CLEAN WATER PRODUCTION PERFORMANCE MEASUREMENT INDICATORS AND FACTORS: A REVIEW ON ULTRAFILTER MEMBRANE

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ABSTRACT: *This review aims to answer the question relating to the problem of measuring the clean water production performance of the Ultrafilter membranes. This review has designed to study the research journal articles recently published (from 2000 to 2022) on the clean water production performance of ultrafilter membranes. The focus of this study was to unlock the influence of feed water quality, pre-treatment efficiency, Productivity, and energy consumption of the ultrafilter membrane on clean water production performance. The outcome of this review revealed that four indicators and thirteen potential factors have used for measuring the clean water production performance of ultrafilter membranes. The potential factors are the feed water pre-treatment, feed water pressure, chemically enhanced backwash, and osmotic pressure. Additionally, the pH, total suspended solids, turbidity, and chemical oxygen demand of feed water are the sources of cake layer formation that affect energy consumption and the operating cost of ultrafilter membranes in producing clean water. The findings of this review have a few industrial and policy implications. The outcomes of this review could be used by industrial engineers and consultants for designing the ultrafilter membrane system to optimize clean water production. The policy makers involved in technology selection for water filtration also can be used. The outcome of this study concludes that the ultrafilter membrane is an effective water treatment technology, but its performance depends on a few potential operating factors. This study recommends further research for optimizing the factors affect UFM performance in producing clean water.*

Keywords: Water sustainability, Ultra-Filter membrane, Sustainable Goal, Clean water, Production performance, Energy consumption, Water production cost

1.0 BACKGROUND OF THE STUDY

This paper aims to unlock the factors that affect the energy consumption and performance of ultrafiltration membranes (UFM) in producing clean water for achieving Sustainable Development Goal 6 (SDG 6). This study focuses on the operating parameters of plant machinery that affect the overall performance of UFM in producing the desired quality water. However, the UFM can divide into two groups, one based on molecular weight cut-off (MWCO) capability. Another one is the mode of water flow through the membrane (crossflow and dead-end flow)[1] [2]. The membrane filtration process is an advanced water treatment process that attracted attention because of its ease of operation, and maintenance requires small footprint installation and less time for project implementation, [2, 3]. Additionally, designing a UFM plant requires medium-level engineering skills, less energy consumption in plant operations, and minimum capital investment. A widespread application of UFM is limited by its poor performance in producing clean water. Various research in this field disclosed the factors responsible for the poor performance of the UFM. Research findings demonstrated that membrane fouling is a potentially identified factor that reduces performance. It was also reported that micro and macro particles, natural organic materials (NOM), suspended solids (TSS), and water-borne bacteria in feed water are the compositions of fouling. Fouling elements of feed water create a cake layer on the membrane and reduce pore size, [4]–[6]. To reduce the cake layer, pre-treatment for feed water is essential for removing fouling elements [7], [8]. The mode of UFM plant operation has appeared as a factor in achieving sustainable performance, which includes plant operating time and plant cleaning efficiency. All these factors are associated with energy consumption, plant maintenance frequency, the life cycle of UFM modules, and water production cost. Indeed optimizing all these factors could play a vital role in achieving the required performance [9], [10]. With this background, this study was conducted to reveal the optimum operating conditions of UFM to achieve sustainable performance by reducing energy consumption and the cost of plant operation for producing clean water at an affordable price.

2.0 MEASURING THE PERFORMANCE OF ULTRAFILEMEMBRANE

The UFM is a low-pressure driven system widely used in water treatment for potable water production, cooling water production for power plants, and process water production for food and chemical industries. Traditionally, this membrane has been installed at the secondary and tertiary levels in the water treatment process [11], [12]. Several indicators have been used for measuring the performance of UFM including permeate flux rate, efficiency in separating TSS and pollutant from feed water, energy consumption rate [kWh.(m^3-water)$^{-1}$], and productivity in clean water production [13]–[15]. The other potential indicators are the pollutant separation capability of UFM from water such as chemical oxygen demand (COD), biological oxygen demand (BOD), and water-born bacteria, [16]–[19].

2.1 Permeate Flux for Measuring the Performance of UFM

A few researchers have used the input-output water production model of the UFM, which presents by the equation (1).[16, 17, 20, 21].

$$J = K\frac{\Delta P}{t} \qquad \text{Eq (1)}$$

Here, J is the permeate flux. ΔP *is* the pressure difference across the membrane. "t" is the membrane thickness. K is the efficiency factor of UFM. Singh & Hankins, 2016 [20], and Ghidossi & Daorelle, 2006 [22] also used a similar model for measuring the performance of UFM.

A few researchers also used permeate flux for transmembrane pressure to measure the performance of UFM.

The cake layer on the membrane surface, the transmembrane pressure increases, which contributes to reducing permeate flux [1], [9]. Anis et al. [23], Giakoumis et al. [24], Weber et al. [25], Singh & Hankings [20], and Ramli & Bolong [18] demonstrate that pore size, the thickness of the membrane, and transmembrane pressure (TMP) have a significant role that affects the performance of UFM. A similar argument has been made by Karabelas & Sioutopoulos [26]. The permeate flux for the transmembrane pressure presents by the equation (**Error! Reference source not found.**2):

$$Jw = \frac{1}{A}\frac{dV}{dt} = \frac{[\Delta P]}{\mu[R_m + R_c]} \qquad \text{Eq (2)}$$