow fibre membrane modules with the intent of influencing the price of water through controlling the price of membrane modules. The index encourages the use of product lifecycle management systems in the design and production of membrane type filters to aid in minimizing increases to the price of membrane modules. It specifies focus in the areas of quality, reliability and environmental impact.

This research benefits the water industry stakeholders in the following ways:

- Quality and reliability: evaluating quality and reliability of the membrane module which would translate directly into improved quality and reliability of water supply.
- Planning: improved definition of known lifetime of the membrane module which in turn will assist communities, municipalities and cities in long term planning for maintaining continuous long term supply of water.
- Investment: in addition to defining known lifetime of the membrane module, the index will aid in the evaluation of the investment. This will allow communities, municipalities, cities and aid agencies to commit to water supply projects over given periods.
- Cost: the above assists keep the cost of water known and controlled.

The low pressure membrane filtration process, as depicted by Fig. 1 has 3 sub-processes. These are filtration, backwash and chemical clean. While filtration is the primary sub-process, the backwash and chemical clean improve long term membrane performance. The filtration process requires infrastructure which includes buildings along with supporting process equipment. Labour and energy are required for the successful operation of the processes while chemicals are utilized for the chemical clean process. This paper focuses on the membrane component of Fig. 1. Future papers, which are in preparation, will focus on other parts of Fig. 1.

In the next section, the manufacturing process used for one of the membrane module types is discussed. Manufacturing and assembly processes from sourcing of raw materials to packaging of the final product are explained. The entire analytical process for WPI is based on experience in manufacturing low pressure hollow fibre membranes for over 25 years by Memcor®. Memcor® has been providing low pressure ultra filtration and micro filtration membrane systems to various municipalities and industries globally. Memcor has its manufacturing plant in Windsor, NSW, Australia where it currently produces thousands of membrane modules every month.

2. Membrane module manufacturing processes

The manufacturing processes used in the manufacture of Memcor low pressure membrane module is explained in this section. As illustrated by Fig. 2, there are multiple sub-processes which utilize

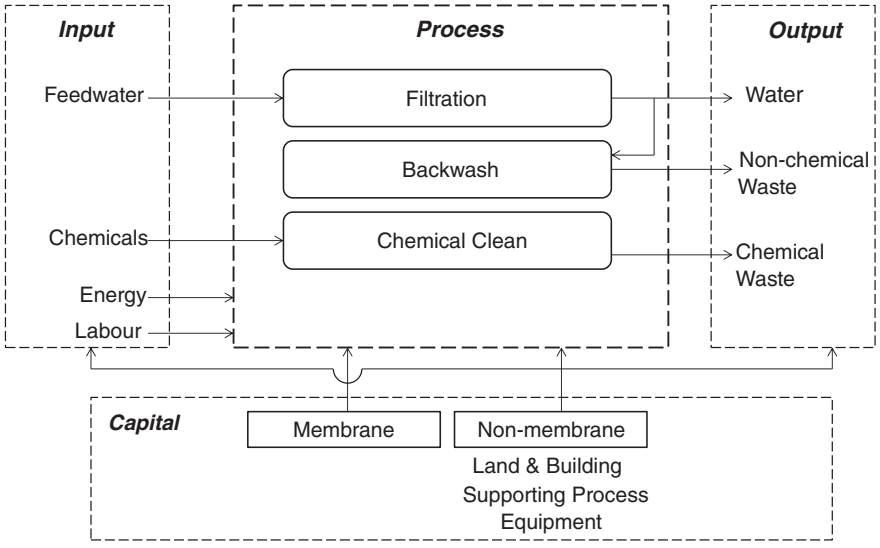

Fig. 1. Block diagram for the low pressure membrane based microfiltration process.