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Impact of Process Control Devices on the Performance of Ultrafilter Membrane in Clean Water Production

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ABSTRACT

This paper aims to publish an experimental finding addressing ultrafilter membranes' higher energy consumption rate (UFM) in producing clean water. The novelty of the research published in this paper is to establish the contribution capability of process control devices (PCD) in reducing the energy consumption rate of UFM and the effect of PCD on the overall performance of UFM in producing clean water (SDG6). The novelty of the research published in this paper is to establish the contribution capability of PCD in reducing the energy consumption rate of UFM and the effect of PCD on the overall performance of UFM in producing clean water (SDG6). An experiment has been conducted with a UFM to answer the question. The UFM plant operated with and without process control devices to evaluate the impact of the process control devices on energy consumption rate [kW/m^3] in producing clean water. Experiments revealed that process control devices are positively associated with energy consumption rate and contributed to reducing 44% of energy consumption in clean water production. This research disclosed that process control devices have contributed to an increase of 38% in the efficiency of the UFM in clean water production. Research outcomes have several implications in the water industry, engineering, and policy implementation domains relating to process control devices in water treatment. From our findings, further research should continue using process control devices for the water treatment plants to increase overall performance and contribute to achieving sustainable development goals (SDG).

1. Introduction

This paper presents experimental research outcomes that unlock the effect of a few plant operating factors on the overall performance of Ultra-filtration membrane (UFM) in producing clean water [1,2]. Membrane filtration is an advanced water treatment process that attracted attention because of its economic benefits [2,3]. Among the membrane family, the UFM has potential due to its simple design, less energy consumption, and minimum capital investment. A myriad of research studies in this field have disclosed the factors responsible for the performance of UFM [4-6]. The

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mode of UFM plant operations has also appeared as a factor in achieving performance. The potential factors are the quality of feed water, 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 factors could be vital in achieving the required performance [3,7]. With this background, this study revealed 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.

1.1 Problem Statement and Research Objectives

Climate change and geopolitical instabilities present a formidable challenge to the fulfillment of clean water demand across the globe. This reality forces researchers and engineers to scale the problem from various perspectives across many disciplines. Some groups look towards diversifying the source of raw water for treatment. An example of this is the work done by Mirmanto *et al.,* [8], which attempts to improve the quantity of water produced by the evaporation coil of a device operating on a refrigeration cycle. Some, on the other hand, are working on improving desalination technology within the context of reducing its reliance on fossil fuels to power the boilers [9]. Others focus their efforts on improving individual subprocesses of the water treatment system, such as evaluating the feasibility of banana peels as a flocculating agent [10].

Studies on clean water production using UFM have established a relationship between energy consumption rate and productivity in water production. Research findings demonstrate that the energy consumption rate in clean water production by UFM has played a vital role in managing the water crisis. Various studies reveal that the clean water crisis partially relates to the poor productivity of plant machinery due to the lack of process control devices in the production process. A few researchers have confirmed that UFM plants operate continuously, and a certain amount of product water is discharged through the overflow pipe due to a lack of water level sensors in the water tank and speed controller for the pump. This statement has raised the question of 'What is the effect of water level sensors on the energy consumption rate [kW/m^3] of a UFM system when operating to produce clean water?' This research project has been undertaken to answer the question stated.

The broad objective of this research is to determine the optimum operating conduction of the UFM system. The experiment is divided into two specific objectives to achieve the research goal. First, to determine the energy consumption rate of UFM's feedwater pump when the plant operates without process control devices. Second, to estimate the energy consumption rate of UFM's feedwater pump when the plant works with process control devices. Third, to evaluate the impact of process control devices on the UFM's energy consumption rate and overall performance.

1.2 Novelty of Research

The novelty of the research published in this paper is to establish the contribution capability of process control devices (PCD) in reducing the energy consumption rate of UFM and the effect of PCD on the overall performance of UFM in producing clean water (SDG).

2. Literature Review on Performance of Ultrafilter Membrane

The UFM is a low-pressure driven system widely used in water treatment for producing potable water, cooling water for power plants, and processing water for food and chemical industries. UFM membrane has been installed at the secondary and tertiary levels in the water treatment system